Rogoff's "Conservative" Central Banker Restored

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Rogoff’s “Conservative” Central Banker Restored

We show that delegation of monetary policy to a weight-conservative central banker can be desirable, although the government can also use an inflation contract, an employment target, an inflation target, or any combination of these to control the central banker. The key feature of our model is a stochastic inflation bias, arising when wage setters receive some information about a supply shock prior to signing nominal wage contracts. Weight-conservatism is found to be desirable if fully state-contingent delegation is not possible and the stochastic inflation bias cannot be eliminated by optimal choice of the delegation parameters.

How SHOULD THE policy objectives of an independent central bank be determined? This question has been the central focus of a recent literature in monetary economics. In an influential article, Rogoff (1985) proposed delegation of monetary policy to a central bank governor (central banker) who is more averse to inflation than the government, in the sense that he places a greater weight on the loss from inflation than the government does. While such a “weight-conservative” central banker will, in equilibrium, produce a lower inflation bias than the government, his stabilization of the real economy will be suboptimally low from the government’s point of view. In other words, inherent in Rogoff’s approach is a trade-off between credibility and flexibility. On the other hand, Walsh (1995b) has recently pointed out that if the government can set the central banker’s remuneration contingent upon realized inflation—an inflation contract—the inflation contract can be designed so that the inflation bias is eliminated, while the central

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1. See Lohmann (1992), Waller (1992), Lockwood, Miller, and Zhang (1997), and Waller and Walsh (1996) for generalizations of Rogoff’s basic model.

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banker’s stabilization of the real economy is at the optimal level. In other words, Walsh’s approach appears to resolve the trade-off between credibility and flexibility, which is inherent in Rogoff’s approach.\(^2\)

Following Walsh’s contribution, the current literature discounts weight-conservatism and concentrates on finding different ways of creating the optimal incentives for a central banker with a given aversion to inflation. Examples, which are perhaps closer to real-world arrangements than an inflation contract, include (i) a dismissal rule (Walsh 1995a); (ii) an employment, or output, targeting arrangement (Lockwood 1995); (iii) an inflation-targeting arrangement (Svensson 1997). In contrast to this recent literature, we suggest that an optimal choice of objectives for an independent central banker is likely to include weight-conservatism, even if, in its delegation decision, the government can choose a linear inflation contract, an employment target, an inflation target, or any linear combination of these, in addition to choosing the optimal degree of weight-conservatism.

The key feature of our model is a stochastic inflation bias, arising because the private sector—in particular, the wage setters—is assumed to receive some information about a supply shock prior to setting the nominal wage. It is shown that providing the delegation decision cannot be made contingent upon this information, which we call non-state-contingent delegation in what follows, delegation does not completely eliminate the inflation bias. More precisely, we show that if delegation is not state contingent, an appropriate choice of employment/inflation targets, or a linear inflation contract, can only drive the mean of inflation bias to zero, but does not eliminate the variance of inflation bias. The only way in which this variance may be lowered is by making the central banker weight conservative. This benefit of weight-conservatism is then traded off against the cost of weight-conservatism identified by Rogoff (1985), namely, inefficiently low stabilization of the real economy. This results in some weight-conservatism being optimal (Proposition 2). Thus, our argument is similar in structure to Rogoff’s, the difference being that the variance of inflation bias plays the role of the mean of inflation bias in Rogoff’s original contribution.

The crucial assumption of our analysis is that the delegation decision of the government (choice of target(s), inflation contract, and weight-conservatism) is not state contingent, that is, cannot be made conditional on the private information of wage setters. As this private information is revealed through the choice of the nominal wage, this is equivalent to assuming that delegation cannot be made conditional on the nominal wage.\(^3\) The assumption of a non-state-contingent delegation can be justified in two ways. First, a possible interpretation of the delegation decision is that it involves choice of a central banker with particular non-state-contingent preferences over employment/inflation pairs. The central banker is then left free to pur-

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3. Indeed, if delegation can be made so contingent, it is an easy matter to show that there is no role for weight-conservatism (Proposition 1).
sue monetary policy. In this case, in Fischer’s (1995) terminology, the central banker is goal independent. Since, with goal independence, the delegation decision is a long-term and irreversible one, the central banker’s non-state-contingent preferences are fixed as long as he remains in post. This is typically seven to ten years in OECD countries. In addition, in many of these OECD countries, it is difficult or impossible to fire the central banker, except for incompetence (Cukierman 1992).

Second, another interpretation of the delegation decision is that the government can set certain targets for the central banker, who is then penalized for nonattainment of these. In this case, there is no goal independence, but only instrument independence, that is, the government can not interfere with daily policy making. With goal dependence, the targets set by the government could, in principle, be contingent upon shocks to the real economy. However, recent experience with explicit inflation targeting in several countries indicates that inflation targets are not fully state contingent: typically, target bands are set for a period of one or more years, and are revised only in extreme circumstances. For example, Freedman (1995, p. 27), commenting on the Canadian experience with inflation targeting, says: “Certain major price shocks would justify a change to the entire [inflation] target path, but this should be done only in very unusual circumstances . . . for example, a very large increase in oil prices.”

The lack of state contingency probably reflects the high transaction and verification costs of setting and enforcing state-contingent inflation targets. For a general discussion of these costs and why they may lead to incomplete contracting, see, for example, Hart (1995). Moreover, the lack of state contingency is due to the fact that not all contingencies are known or describable at the time when the delegation decision is made. Note that this is precisely the reason why monetary policy is not subordinated to a constitutional rule that would exclude any discretionary reaction to unforeseen circumstances.

As stated above, the main result of the paper, Proposition 2, seems somewhat fragile, as it appears that if the delegation decision is conditioned on only one piece of publicly available information, namely, the nominal wage rate, the need for weight-conservatism vanishes. In the last section of the paper, we prove that our main result is in fact more robust than this. In particular, we show that if the government is also incompletely informed about some aspect of private sector preferences, as well as the information the private sector has about the supply shock, then there is a role for weight-conservatism, even if the government’s delegation decision can be made conditional on the nominal wage. The reason is that the government cannot exactly infer the values of both privately observed pieces of information from the nominal wage, and so cannot set the employment/inflation targets and/or an inflation contract contingent on both pieces of information. As inflation bias depends on both these variables, delegation does not entirely eliminate inflation bias, even if it can be conditioned on the nominal wage. This suggests a general principle, namely,

4. In practice, the situation will typically be between the two extremes (Fischer 1995).
that weight-conservatism will be optimal when there are more disturbances to inflation bias than there are publicly observable variables upon which delegation can be conditioned. That this is likely to be the case appears to be widely agreed upon in the literature; see, for example, the discussion by Canzoneri, Nolan, and Yates (1997).

The plan of the rest of the paper is as follows. In section 1, we present our model. Section 2 analyzes both state-contingent and non-state-contingent delegation, and section 3 focusses on the case where the government is incompletely informed about private sector preferences. Section 4 concludes.

1. THE MODEL

Our model has the following agents; a government, a central banker and a private sector, the latter being composed of a large number of identical trade unions and firms. Technically, we assume continua of measure 1 of identical trade unions and firms. Each trade union represents \( I \) households who supply labor to a particular firm, and has monopoly power over wage setting—a so-called monopoly union. A firm, the \( I \) households who supply labor to it, and the trade union that represents them constitute a sector of the economy. We assume that households have sector-specific skills, implying that they are immobile between sectors. Furthermore, each household is assumed to supply one indivisible unit of labor at a reservation wage, which we set to zero without loss of generality. Thus, competitive labor supply in any sector and at the aggregate level is perfectly elastic up to full employment \( \bar{I} \), and inelastic thereafter.\(^5\)

At time \( t = 0 \), the government delegates monetary policy to the central banker and specifies his objectives as part of the constitution (institutional design stage). In order to ensure that this serves as a precommitment device, we assume that it is impossible to change the constitution at \( t = 1 \), and that the constitution grants instrument independence to the central bank, that is, that it prohibits government interference with daily monetary-policy making (Fischer 1995b). Note that we assume away McCallum’s (1995) criticism that delegation of monetary policy merely reallocates the time consistency problem from the monetary authority to the government.\(^6\)

At \( t = 1 \), the sequence of events is as follows: (i) a supply shock \( \varepsilon \sim N(0, \sigma_{\varepsilon}^2) \) is realized with \( 0 < \sigma_{\varepsilon}^2 < \infty \); (ii) every trade union observes a noisy signal \( s \sim N(0, \sigma_{s}^2) \)

5. Alternatively, we could allow households to be mobile between sectors, but assume that there is a closed-shop situation, in which each monopoly union represents only a given number of households, the insiders. This would lead to the same labor market equilibrium; see Herrendorf and Neumann (1996).

6. Our justification is twofold. First, it is more difficult for the government to influence monetary policy when it is delegated to an instrument independent central bank than when the central bank is government dependent and policy making is discretionary. Second, the public can monitor government attempts to create surprise inflation more easily when monetary policy is delegated than when it is discretionary. Herrendorf (1996) showed that, for these reasons, delegation provides precommitment even if the government can renge on the delegation decision.
of $\epsilon$, where $s = \epsilon + \theta$, $0 < \theta < \infty$, and $s$ is not directly observed by either the central banker or the government. (iii) every trade union chooses the nominal wage, $w$, for its sector; (iv) the central banker observes the supply shock $\epsilon$ itself; (iv) the central banker chooses inflation, $p$; (v) employment, $I$, results from firms’ labor demand. As all sectors are alike, we do not need to index $w$ and $I$ by sector, but can simply interpret them as aggregate nominal wage and employment, respectively.

Normalizing the nominal wage and the price level at time $t = 0$ to zero, for simplicity, $w$ and $p$ stand for the growth rates as well as for the levels of the nominal wage and the price at $t = 1$. Hence, $(w - p)$ denotes the real wage and a typical firm’s labor demand may be written as

$$I = \alpha(p - w) + \epsilon,$$

where $\alpha > 0$ is a constant. Wage-setting behavior is modeled by supposing that a trade union in any sector has both an employment objective, $I_u$, and a real wage objective, $v_u$,

$$U_u = -(l - l_u)^2 - c_u(w - p - v_u)^2, \quad c_u > 0,$$

where $l_u < \tilde{I}$ and $v_u < -\tilde{I}/\alpha$. These two standard assumptions mean that the union’s employment target falls short of full employment, whereas its real wage target exceeds the real wage that, ex ante, is consistent with full employment. Note that as we assume a continuum of measure one of identical trade unions, $I_u$ and $v_u$ can be interpreted both as the employment and the real wage objectives of a representative trade union and as the employment and real wage objectives at the aggregate level.

We specify the government’s utility by assuming that it also has an employment target, $l_g$, and that it dislikes the adverse effects of nonzero inflation.

$$U_g = -(l - l_g)^2 - c_g p^2, \quad c_g > 0.$$  

Given that labor supply in each sector is perfectly elastic up to full employment, $\tilde{I}$, it is natural to assume that the government’s employment target is full employment, that is, $l_g = \tilde{I} > l_u$. Note that the government’s target does not vary with the size of the supply shock $\epsilon$, but is constant, because labor supply at $\tilde{I}$ is vertical.

Our parametrization of the central bank’s objective function is fairly general,

$$U_b = -(l - l_b)^2 - c_b(p - p_b)^2 - 2\tau k p,$$  

7. It may seem a strong assumption that every trade union has the same signal. However, this is without loss of generality, because if each trade union $i \in [0, 1]$ receives a signal $s(i) = \epsilon + \theta + \phi(i)$, where the $\phi(i)$ are independent with mean zero, and $\theta$ is common across trade unions, then, in equilibrium, the net effect of the $\phi(i)$ on aggregate wages and employment is zero.

8. $w$ and all other variables of the model are in logs.

9. Alesina and Tabellini (1987) worked with a special case of (2) in which the trade union only aims at a real wage target.

10. Note that it is straightforward to extend our setting to situations in which the government seeks to extract seigniorage from the private sector and, thus, has a positive inflation target.
where \( l_b \) is the central bank’s employment target, \( c_b \) is its weight on inflation relative to employment, \( p_b \) is its inflation target, and \( 2t bp \) is a transfer payment [expressed in “utility units”] from the government to the central bank. We will call a central bank with \( c_b > c_g \) [\( c_b = c_g \)] weight-conservative [weight-neutral]. Also, by delegation we will mean a choice of \((l_b, c_p, p_b, t_b)\) by the government at \( t = 0 \).

The specifications of the policy objectives of the central bank and the government, given in (3) and (4), allow us to express most types of delegation studied in the literature as special cases. For example, Walsh’s (1995b) model of delegation to a central bank with a linear inflation contract is the special case where \((l_b, c_b, p_b) = (l_g, c_g, 0)\) and \(t_b\) is chosen by the government. To our knowledge, the only kind of delegation that we cannot deal with in this framework is delegation with a dismissal rule of the type analyzed by Lohmann (1992) and Walsh (1995a).

In what follows, we consider two different kinds of delegation, namely, state-contingent and non-state-contingent delegation. In the former case, the delegation parameters in (4), \((l_b, c_b, p_b, t_b)\), can be specified contingent upon all parameters known to the government and upon all (or some) variables publicly observable at the end of period \( t = 1 \), that is, the nominal wage, \( w \), the shock, \( \varepsilon \), and employment, \( l \). In contrast, in the latter case, \((l_b, c_b, p_b, t_b)\) may depend only upon the information available to the government at the time of delegation at \( t = 0 \), notably, the model parameters. The main result of this paper (Proposition 2) is for the case where delegation is non-state contingent, and so we offer some reasons why this might be an interesting and relevant case to consider.

The first reason for non-state-contingent delegation is that the delegation decision is often a long-term and relatively irreversible one. For example, evidence collected by Cukierman (1992) suggests that in many OECD countries, there is either no provision for early dismissal of the central bank governor once appointed, or that dismissal is only possible for nonpolitical reasons, for example, incompetence. Moreover, the turnover rates of CB governors indicate that the average period in office is between seven and ten years. This in itself does not prove that delegation cannot be state contingent. However, if the parameters \((l_b, c_b, p_b)\) in the central banker’s utility function are interpreted as preference parameters (as, for example, in Rogoff 1985), then these parameters are irrevocably fixed by a choice of central banker, and, thus, not state contingent. On the other hand, if one or more of the parameters, for example, \( l_b \) or \( p_b \), are interpreted as targets set by the government, one might expect these targets not to be fully contingent upon stochastic shocks for reasons explained in the literature on incomplete contracts, for example, transactions costs, costly verification, etc.; see Hart (1995). As discussed in the introduction, the empirical experience with inflation targeting confirms this expectation; in countries where they are used, inflation target bands are set for a year or more, at a time, and are only revised in unusual circumstances.

11. This is the case in ten OECD countries over the period 1980–89 (Cukierman 1992, ch. 19, Appendix A).

12. Note that these costs also appear to be the implicit reason why nominal wage contracts are typically not state contingent.

13. See, for example, Freedman (1995) and Fischer (1995a) on the Canadian and the New Zealand experience with inflation targeting.
2. DELEGATION AND WEIGHT-CONSERVATISM

In this section, we consider the nature of delegation, both when it can be state contingent and, in the more realistic case, when it cannot. We begin with analysis of the discretionary equilibrium that prevails once delegation has taken place.

2.1 The Discretionary Equilibrium and the Precommitment Rule

Here, we study the interaction at $t = 1$ between the appointed central banker with a given objective function and the trade unions and solve for inflation, the nominal wage and employment. As the agents move sequentially and the signal, $s$, is assumed to be private information of the trade unions, the appropriate solution concept is perfect Bayesian equilibrium; see Fudenberg and Tirole (1991). In the original Barro and Gordon (1983) article, the private sector and the government were assumed to take each other’s decisions as given, that is, the solution concept was Nash. Here, in spite of the sequential move structure, the trade unions, in equilibrium, take the subsequent choice of monetary policy by the central banker as given, as the number of identical trade unions is large. So, the equilibrium is similar to a Nash equilibrium—the complication in our model being that the signal $s$ is not known to the central bank and the government, but must be inferred from observable variables. Following Barro and Gordon’s terminology, however, we will continue to call the equilibrium a discretionary equilibrium.

We begin the characterization of the discretionary equilibrium with the central banker’s choice of $p$. Inspection of equation (4) with (1) substituted in reveals that the signal $s$ does not affect the central banker’s payoff directly, but only indirectly through $w$. Consequently, the central banker has no reason to try to infer $s$ from $w$. This means that, given $w$, his optimal choice of $p$ simply maximizes his conditional expectation of the objective function (4) subject to (1). The first-order condition is

$$
\alpha[\alpha(p - w) + \epsilon - \lambda_p] + c_b(p - p_b) + t_b = 0.
$$

(5)

Taking inflation expectations conditional on $s$ through (5), we obtain an equation for the representative trade union’s expectation of inflation, $E(p|s)$,

$$
\alpha[\alpha[E(p|s) - w] + \beta_s - \lambda_p] + c_b[E(p|s) - p_b] + t_b = 0,
$$

(6)

where $\beta_s = E(\epsilon|s)$ and $\beta = \sigma_e^2/(\sigma_e^2 + \sigma_\alpha^2)$. The next step is to characterize the choice of $w$. Recall that a representative trade union is assumed so small that it cannot affect $p$, as defined in equation (5), by its individual choice of $w$. Therefore, the optimal $w$ simply maximizes $E(U_u|s)$ subject to (1) and taking $p$ as given, where $U_u$ is defined in (2). This leads to the first-order condition

$$
(\alpha^2 + c_w)[E(p|s) - w] + \alpha(\beta_s - \lambda_u) + c_u\nu_u = 0.
$$

(7)

From (5), (6), and (7), we can determine $p$, $E(p|s)$ and $w$ in discretionary equilibrium. To this end, we first solve (7) for $w$.
\[ w = E(p|s) - \frac{1}{\alpha} \bar{l}_u + \frac{\beta y}{\alpha} s , \]  

(8)

where \( \bar{l}_u = [\alpha^2 l_u - c_u \alpha v_u]/[\alpha^2 + c_u] \) and \( \gamma = \alpha^2/[\alpha^2 + c_u] \). Then, substituting (8) into the central bank's first-order condition (5), we find

\[ \alpha^2[p - E(p|s)] + \alpha(\epsilon - \beta \gamma s + \bar{l}_u - l_b) + c_b(p - p_b) + t_b = 0 . \]  

(9)

After taking the expectation conditional on \( s \) through this equation and using the law of iterated expectations, \( E[E(p|s)|s] = E(p|s) \), we can obtain an expression for expected inflation in the discretionary equilibrium,

\[ E(p|s) = p_b - \frac{t_b}{c_b} + \frac{\alpha}{c_b} [(l_b - \bar{l}_u) - \beta(1 - \gamma)s] . \]  

(10)

Subtracting (6) from (5) implies

\[ p - E(p|s) = \frac{\alpha}{\alpha^2 + c_b} (\epsilon - \beta s) . \]  

(11)

Finally, combining (10) and (11), we see that actual inflation in discretionary equilibrium is

\[ p^d = p_b - \frac{t_b}{c_b} + \frac{\alpha}{c_b} [l_b - \bar{l}_u] - \beta(1 - \gamma)s - \frac{\alpha}{\alpha^2 + c_b} e , \]  

(12)

where \( e = \epsilon - \beta s \) is the trade union's error in predicting \( \epsilon \). From (1), (8), (10), and (12), we can also calculate the nominal wage and employment in the discretionary equilibrium,

\[ w^d = p_b - \frac{t_b}{c_b} + \frac{\alpha}{c_b} l_b - \frac{\alpha^2 + c_b}{\alpha c_b} \bar{l}_u + \left[ 1 - \frac{c_u}{c_b} \right] \frac{\beta y}{\alpha} s , \]  

(13a)

\[ l^d = \bar{l}_u + \beta(1 - \gamma)s + \frac{c_b}{\alpha^2 + c_b} e , \]  

(13b)

where \( \bar{l}_u \) is the natural rate of employment. \( \bar{l}_u \) is smaller than full employment. This follows from the assumed targets of the trade unions, that is, \( l_u < \bar{l} \) and \( v_u > -\bar{l}/\alpha \), and the identity \( \bar{l}_u = [\alpha^2 l_u - c_u \alpha v_u]/[\alpha^2 + c_u] \), which yield \( \bar{l}_u < [\alpha^2 l_u + c_u l]/[\alpha^2 + c_u] < \bar{l} \).

The properties of the discretionary equilibrium outcome can best be understood in comparison with the outcome that would arise if at \( t = 0 \) the government could precommit to a policy rule for inflation. This precommitment inflation rule must have three properties. First, given that the government has an inflation target of
zero, mean inflation with the precommitment rule must be zero, too. Second, since the signal $s$ is known to the trade unions, the precommitment rule must result in the degree of stabilization of $s$ that the unions want. From the government’s point of view, this is most efficiently achieved when the unions adjust the nominal wage because this avoids costly inflation variability. Consequently, the precommitment rule will be independent of the signal $s$. Third, from the point of view of the government, the precommitment rule must optimally stabilize employment. As the objective function of the central bank and the government have the same structure, we can obtain the stabilization coefficient in the precommitment rule by replacing $c_b$ by $c_g$ in the fourth term of (12), which leads to $[\alpha/(\alpha^2 + c_g)]e$. The precommitment rule therefore is

$$p^r = -\frac{\alpha}{\alpha^2 + c_g} e. \quad (14)$$

The nominal wage and employment under precommitment follow directly from (1), (8), and (14), taking into account that $E(p^r|s) = 0$,

$$w^r = -\frac{1}{\alpha} \bar{I}_u + \frac{\beta \gamma}{\alpha} s, \quad (15a)$$

$$I^r = \bar{I}_u + \beta(1 - \gamma)s + \frac{c_g}{\alpha^2 + c_g} e. \quad (15b)$$

Comparison of (12) and (14) confirms the standard result that, in discretionary equilibrium, stabilization of the shock $e$ is optimal from the government’s point of view, if and only if the central bank is weight neutral, that is, $c_b = c_g$. Furthermore, an inflation bias, equal to $p_b - (t_b/c_b) + (\alpha/c_b)[(l_b - \bar{l}_u) - \beta(1 - \gamma)s]$, arises under discretion. It may be helpful to distinguish between the mean of inflation bias, that is, $p - (t_b/c_b) + (\alpha/c_b)(l_b - \bar{l}_u)$, and the deviation from the mean, that is, $-(\alpha/c_b)\beta(1 - \gamma)s$. We call the first component mean inflation bias and the second stochastic inflation bias.

The mean inflation bias arises for two reasons. First, in general, the central banker’s inflation target and contract imply an incentive to inflate. Second, any systematic difference between the central bank’s employment target $l_b$, on one hand, and the natural rate of employment $\bar{l}_u$, on the other hand, leads to the standard time consistency problem.

To understand the origin of the stochastic inflation bias, it is instructive to focus on the special case where $c_b = c_w$, that is, the trade unions have the same relative aversion to real wage variability as the central bank has to inflation variability. Moreover, for expository purposes, we set the mean inflation bias equal to zero for a moment, that is, $p_b - (t_b/c_b) + (\alpha/c_b)(l_b - \bar{l}_u) = 0$, and also assume that the trade unions’ signal is not noisy, that is $s = \epsilon$. Referring to (12), (13a), and (13b) and noting that now $\beta = 1$ and $(\alpha/c_b)(1 - \gamma) = \gamma/\alpha$, we see that
The important point to note is that in this special case, discretion delivers the same level of employment as precommitment, but with discretion, the shock is stabilized by adjusting the price level, rather than the nominal wage. This is clearly suboptimal from the point of view of government and central bank because it leads to inflation variability. To see why this results in the discretionary equilibrium, consider Figure 1 below. The upward-sloping lines are labor demand curves in \((p, l)\) space for varying values of the nominal wage and the signal. In particular, \(AA\) is the labor demand curve when \(s = 0\), whereas \(BB\) is the labor demand curve if some negative signal is received and adjustment is done entirely through the nominal wage (as under precommitment). Moreover, the points \(P_0\) and \(P_1\) indicate the precommitment values of \(p^r\) and \(l^r\) for \(s = 0\) and \(s < 0\), respectively. They follow immediately from (17).

Consider now what would happen if the labor demand curve in discretionary equilibrium was also \(BB\). Given that, under the assumptions made, the central bank has indifference curves centered around a bliss point of \((\bar{L}, 0)\), it would then have an ex post temptation to "cheat" and raise the price level to that indicated by point \(C\). This is in the spirit of Barro and Gordon, except that it is not a temptation to raise the average level of employment, but rather a temptation to overstabilize the real

\[
p^d = -\frac{\gamma}{\alpha} s, \quad w^d = -\frac{1}{\alpha} \bar{l}_u, \quad l^d = \bar{l}_u + (1 - \gamma)s.
\]

These compare to

\[
p^r = 0, \quad w^r = -\frac{1}{\alpha} \bar{l}_u + \frac{\gamma}{\alpha} s, \quad l^r = \bar{l}_u + (1 - \gamma)s.
\]
economy, relative to the unions’ most desired degree of stabilization.\textsuperscript{14} Since rational wage setters take the central bank’s incentive to cheat into account, the nominal wage adjusts until the labor demand schedule under discretion is $CC$, and the equilibrium is at point $D$, where employment still is $l^r$ and inflation is such that the central bank’s incentive to overstabilize is eliminated. The discretionary equilibrium obviously has the property that the price level varies with the shock $s$, implying that inflation bias is stochastic from the point of view of government at $t = 0$.\textsuperscript{15}

In the general case, $c_b$ is different from $c_g$ and the discretionary wage is no longer independent of the signal $s$. Equations (12) and (13a) show that the adjustment to the shock is then done through both the nominal wage and the price level. In effect, the trade unions rationally anticipate that the central bank will try to choose a different level of stabilization to their own, and adjust the nominal wage accordingly so as to achieve their own desired level of stabilization of employment. As a result, employment is the same under discretion and precommitment, apart from a possible difference in stabilizing the unions’ prediction error $e$.

2.2 State-Contingent Delegation

We begin the analysis of the government’s delegation decision at $t = 0$ with the benchmark case of state-contingent delegation. Formally, the delegation problem for the government at $t = 0$ is to choose the parameters $(l_g, c_b, p_b, t_b)$ in the central bank’s objective so as to maximize the unconditional expectation of the objective function (3) subject to (12) and (13b). It is intuitively clear that the government wishes to specify the delegation parameters so as to obtain the precommitment inflation rule (14). The following proposition shows that this is indeed possible.

**Proposition 1.** With state-contingent delegation, the government can implement its precommitment inflation rule, (14). Its optimal delegation decision is characterized by weight-neutrality and a zero inflation bias for all values of $s$, that is,

\begin{align*}
    c_b^* &= c_g \quad \text{(weight-neutrality)}, \quad (18a) \\
    p_b^* - \frac{1}{c_b^*} t_b^* + \frac{\alpha}{c_b^*} [(l_b^* - \bar{l}_w) - \beta(1 - \gamma)s] &= 0 \quad \text{(zero inflation bias)}.
\end{align*}

To achieve (18a) and (18b), $(p_b^*, l_b^*, t_b^*)$ need to be set conditional upon the nominal wage $w$ as follows:

14. One way to see this is to observe that if $s$ were positive, ex post, the central bank would like to choose negative inflation.

15. Within a static, two-sector model, Walsh (1995a) has independently arrived a similar result. The literature has identified many additional sources that may give rise to stochastic inflation bias: a motive of real interest rate smoothing (Canzoneri et al. 1997); changes in the degree of indexation of individual contracts to realized inflation (Devereux 1987); financial innovations (Fischer and Summers 1989); persistence in unemployment (Drazen and Masson 1994; Lockwood and Philippopoulos 1994; Lockwood 1997), or changes in the stock of nonindexed, net nominal liabilities of the public sector (Herrendorf 1997). Note that the last two possibilities are relevant only in multiperiod, dynamic models.
The proof proceeds by showing that the precommitment inflation rule can be implemented in discretionary equilibrium by an appropriate choice of delegation parameters conditional upon the nominal wage, \( w \). Comparison of (12) and (14) indicates that if this is to be the case, then the two conditions (18a) and (18b) have to hold for all \( s \). Next, from (10) and (18b), it must be that \( \epsilon(p|s) = 0 \). Using this and equation (8), we get

\[
p_b^* - \frac{t_b^*}{c_g} + \frac{\alpha}{c_b} t_b^* - \frac{\alpha}{c_g} \gamma \bar{I}_u + (1 - \gamma)\alpha w.
\]  

Finally, if we solve (20) for \( s \) and substitute the result and (18a) into (18b), then (19) follows. QED

Proposition 1 shows that the optimal state-contingent delegation decision does not imply weight-conservatism. The intuition is as follows: since weight-conservatism, \( c < c_b \), causes the central bank’s stabilization policy to differ from that desired by the government [compare (12) and (14)], it is not optimal when there are alternative delegation instruments available that eliminate inflation bias without distorting stabilization policy. As the proposition indicates, there exists a whole range of such alternatives \((l_b^*, p_b^*, t_b^*\)). We note some special cases that relate to the results of Walsh (1995b), Lockwood (1995), and Svensson (1997):

**Corollary 1.** Each of the following nominal-wage-contingent delegation choices results in the government’s precommitment inflation rule:

1. A weight-neutral central banker and a linear inflation contract:
   \((l_g, c_g, 0, t_b^*\)), where \( t_b^* \equiv [\alpha/\gamma][\gamma l_g - \bar{I}_u - (1 - \gamma)\alpha w]; \)
2. A weight-neutral central banker and an employment target:
   \((l_b^* c_g, 0, 0\)), where \( l_b^* \equiv [1/\gamma] [\bar{I}_u + (1 - \gamma)\alpha w]; \)
3. A weight-neutral central banker and an inflation target:
   \((l_g, c_g, p_b^*, 0\)), where \( p_b^* \equiv -[\alpha/c_g \gamma][\gamma l_g - \bar{I}_u - (1 - \gamma)\alpha w]. \)

Two novel aspects of these results are worth noting: first, we have established a rather general form of equivalence between alternative delegation choices; secondly, in spite of the static framework employed here, we have found that the optimally chosen delegation parameters are not constant, but contingent upon the nominal wage.

### 2.3 Non-State-Contingent Delegation

We will now characterize the best delegation decision under the restriction that the parameters \((l_b, c_b, p_b, t_b)\) cannot be made state contingent, but are constants. The government’s expected utility at \( t = 0 \) is then found by substituting (12) and (13b) into (3) and calculating the unconditional expectation of \( U_g \), while using the fact that \( E(se) = 0 \):
\[ E_0(U_g) = -[(\bar{I}_u - I_g)^2 + \beta^2(1 - \gamma)^2\sigma_s^2] - c_b \left[ p_b - \frac{t_b}{c_b} + \frac{\alpha}{c_b} (I_b - \bar{I}_u) \right]^2 \]

\[ - \frac{c_b^2 + c_g \alpha^2}{(\alpha^2 + c_b^2)^2} \sigma_e^2 - \frac{c_g \alpha^2 \beta^2 (1 - \gamma)^2}{c_b^2} \sigma_s^2. \]

(21)

The last three elements of the right-hand side of (21) depend in different ways on the delegation choice: the second term depends upon all delegation parameters; the third and the fourth term are functions solely of the central bank’s relative weight on inflation, \(c_b\). Note that these terms can be given an intuitive explanation: the second one measures the expected loss associated with the nonzero mean inflation bias, the third one measures the expected loss associated with incomplete stabilization of employment and inflation (it is impossible to stabilize both), and the last one measures the expected loss associated with the stochastic inflation bias.

**Proposition 2.** If the delegation parameters cannot be made state-contingent, the government cannot implement its precommitment inflation rule, (14). The delegation decision that maximizes \(E_0(U_g)\) is then characterized by

\[ c_g < c_b^* < \infty \quad \text{(weight-conservatism)}, \]

(22a)

\[ p_b^* - \frac{t_b^*}{c_b^*} + \frac{\alpha}{c_b^*} (I_b^* - \bar{I}_u) = 0 \quad \text{(zero expected inflation bias)}. \]

(22b)

As \(s\), the private sector’s signal of \(\varepsilon\), becomes completely informative \(\left[\sigma_\theta^2 \rightarrow 0\right]\), the optimal degree of weight conservatism approaches infinity, \(c_b^* \rightarrow \infty\); as the signal becomes completely uninformative \(\left[\sigma_\theta^2 \rightarrow \infty\right]\), weight-neutrality becomes optimal, \(c_b^* \rightarrow c_g\). More generally, the optimal degree of weight conservatism is increasing in \(1/\sigma_\theta^2\), the informativeness of \(\theta\).

**Proof:** See the appendix.

Proposition 2 contains the main result of this paper, namely, that weight-conservatism is part of the optimal delegation decision. The most obvious way in which the central bank can be made weight-conservative is to appoint an individual as central bank governor who has previously revealed his inflation aversion. In particular, central bankers are often chosen from the “conservative elements of the financial community” (Rogoff 1985).

Intuitively, the optimality of weight-conservatism can be best understood by substituting (22b) into (12), which yields discretionary equilibrium inflation after the parameters \((l_b, p_b, t_b)\) have been chosen optimally,

\[ p = -\frac{\alpha \beta}{c_b} (1 - \gamma) s - \frac{\alpha}{c_b + \alpha^2} \varepsilon. \]

(23)

Comparison of this expression with (12) shows that setting \((l_b, p_b, t_b)\) according to (22a) eliminates entirely the mean inflation bias. However, discretionary inflation
under weight-neutrality [that is, \( c_b = c_g \)] still differs from the government’s precommitment inflation rule, by the stochastic inflation bias \(- (\alpha B/c_g)(1 - \gamma)s\). The stochastic inflation bias remains since, by assumption, the delegation parameters cannot be state contingent. So, it is clear from (23), that, as in Rogoff (1985), a change from weight-neutrality to weight-conservatism [that is, an increase in \( c_b \) from \( c_g \)] has two consequences. First, it enhances credibility and, therefore, reduces the stochastic inflation bias. Second, it lowers stabilization below what is optimal from the point of view of the government, leading to too much employment variability. Optimally trading off these two effects leads to choice of a (finitely) weight-conservative central banker.\(^{16}\)

As in the case with state-contingent delegation, the delegation parameters are not uniquely determined—a number of different combinations of them are optimal. Corollary 2, below, lists some examples.

**Corollary 2.** If the delegation decision cannot be made state contingent, each of the following delegation choices is optimal for the government:

1. **Optimal weight-conservatism and a linear inflation contract with constant slope:**

   \[(l_g, c_g^*, 0, \tau_g^*)\], where \( c_g < c_b^* < \infty \) and \( \tau_g^* = \alpha[l_g - \bar{u}] \).

2. **Optimal weight-conservatism and a constant employment target:**

   \[(l_b^*, c_b^*, 0, 0)\], where \( c_g < c_b^* < \infty \) and \( \bar{u} = \bar{u} \).

3. **Optimal weight-conservatism and a constant inflation target:**

   \[(0, c_b^*, p_b^*, 0)\], where \( c_g < c_b^* < \infty \) and \( p_b^* = -[\alpha/c_b^*][l_g - \bar{u}] \).

One implication of Corollary 2 (ii) is that the government’s precommitment inflation rule can no longer be achieved by choosing an appropriate employment target for the central bank. This is interesting, because it has often been claimed that the time-consistency problem in the Barro and Gordon model is artificial in that it could easily be removed by assigning an employment target equal to equilibrium employment to the central bank. While this is indeed possible in simple versions of the Barro-Gordon model, in which equilibrium employment is not stochastic, our results suggest that it is likely to be impossible in more realistic settings with stochastic equilibrium employment.

\(^{16}\) Note that when (22b) is satisfied, the optimally chosen \( c_b^* \) is smaller (and stabilization of employment is less distorted) than for any other non-state-contingent choice of the delegation parameters, \((l_b, p_b, \tau_b)\). This means that combining weight-conservatism with delegation parameters chosen according to (22b) dominates Rogoff’s suggestion of appointing only a weight-conservative central banker \([c_g < c_b^*\) and \((l_b, p_b, \tau_b) = (l_e, 0, 0)\)]. The intuition for this is similar to that in Lockwood, Miller, and Zhang (1996), who proposed that weight-conservatism can be smaller when the central banker has more reputation, since then the inflation bias is smaller.

\(^{17}\) Recently, Svensson (1997) has shown that if output is persistent in a multiperiod version of the Barro-Gordon model, weight-conservatism is also desirable, if the government’s other delegation instrument is a state-contingent inflation target. His model and arguments are rather different from ours. The intuition for his result is again different to ours; with a state-contingent inflation target and weight-neutrality, productivity shocks are overstabilized, and so raising the central banker’s weight on the inflation target above that of the government improves the stabilization performance of the central banker. In contrast, in our model, weight-conservatism reduces the variance of inflation bias, but worsens the stabilization performance. One consequence of the differences in approach is that, in Svensson, combination of a state-contingent inflation target with weight-conservatism can implement the government’s precommitment outcome, whereas, in our model, the government cannot achieve its precommitment outcome in general.
3. DELEGATION WHEN TRADE UNION OBJECTIVES ARE PRIVATE INFORMATION

Comparison of Propositions 1 and 2 indicates that our main result may not be robust; if the government can condition its delegation just on a single piece of information publicly available at \( t = 1 \), namely the nominal wage \( w \), weight-conservatism is not desirable (Proposition 1). In this section, we will show that Proposition 2 is robust in the following sense. If we introduce an additional information asymmetry between the private sector, on one hand, and the government and the central bank, on the other hand, then a result similar to Proposition 2 goes through, even if the delegation decision can be conditioned on \( w \). This suggests a general principle—which we conjecture is true, but have not proved—that if the number of stochastic disturbances to the inflation bias exceeds the number of variables publicly observed at \( t = 1 \), on which the government can condition its delegation decision, then the government cannot achieve its precommitment outcome by delegation, and weight-conservatism is desirable.

The additional information asymmetry is introduced through the assumption that each trade union’s real wage target, \( v_u \), is a random variable, implying that \( \bar{I}_u = (\alpha^2 I_u - c_v v_u)/(\alpha^2 + c_v) \) is a random variable, too. Let \( \varphi \) be a zero-mean disturbance in \( I_u \) common to all trade unions and \( \bar{I}_u = E(I_u) + \varphi \) at the aggregate level.\(^{18}\) Moreover, we assume that the realization of \( \varphi \) is only known to the trade unions. So, both \( I_u \) and \( s \) are now private information of the trade unions. Equation (8) indicates the complication introduced by this assumption, namely, the signal, \( s \), can no longer be inferred unambiguously from the observation of the nominal wage.

As the value of \( I_u \) is not pay-off relevant for the central bank, the discretionary equilibrium is not affected by the change in the information structure, so (8), (12), and (13b) are still valid. The delegation decision is now to choose \((l_b, c_b, p_b, t_b)\) conditional upon \( w \) so as to maximize \( E[-(1 - l_b)^2 - p^2] \). We first show that, unlike in the complete information case, the government can no longer implement the precommitment inflation rule via delegation conditional upon \( w \).

**Proposition 3.** Even with delegation contingent on \( w \), the government cannot implement its precommitment inflation rule, (14), as long as the signal \( s \) of \( \epsilon \) is noisy \([\sigma^2_0 > 0]\).

**Proof:** First, we note that as long as \( \sigma^2_0 > 0 \), the signal \( s \) differs from the supply shock \( \epsilon \). Since \( I_u \) is not known to the government, it is no longer possible to infer \( s \) from \( w \); see (8). Second, comparison of (12) with (14) implies that for the precommitment rule to be implemented in discretionary equilibrium, we need \( c_b = c_g \) and

\[
E(p \mid s, \bar{I}_u) = p_b - \frac{I_b}{c_b} + \frac{\alpha}{c_b} [l_b - \bar{I}_u - \beta(1 - \gamma)s] = 0. \tag{24}
\]

\(^{18}\) The employment target of any single trade union, \( i \in [0, 1] \), could more generally be represented as \( I_u(i) = E(I_u) + \varphi + \mu(i) \), where the \( \mu(i) \) are independent and mean-zero. This would not change the results, because, by the law of large numbers, the effect of \( \mu(i) \) would disappear at the aggregate level.
In addition, from $E(p|s, l_u) = 0$ and (8), we have $s = (\alpha w + l_u)/\beta \gamma$. Substituting this into (24) yields

$$p_b - \frac{t_b}{c_b} + \frac{\alpha}{c_b} \left[ l_b - \bar{l}_u - (1 - \gamma) \frac{\alpha w + \bar{l}_u}{\gamma} \right] = 0.$$  

(25)

Since $(l_b, p_b, t_b)$ can be conditioned only on $w$, but not on $\bar{l}_u$, this equation will fail to hold in general. QED

Proposition 3 shows that the benchmark result of Proposition 1 does not go through when the government has incomplete information about the structure of the model. Therefore, the question arises whether weight-conservatism is still desirable. To answer this, first note that the delegation decision can equivalently be expressed as the problem of choosing $(l_b, c_b, p_b, t_b)$ so as to maximize $E[-(1 - \gamma)^2 - p^2|w]$, subject to (12) and (13b). Note also that $E[-(1 - \gamma)^2 - p^2|w]$ is identical to (21), except that (i) $\bar{l}_u$ is now stochastic; (ii) all variances are conditional upon $w$. More precisely,

$$E_0(U_g|w) = - \left[(l_g - E(\bar{l}_u))^2 + \beta^2(1 - \gamma)^2 \sigma^2_{x|w} \right]$$

$$- c_g \left[ p_b - \frac{t_b}{c_b} + \frac{\alpha}{c_b} [l_b - E(\bar{l}_u)] \right]^2$$

$$- \frac{c_b^2 + c_g \alpha^2}{(\alpha^2 + c_b^2)} \sigma^2_{x^2|w} - \frac{c_g \alpha^2 \beta^2(1 - \gamma)^2}{c_b^2} \sigma^2_{x|w}$$

$$- \left[ 1 + \frac{c_g \alpha^2}{c_b^2} \right] \sigma^2_{\phi|w},$$  

(26)

where $\sigma^2_{x|w} = E(x^2|w)$, $x = \theta$, $s$, $\phi$. Inspection of (26), combined with reference back to the proof of Proposition 2, shows that $c_b^* > c_g$ is optimal, as long as, for every possible value of $w$, at least one of $\sigma^2_{x|w}$ and $\sigma^2_{x^2|w}$ is positive. Since the proof of Proposition 3 implies that $\bar{l}_u$, and, therefore, $\phi$, cannot be inferred from $w$, we must have $\sigma^2_{\phi|w} > 0$. So we have shown:

**Proposition 4.** Suppose that the delegation parameters can all be made contingent on $w$. Then, for every value of $w$, weight-conservatism is still optimal, that is, $c_b^* > c_g$, providing the real wage target $\nu_u$ and the signal $s$ are private information of the trade unions.

Proposition 4 shows that our main result (Proposition 2) is relatively robust, since it does not disappear when delegation is "partially" state contingent. The intuition is that, now, there are two sources of stochastic variation in the inflation bias term in (12) above, that is, $s$ and $\phi$, but only one variable, that is $w$, on which delegation can be conditioned. Our result suggests that weight-conservatism will be optimal...
whenever the number of different sources of stochastic variation in inflation bias exceeds the number of variables on which delegation can be conditioned.

4. CONCLUSION

We have argued that there exist disturbances to inflation bias upon which delegation of monetary policy to an independent central banker cannot be made contingent and if delegation is not fully contingent in this way, inflation bias cannot entirely be eliminated. We have shown that if a (stochastic) inflation bias remains after optimally choosing a linear inflation contract to the central bank, or an employment target, or an inflation target, then, indeed, the optimal delegation choice will also involve weight-conservatism. Our results suggest that, except in very special cases, a combination of weight-conservatism with a linear inflation contract, or an employment target, or an inflation target, dominates the solutions discussed in the literature, which consider only one of these delegation instruments.

APPENDIX: PROOF OF PROPOSITION 2

We want to find a quadruple \((l^*_b, c^*_b, p^*_b, t^*_b)\) that maximizes (21). The first term of (21) is unaffected by \((l^*_b, c^*_b, p^*_b, t^*_b)\), so it must be taken as given. Maximizing the second term (by setting it equal to zero) leads to (22b). Since this still leaves us free to choose the desired degree of weight-conservatism, we may pick \(c_b\) so as to maximize the sum of the third and the fourth term. However, this is equivalent to minimizing

\[
 f(c_b) = \frac{c_b^2 + c_s \alpha^2}{(\alpha^2 + c_b)^2} \sigma_v^2 + \frac{c_s \alpha^2 \beta^2 (1 - \gamma)^2}{c_b^2} \sigma_s^2. \tag{A.1}
\]

The first and second derivative of \(f(c_b)\) can be shown to equal

\[
 \frac{\partial f(c_b)}{\partial c_b} = \frac{2 \alpha^2 (c_b - c_s)}{(\alpha^2 + c_b)^3} \sigma_v^2 - \frac{2 c_s \alpha^2 \beta^2 (1 - \gamma)^2}{c_b^3} \sigma_s^2, \tag{A.2a}
\]

\[
 \frac{\partial^2 f(c_b)}{\partial c_b^2} = \frac{2 \alpha^2 (\alpha^2 - 2 c_b + 3 c_s)}{(\alpha^2 + c_b)^4} \sigma_v^2 + \frac{6 c_s \alpha^2 \beta^2 (1 - \gamma)^2}{c_b^4} \sigma_s^2, \tag{A.2b}
\]

Substituting the first-order condition into (A.2b), it follows that the second derivative of \(f(.)\) is larger than zero when the first-order condition is satisfied. In other words, \(f(.)\) cannot have an interior maximum. Moreover, since \(\frac{\partial f(c_s)}{\partial c_b} < 0\) and \(\frac{\partial f(c_b)}{\partial c_b} > 0\) for sufficiently large \(c_b\), there must be at least one interior minimum. Hence, there is a unique interior minimum, \(c^*_b\), with \(c_s < c^*_b < \infty\). We complete the first part of the proof by noting that since under weight-conservatism, the variance of inflation bias remains larger than zero and stabilization of employment becomes
suboptimally low, the government can no longer achieve its precommitment inflation rule, (14).

To prove the last part of the Proposition, we note first that as $\sigma^2_s \to 0$, $\sigma^2_\delta \to \sigma^2_\epsilon$, $\beta \to 1$ and $e \to 0$, implying that $\sigma^2_\epsilon \to 0$. So, from (A.1), as $\sigma^2_\delta \to 0$,

$$f(c_b) \to \frac{c_b \alpha^2(1 - \gamma)^2}{c_b^2} \sigma^2_\epsilon,$$  \hspace{1cm} (A.3)

which is minimized at $c^*_b = \infty$. Second, as $\sigma^2_\delta \to \infty$, $\beta \to 0$ and $e \to 0$, implying that $\sigma^2_\epsilon \to \sigma^2_\epsilon$. Moreover, since $\sigma^2_s = \sigma^2_\epsilon + \sigma^2_\delta$, $\sigma^2_\delta \to \infty$ implies $\sigma^2_s \to \infty$. Also, since $\beta^2 \sigma^2_s \to \sigma^4_s/\sigma^2_s$, $\beta^2 \sigma^2_\epsilon \to 0$, as $\sigma^2_\delta \to \infty$. Putting these facts together, we obtain from (A.1) that as $\sigma^2_\delta \to \infty$,

$$f(c_b) \to \frac{c^2_b + c_b \alpha^2}{(\alpha^2 + c_b)^2} \sigma^2_\epsilon,$$  \hspace{1cm} (A.4)

which is minimized at $c^*_b = c^*_s$. Finally, in order to prove that $\partial c^*_b/\partial \sigma^2_\delta > 0$, we implicitly differentiate the first-order condition to get

$$\frac{\partial c^*_b}{\partial \sigma^2_\delta} = - \frac{\partial^2 f(c^*_b)/\partial c^*_b \partial \sigma^2_\delta}{\partial^2 f(c^*_b)/\partial^2 \sigma^2_\delta}. \hspace{1cm} (A.5)$$

As shown above, the denominator of (A.5) is positive. Concerning the numerator, using that $\partial f(c^*_b)/\partial c_b = 0$, $\sigma^2_\epsilon = (1 - \beta)^2 \sigma^2_\epsilon + \beta^2 \sigma^2_\delta$, and $\sigma^2_s = \sigma^2_\epsilon + \sigma^2_\delta$, we obtain from (A.2a):

$$\frac{\partial^2 f(c^*_b)}{\partial c^*_b \partial \sigma^2_\delta} = - (1 - \beta^2) \frac{2\alpha^2(c^*_b - c^*_s)}{(\alpha^2 + c^*_s)^3} < 0. \hspace{1cm} (A.6)$$

Thus, $\partial c^*_b/\partial \sigma^2_\delta > 0$. QED

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