ROGOFF'S 'CONSERVATIVE' CENTRAL BANKER RESTORED

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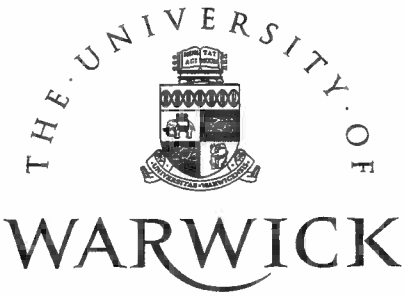

DEPARTMENT OF ECONOMICS

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Rogoff's 'Conservative' Central Banker Restored*

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Abstract

This paper shows that delegation of monetary policy to a weight–conservative central banker is optimal, 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 shown to be desirable if the stochastic inflation bias cannot be eliminated by optimal choice of the delegation parameters.

KEYWORDS: Conservative Central Banker; Delegation; Incomplete Information.

JEL CLASSIFICATION: E52; E58.

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1 Introduction

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,[1] 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.[2] On the other hand, Walsh (1995b) has recently pointed out that the government could set the central banker's remuneration contingent upon realized inflation – an *inflation contract*. It turns out that an inflation contract can be designed so as to eliminate the inflation bias, whilst ensuring that the central 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.[3]

Following Walsh's contribution, the current literature discounts weight–conservatism, and rather focuses on finding alternative ways of creating the optimal incentives for the central banker. 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 [Persson and Tabellini (1990) and Lockwood (1995a)]; (iii) an inflation targeting arrangement [Svensson (1995)]. In contrast to this recent literature, we suggest that an optimal choice of objectives for an independent central

[1] Throughout the paper, by "inflation bias" we mean the excess of equilibrium inflation above the level desired by the government.

[2] See Lohmann (1992), Waller (1992) and Lockwood, Miller and Zhang (1994) for generalizations of Rogoff's basic model.

[3] The contracting solution of Walsh (1995b) has been extended in various directions by, among others, Persson and Tabellini (1993), Fratianni, von Hagen and Waller (1995), Lockwood (1995a,b) and Walsh (1995a).

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 below that, providing the delegation decision cannot be made contingent upon this information, 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 increasing the weight–conservatism of the central banker. 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 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], 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.[4] We call such delegation *non–state–contingent*. The assumption of 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 pursue monetary policy. In this case, in Fischer's (1995) terminology, the central banker is *goal*

[4] 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].

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 possible interpretation of the delegation decision is that the government can set certain targets for the central banker, who is then penalized for non–attainment 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.[5] 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, because target bands are typically set for a period of one or more years, and would only be revised 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." This lack of state contingency probably reflects the high transaction and verification costs of setting and enforcing state–contingent inflation targets.[6] It may also be due to the fact that not all contingency are known or describable at the time when the target is set; see Fischer (1990) for further discussion.

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

[5] Empirically, the situation will typically be between the two extremes [Fischer (1995)].

[6] For a general discussion of these costs and why they may lead to incomplete contracting, see e.g. Hart (1995).

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 disturbances from the nominal wage, and so cannot set the employment/inflation targets and/or an inflation contract contingent on both disturbances. Thus, delegation does not entirely eliminate inflation bias, which depends on *both* these variables. This suggests a general principle, namely, 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 e.g. the discussion in Canzoneri, Nolan and Yates (1995).

The plan of the rest of the paper is as follows. In section 2, we present our model. Section 3 analyzes both contingent and non–contingent delegation, and section 4 focuses on the case where the government is incompletely informed about private sector preferences. Finally, section 5 concludes.

2 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.[7] Each trade union represents all households who supply labour to a particular firm, and has monopoly power over wage setting – a so–called monopoly union. There are $\bar{l}$ households in any sector, who will each supply an indivisible unit of labour at a reservation wage, which we set to zero without loss of generality. Thus, competitive labour supply in any sector and on the aggregate level is perfectly elastic up to full employment $\bar{l}$, and inelastic thereafter.

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

[7] Technically, we assume continua of measure 1 of identical trade unions and firms.

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)].

At $t = 1$, the sequence of events is as follows: (i) a supply shock ϵ is realized with $E\epsilon = 0$ and $0 < \sigma_\epsilon^2 < \infty$; (ii) every trade union observes a noisy signal $s = \epsilon + e$ of ϵ, where $Ee = 0$ and $0 < \sigma_e^2 < \infty$, and s is not directly observed by either the central banker or the government;[8] (iii) the trade union chooses the nominal wage, w; (iv) the central banker observes the supply shock ϵ itself; (iv) the central banker chooses the inflation rate, p; (v) employment, l, results from firms' labor demand.

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 level at $t = 1$. Hence, $(w - p)$ denotes the real wage and a typical firm's labor demand may be written as

$$l = \alpha(p - w) + \epsilon, \tag{1}$$

where $\alpha > 0$ is a constant. Wage–setting behavior is modelled by supposing that a representative trade union has both an employment objective, l_u, and a real wage objective, v_u,[9]

$$U_u \equiv -(l - l_u)^2 - c_u[w - p - v_u]^2, \quad c_u > 0, \tag{2}$$

where $l_u < \bar{l}$ and $v_u > -\bar{l}/\alpha$. 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.

[8] 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 $s(i) = \epsilon + \psi + \phi(i)$, where the $\phi(i)$ are independent with mean zero, and ψ is common across trade unions, then, in equilibrium, the net effect of $\phi(i)$ on aggregate wages and employment are zero.

[9] As we assume a continuum of measure one of identical trade unions, l_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 non–zero inflation,[10]

$$U_g \equiv -(l - l_g)^2 - c_g p^2, \quad c_g > 0. \tag{3}$$

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

Finally, our parametrization of the central bank's objective function is fairly general,

$$U_b \equiv -(l - l_b)^2 - c_b(p - p_b)^2 - 2t_b p, \tag{4}$$

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 $2t_b p$ 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_b, 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 suggestion that we cannot deal with is 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*. 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 gov-

[10] Note that it is straightforward to extent our setting to situations in which the government seeks to extract seigniorage from the private sector and, thus, has a positive inflation target.

ernment *and* upon all (or some) variables publicly observable at the end of period $t = 1$, i.e. the nominal wage, w, the shock, ϵ, 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 it may be helpful to 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 non-policy reasons, e.g. incompetence.[11] Moreover, the turnover rates of CB governors indicate that the average period in office is between 7 and 10 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, e.g. 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, e.g. 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.[12]

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[11] This is the case in ten OECD countries over the period 1980-89 [Cukierman (1992, Chapter19, Appendix A)].

[12] See, for example, Freedman (1995) and Fischer (1995a) on the Canadian and the New Zealand experience with inflation targeting.

3 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.

3.1 Discretionary Equilibrium

Here, we study the interaction at $t = 1$ between the appointed central banker with a given objective function and the trade union and solve for inflation, the nominal wage and employment. As the agents move sequentially and s is assumed to be known only to the trade unions, there is private information and the solution concept is perfect Baysian 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, i.e. the solution concept was Nash. Here, in spite of the sequential move structure, the private sector, in equilibrium, takes 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 infer s from w. This means that, given w, his optimal choice of p simply maximizes the objective function (4) subject to (1). The first order condition is

$$\alpha[\alpha(p - w) + \epsilon - l_b] + c_b(p - p_b) + t_b = 0. \tag{5}$$

Taking inflation expectations conditional on s through (5), we obtain an equation for

the representative trade union's expectation of inflation, $E(p|s)$,

$$\alpha[\alpha[E(p|s) - w] + s - l_b] + c_b[E(p|s) - p_b] + t_b = 0, \tag{6}$$

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. Taking p as given, the optimal w, therefore, simply maximizes (2) subject to (1). This leads to the first order condition

$$(\alpha^2 + c_u)[E(p|s) - w] + \alpha(s - l_u) + c_u v_u = 0. \tag{7}$$

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,

$$w = E(p|s) + \frac{\gamma}{\alpha}s - \frac{1}{\alpha}\bar{l}_u, \tag{8}$$

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

$$\alpha^2[p - E(p|s)] + \alpha(\epsilon - \gamma s + \bar{l}_u - l_b) + c_b(p - p_b) + t_b = 0. \tag{9}$$

After taking the expectation conditional on s through this equation, we can solve for expected inflation in the discretionary equilibrium,

$$E(p|s) = p_b - \frac{t_b}{c_b} + \frac{\alpha}{c_b}\Big[(l_b - \bar{l}_u) - (1 - \gamma)s\Big]. \tag{10}$$

Finally, since subtracting (6) from (5) implies

$$p - E(p|s) = -\frac{\alpha}{\alpha^2 + c_b}(\epsilon - s), \tag{11}$$

actual inflation in discretionary equilibrium is

$$p^d = p_b - \frac{t_b}{c_b} + \frac{\alpha}{c_b}\Big[(l_b - \bar{l}_u) - (1-\gamma)s\Big] - \frac{\alpha}{\alpha^2 + c_b}e, \tag{12}$$

where $e \equiv \epsilon - s$ is the trade union's error in predicting ϵ. Equilibrium inflation has three clear elements: first, the "effective" inflation target $p_b - t_b/c_b$; second, the inflation bias $[\alpha/c_b][(l_b - \bar{l}_u) - (1-\gamma)s]$; and third, the stabilization term $\alpha e/(\alpha^2 + c_b)$.

From (1), (8), (10) and (12), we can also calculate employment in the discretionary equilibrium,

$$l^d = \bar{l}_u + (1-\gamma)s + \frac{c_b}{c_b + \alpha^2}e. \tag{13}$$

So, equilibrium employment is equal to the natural rate of employment, $\bar{l}_u$, plus the part of the anticipated shock that is not stabilized by the trade union, $(1-\gamma)s$, plus the part of the prediction error, e, that is not stabilized by the central bank, $c_b e/(c_b + c_u^2)$. Note that, in our model, the natural rate of employment, $\bar{l}_u$, is smaller than full employment, $\bar{l}$. In our model, the underlying labor market distortion comes from the assumed targets of the trade union's, i.e. $l_u < \bar{l}$ 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 $\bar{l}_u < [\alpha^2 l_u + c_u \bar{l}]/[\alpha^2 + c_u] < \bar{l}$. Alternatively, one could consider a competitive labor market with a distortion due to the existence of taxes.

It is interesting to observe from (12) and (13) that whenever a representative trade union assigns a positive weight to its real wage target [i.e. $c_u > 0$, implying that its stabilization coefficient γ is smaller than one], then inflation and employment in discretionary equilibrium vary with the signal s about the productivity shock. The reason is as follows. In anticipation of a (say) negative productivity shock ϵ, a representative union will adjust the nominal wage downward to stabilize employment; this adjustment will be proportional to s. However, since complete stabilization of employment would mean that the expected real wage bears the entire burden of adjustment, stabilization will be incomplete, as long the trade unions put *some* weight on their real wage targets; hence, the fact that l^d depends on s. Moreover, since the central banker will in general

prefer more stabilization of the supply shock than a representative trade union, each trade union will set the nominal wage so as to eliminate the central banker's incentive to correct its preferred stabilization of s. Consequently, inflation bias in discretionary becomes stochastic from the point of view of government, and the central banker, in equilibrium, only stabilizes employment in proportion to the trade union's prediction error, e, which explains the last term in (12) and the last term in (13).[13]

3.2 State–Contingent Delegation

We begin the analysis of the government's delegation decision at $t = 0$ with the benchmark case of state–contingent delegation. It is convenient to characterize first the policy rule for inflation that the government would choose if it could precommit at $t = 0$. This precommitment inflation rule must have two properties. First, given the government's inflation target of zero, mean inflation with the precommitment rule is to be zero too. Second, the precommitment rule must optimally stabilize employment from the point of view of the government. 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 $\alpha/(c_g + \alpha^2)$. Thus, the precommitment rule is

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

Now, formally, the delegation problem for the government at $t = 0$ is to choose the parameters $(l_b^*, c_b^*, p_b^*, t_b^*)$ in the central bank's objective so as to maximize the unconditional expectation of the objective function (3) subject to (12) and (13). It is intuitively

[13] 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. (1995)]; 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) and Lockwood (1995b)], or changes in the stock of non–indexed, net nominal liabilities of the public sector [Herrendorf (1995b)]. Note that the last two possibilities are relevant only in multiperiod, dynamic models.

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 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,*

$$c_b^* = c_g \qquad \textit{(weight–neutrality)}\,, \tag{15a}$$

$$p_b^* - \frac{1}{c_b^*}\, t_b^* + \frac{\alpha}{c_b^*}[(l_b^* - \bar{l}_u) - (1-\gamma)s] = 0 \qquad \textit{(zero inflation bias)}\,. \tag{15b}$$

To achieve (15a) and (15b), (p_b^*, l_b^*, t_b^*) need to be set conditional upon w as follows:

$$p_b^* - \frac{t_b^*}{c_g} + \frac{\alpha}{c_g} l_b^* = \frac{\alpha}{c_g \gamma}[\bar{l}_u + (1-\gamma)\alpha w]. \tag{16}$$

Proof: 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 (15a) and (15b) have to hold for all s. Next, from (10) and (15b), it must be that $E(p|s) = 0$. Using this fact in equation (8), we get

$$w = \frac{\gamma}{\alpha}\, s - \frac{1}{\alpha}\, \bar{l}_u. \tag{17}$$

If we solve (17) for s and substitute the result and (15a) into (15b), then (16) follows. QED

So, the optimal state–contingent delegation decision does not imply weight–conservatism. The intuition is as follows: since weight–conservatism, $c_g < c_b^*$, causes the central bank's stabilization policy to differ from that desired by the government [compare (12) and (14)], it is not optimal whenever 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 may report some special cases that relate to the results of Walsh (1995b), Lockwood (1995a)

and Svensson (1995):

Corollary 1. *Each of the following nominal-wage-contingent delegation choices achieves the government's precommitment inflation rule:*
(i) to appoint a weight–neutral central banker and set a linear inflation contract:
$(l_g, c_g, 0, t_g^*)$, *where* $t_b^* \equiv [\alpha/\gamma][\gamma l_g - \bar{l}_u - (1-\gamma)\alpha w]$;
(ii) to appoint a weight–neutral central banker and set an employment target:
$(l_b^*, c_g, 0, 0)$, *where* $l_b^* \equiv [1/\gamma][\bar{l}_u + (1-\gamma)\alpha w]$;
(iii) to appoint a weight–neutral central banker and set an inflation target:
$(l_g, c_g, p_b^*, 0)$, *where* $p_b^* \equiv -[\alpha/c_g\gamma][\gamma l_g - \bar{l}_u - (1-\gamma)\alpha w]$.

Two novel aspects of these results are worth noting: firstly, 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. It is this feature that will prove to be important for what follows.

3.3 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 using (3), (12), (13), and the fact that $E(s|e) = 0$:

$$\begin{aligned} E_0(U_g) &= -\left[(\bar{l}_u - l_g)^2 + (1-\gamma)^2\sigma_s^2\right] - c_g\left[p_b - \frac{t_b}{c_b} + \frac{\alpha}{c_b}(l_b - \bar{l}_u)\right]^2 \\ &\quad - \frac{c_b^2 + c_g\alpha^2}{(\alpha^2 + c_b)^2}\sigma_e^2 - \frac{c_g\alpha^2(1-\gamma)^2}{c_b^2}\sigma_s^2. \end{aligned} \tag{18}$$

We can observe that the four elements of the right hand side of (18) depend in different ways on the delegation choice: the first term is a constant from the point of view of government; 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.

Proposition 2. *If the delegation parameters cannot be made state–contingent, then the*

government cannot implement its precommitment inflation rule, (14). The delegation decision that maximizes $E_0(U_g)$ is then characterized by:

$$c_g < c_b^* < \infty \qquad \textit{(weight–conservatism)}\,, \tag{19a}$$

$$p_b^* - \frac{t_b^*}{c_b^*} + \frac{\alpha}{c_b^*}(l_b^* - \bar{l}_u) = 0 \qquad \textit{(zero expected inflation bias).} \tag{19b}$$

Proof. We want to find a quadruple $(l_b^*, c_b^*, p_b^*, t_b^*)$ that maximizes (18). Since the first term of (18) is unaffected by $(l_b^*, c_b^*, p_b^*, t_b^*)$, it must be taken as given. Maximizing the second term [by setting it equal to zero] leads to (19b). Since this still leaves us free to choose the desired degree of 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

$$f(c_b) \equiv \frac{c_b^2 + c_g\alpha^2}{(\alpha^2 + c_b)^2}\sigma_e^2 + \frac{c_g\alpha^2(1-\gamma)^2}{c_b^2}\sigma_s^2. \tag{20}$$

The first and the second derivative of $f(c_b)$ can be shown to equal:

$$\frac{\partial f(c_b)}{\partial c_b} = \frac{2\alpha^2(c_b - c_g)}{(\alpha^2 + c_b)^3}\,\sigma_e^2 - \frac{2c_g\alpha^2(1-\gamma)^2}{c_b^3}\,\sigma_s^2, \tag{21a}$$

$$\frac{\partial^2 f(c_b)}{\partial c_b^2} = \frac{2\alpha^2(\alpha^2 + c_g)}{(\alpha^2 + c_b)^4}\,\sigma_e^2 + \frac{6c_g\alpha^2(1-\gamma)^2}{c_b^4}\,\sigma_s^2 > 0. \tag{21b}$$

(21b) implies that $f(.)$ is convex in c_b. Furthermore, from (21a),

$$\frac{\partial f(c_g)}{\partial c_b} < 0 \quad \text{and} \quad \lim_{c_b \to \infty} \frac{\partial f(c_b)}{\partial c_b} > 0. \tag{22}$$

Therefore, in the interior of (c_g, ∞), there must exist a unique minimum of $f(.)$, implying that $c_g < c_g^* < \infty$. We complete 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 is no longer able to achieve its precommitment inflation rule, (14). QED

Proposition 2 contains the main result of our paper; namely, that weight–conservatism is now part of the optimal delegation decision. Intuitively, the optimality of weight–

conservatism can be best understood by substituting (19b) into (12), which yields discretionary equilibrium inflation after the parameters (l_b, p_b, t_b) have been chosen optimally,

$$p = -\frac{\alpha}{c_b}(1-\gamma)\, s - \frac{\alpha}{c_b + \alpha^2}\, e. \tag{23}$$

Comparison of this expression with (12) shows that setting (l_b, p_b, t_b) according to (19a) eliminates entirely the *mean* inflation bias. However, as (23) shows, discretionary inflation under weight–neutrality [i.e. $c_b^* = c_g$] still differs from the government's pre-commitment inflation rule, by the term $-\alpha(1-\gamma)s/c_g$, that is, by the deviation of *actual* inflation bias from zero. This term remains in (23) since, by assumption, the delegation parameters cannot be state–contingent. So, it is clear from (23), that, as in Rogoff (1985), moving from weight–neutrality to weight–conservatism [i.e. an increase in c_b from c_g] has two consequences here. First, it enhances credibility and, therefore, reduces [stochastic] inflation bias, $\alpha(1-\gamma)s/c_b$. 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.[14]

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:*
(i) to choose the optimal degree of weight–conservatism and set a linear inflation contract with constant slope:
$(l_g, c_b^*, 0, t_g^*)$, *where* $c_g < c_b^* < \infty$ *and* $t_b^* \equiv \alpha[l_g - \bar{l}_u]$;

[14] Note that when (19b) 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, t_b). In particular, this means that supplementing weight–conservatism with delegation parameters chosen according to (19b) dominates Rogoff's suggestion of appointing only a weight–conservative central banker [$c_g < c_b^*$ and $(l_b, p_b, t_b) = (l_g, 0, 0)$]. The intuition for this is similar to that in Fratianni and Huang (1995) and Lockwood, Miller and Zhang (1995), who proposed that weight–conservatism can be smaller when the central banker has more reputation, since then the inflation bias is smaller.

(ii) to choose the optimal degree of weight–conservatism and set a constant employment target:

$(l_b^*, c_b^*, 0, 0)$, *where* $c_g < c_b^* < \infty$ *and* $l_b^* \equiv \bar{l}_u$;

(iii) to choose the optimal degree of weight–conservatism and set a constant inflation target:

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

One interesting 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 important, because it has often been claimed in the literature 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.

4 Delegation When Trade Union Objectives are Private Information

One possible objection to our main result on weight–conservatism [Proposition 2] is that it is not 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 [as Proposition 1 shows]. In this section, we show that our main result is robust in the following sense: if an *additional* information asymmetry is introduced 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 $\bar{l}_u \equiv [\alpha^2 l_u - c_u \alpha v_u]/(\alpha^2 + c_u)$ is a random variable too. Let $\hat{l}_u$ denote the expected value of $\bar{l}_u$ and φ be a zero–mean disturbance in $\bar{l}_u$ common to all trade unions. Then, $\bar{l}_u = \hat{l}_u + \varphi$ on the aggregate level.[15] Moreover, we assume that the realization of φ is only known to the trade unions. So, both $\bar{l}_u$ 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 $\bar{l}_u$ 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 (13) 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 $E[-(l - l_g)^2 - p^2]$. We first show that, unlike in the complete information case, the government now 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 is noisy [$\sigma_\psi > 0$].*

Proof: First, we note that, as long as $\sigma_\psi > 0$, the signal s differs from the supply shock ϵ. Since $\bar{l}_u$ 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

$$E(p|s, \bar{l}_u) = p_b - \frac{t_b}{c_b} + \frac{\alpha}{c_b} l_b - \bar{l}_u - (1 - \gamma)s = 0. \tag{24}$$

In addition, from $E(p|s, \bar{l}_u) = 0$ and (8), we have $s = (\alpha w + \bar{l}_u)/\gamma$. Substituting this

[15] The real wage target of any single trade union, $i \in [0, 1]$, could more generally be represented as $\bar{l}_u(i) = \hat{l}_u + \varphi + \mu(i)$, 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 on the aggregate level.

into (24) yields

$$p_b - \frac{t_b}{c_b} + \frac{\alpha}{c_b} l_b - \bar{l}_u - (1-\gamma)\frac{\alpha w + \bar{l}_u}{\gamma} = 0 \tag{25}$$

However, since the (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 $E[-(l-l_g)^2 - p^2|w]$, subject to (12) and (13). However, $E[(-l_g)^2 - p^2|w]$ turns out to be identical to (18), except that (i) $\bar{l}_u$ is now stochastic; (ii) all variances are conditional upon w. More precisely,

$$\begin{aligned} E_0(U_g|w) \;=\; & -\Big[(\hat{l}_u - l_g)^2 + (1-\gamma)^2\sigma^2_{s|w}\Big] - c_g\Big[p_b - \frac{t_b}{c_b} + \frac{\alpha}{c_b}(l_b - \hat{l}_u)\Big]^2 \\ & - \frac{c_b^2 + c_g\alpha^2}{(\alpha^2 + c_b)^2}\sigma^2_{e|w} - \frac{c_g\alpha^2(1-\gamma)^2}{c_b^2}\sigma^2_{s|w} - \Big[1 + \frac{c_g\alpha^2}{c_b^2}\Big]\sigma^2_{\varphi|w}, \end{aligned} \tag{26}$$

where $\sigma^2_{x|w} = E(x^2|w)$, $x = e, s, \varphi$. 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 $\sigma^2_{s|w}$ and $\sigma^2_{\varphi|w}$ is positive. Since the proof of Proposition 3 implies that $\bar{l}_u$, and, therefore, φ, cannot be inferred from w, we must have $\sigma^2_{\varphi|w} > 0$. 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, i.e. $c_b^* > c_g$, providing the real wage target v_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 may be "partially" state–contingent. The intuition is that, now, there are *two* sources of stochastic variation in the inflation bias term in (12) above, i.e. s and φ, but only *one* variable, i.e. 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.

5 Concluding Remarks

We have argued that, in the real world, there exist disturbances to inflation bias upon which delegation of monetary policy to an independent central banker cannot be contingent. However, if delegation is not fully state–contingent, inflation bias cannot entirely be eliminated. We have shown that whenever a [stochastic] inflation bias remains after choosing optimally 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 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.

A recent paper by Svensson [Svensson (1995)] has independently arrived at some similar conclusions; although the model and the arguments used are rather different to ours, Svensson shows that if output is persistent, weight–conservatism is desirable, if the government's other delegation instrument is a state–contingent inflation target, whereas weight–neutrality is desirable, if the government's other delegation instrument is a state–contingent linear inflation contract. 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.

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