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INFLATION TARGETS AND CONTRACTS WITH UNCERTAIN CENTRAL BANKER PREFERENCES

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Inflation Targets and Contracts with Uncertain Central Banker Preferences

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Abstract

Within a standard model of monetary delegation we show that an optimal linear inflation contract performs strictly better than an optimal inflation target when there is uncertainty about the central banker's preferences. The optimal combination of a contract and a target performs best and eliminates the inflation bias and any variability not associated with economic shocks. However, the variability due to such shocks is enhanced by the uncertain central banker preferences and this may or may not dominate the advantages of delegation.

Keywords: Monetary delegation; inflation contracts; inflation targets; uncertainty.

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1. Introduction

Reform of monetary institutions is high on the agenda of both policymakers and researchers. The most promising proposals for reform are the implementation of performance contracts for central bankers (as explored in Walsh [1995a] and Persson and Tabellini [1993]) and the implementation of inflation targets (see Svensson [1996]). Both arrangements involve the delegation of monetary policy to a central bank which has "instrument independence" (i.e., which is free to choose policy without inference by the government). However, while under a contract the central bank is also granted "goal independence" (i.e., is free to determine the policy goals), this is not the case under a target regime.[1]

Svensson [1996] shows that (in the absence of output persistence) the optimal inflation target and the optimal linear inflation contract both lead to the same equilibrium and, hence, to equal welfare losses. In particular, if optimally implemented, either type of arrangement can eliminate the traditional inflation bias as well as ensure efficient stabilization of macroeconomic shocks. This makes both types of arrangements superior to Rogoff's [1985] widely-discussed suggestion to delegate monetary policy to a "conservative" central banker, i.e., a central banker who attaches a larger relative weight to low and stable inflation than society does. Such an arrangement would reduce the inflation bias at the cost, however, of less efficient stabilization in the presence of supply-side shocks.[2]

We show in this paper that the equivalence between a contract and a target breaks down when there is uncertainty about the central banker's preferences over output and inflation. Intuitively, when the government is risk-averse, uncertainty about the central banker's preferences may affect the choice of optimal delegation and the desirability of different delegation forms.[3] Uncertainty about the central banker's preferences plays an important role in practice, as argued in, for example, Havrilesky [1991] (see also the discussions in, e.g., Backus and Driffill [1985], Cukierman and Meltzer [1986], Vickers

[1]See, e.g., Fischer [1995] for a discussion of the two types of independence. Note that these proposals (as well as our paper) focus on the structure of optimal monetary institutions. The credible implementation of such institutions is, however, still very much an open question (see McCallum [1995]) which we do not address here.

[2]Herrendorf and Lockwood [1996] demonstrate that in the case where wage setters receive prior (private) information about a future supply shock, some degree of "Rogoff-conservativeness " is still needed as a part of the optimal monetary institution (see also Canzoneri et al. [1996]). As a byproduct of their analysis, they confirm Svensson's [1996] equivalence result.

[3]Given that monetary delegation is often interpreted as an agreement between a principal (the government) and an agent (the central bank), pre-contractual asymmetry of information constitutes a non-trivial *friction* in the principal-agent relationship, and should in general be expected to reduce the principal's gains from the arrangement (Sappington [1991], Laffont and Tirole [1993]). This is also the case in our model, as will be seen below.

[1986] and Cukierman [1996]).

It turns out that the optimal linear inflation contract performs strictly better than the optimal inflation target. The reason is that the optimal linear inflation contract helps to stabilise output and inflation fluctuations resulting from the uncertainty about the central banker's preferences, while the optimal inflation target only affects the performance in terms of average inflation. In particular, the optimal target cannot affect the additional variability in inflation and output that is attributable to uncertain preferences.

The solution for the optimal linear contract is of interest in itself. In particular, it is optimal to offer a contract in which the additional marginal punishment for inflation is increasing in the degree of uncertainty about the central banker's preferences. As such, the optimal contract violates the certainty-equivalence property often encountered in the literature. This is not surprising given the classic results by Brainard [1967], who showed that the optimal policy choices are affected by uncertainty in the transmission from instrument to target variable.

Although the optimal linear contract outperforms the optimal target, none of the two arrangements is able to eliminate all the variability that is not associated with economic shocks. We show, however, that any such variability is eliminated under the optimal *combination* of a contract and a target. This combination *strictly* outperforms either type of arrangement when implemented in isolation. Moreover, while the optimal inflation target derived by Svensson [1996] is below the socially optimal inflation rate — a result which does not seem to be in accordance with what we observe in practice — our optimal combination arrangement is characterised by an inflation target which exceeds the socially optimal inflation rate. Our combination arrangement might well capture the most important features of New Zealand's monetary arrangements.[4] These are characterised by a combination of an inflation target and a dismissal rule for the central banker. Indeed, the additional penalty imposed through the contract could be interpreted as the utility loss from dismissal.

Finally, welfare losses under the optimal combination arrangement are compared with the case where monetary policy is selected by the government itself rather than by the central bank. In deciding whether or not to delegate, a trade-off arises between the elimination of the inflation bias and the additional variability in the outcomes due to supply shocks that arises from uncertain central banker preferences. Delegation is preferred when the uncertainty about the central banker's preferences and the variance of the supply shocks are not too large, when the output target is rather ambitious and when the government's weight attached to output is relatively high.[5]

The paper is organised as follows: Section 2 describes the model. To facilitate

[4]See Walsh [1995b] for a detailed account of these arrangements.

[5]Alesina and Gatti [1995] present a model with uncertainty about the preferences of the government rather than the central bank. Introducing political uncertainty leads to the opposite conclusion that delegation becomes more attractive. The relative importance of political uncertainty and uncertainty about central banker preferences is of course an empirical matter.

future comparisons, we derive the outcomes under pre-commitment and discretion in the absence of delegation. Section 3 derives the optimal linear inflation contract and characterises the equilibrium. Section 4 does the same for the optimal inflation target. Welfare losses under each of the two arrangements are compared in Section 5. Section 6 studies the optimal combination of a contract and a target, while Section 7 studies the desirability of monetary policy delegation. Section 8 offers some concluding remarks. The Appendix derives a state-contingent contract which yields the pre-commitment equilibrium.

2. The Model

The basics of the model is adapted from Svensson [1996]. For illustrative purposes, it is kept as simple as possible. Nominal wages within the single period under consideration are contractually fixed before monetary policy is conducted. Therefore, the log of output, y, is given by the conventional Lucas supply function:

$$y = \pi - \mathrm{E}\left[\pi\right] - \epsilon, \tag{2.1}$$

where π and $\mathrm{E}[\pi]$ are actual and (rationally) expected inflation, respectively, and ϵ is a supply shock with $\mathrm{E}[\epsilon] = 0$ and $\mathrm{E}[\epsilon^2] = \sigma_\epsilon^2$. Given these distributional characteristics it follows that the natural rate of output in the model — by convenient normalization — is zero (in logs). The welfare loss of the government (and of society) is given as

$$L^G \equiv \frac{1}{2}\left[\lambda\left(y-\overline{y}\right)^2 + \left(\pi - \overline{\pi}\right)^2\right], \quad \overline{y} > 0, \quad \lambda > 0, \tag{2.2}$$

where $\overline{y}$ and $\overline{\pi}$, respectively, denote the government's target values for output and inflation.

2.1. No Delegation of Monetary Policy

Monetary policy involves the choice of the inflation rate, which is assumed to be under direct control of the authority who is in charge of monetary policy. For the moment assume that monetary policy is not delegated to an independent central banker, but rather chosen directly by the government.

Pre-commitment:

Our benchmark solution is attained when the government is able to commit ex ante to some inflation rate. This is the equilibrium which yields the lowest welfare loss. It amounts to the optimal state-contingent rule and is derived by minimising the expected value of (2.2) subject to (2.1) and the restriction that $\pi = \mathrm{E}[\pi]$. The solution is characterised by the following expressions for, respectively, expected inflation, the variances of inflation and output, and the government's welfare loss:[6]

$$\begin{aligned} \mathrm{E}[\pi] &= \bar{\pi}, \qquad \sigma_\pi^2 = \frac{\lambda^2}{(1+\lambda)^2}\sigma_\epsilon^2, \qquad \sigma_y^2 = \frac{1}{(1+\lambda)^2}\sigma_\epsilon^2, \\ L^G &= \frac{\lambda}{2}\bar{y}^2 + \frac{\lambda}{2(1+\lambda)}\sigma_\epsilon^2. \end{aligned} \tag{2.3}$$

Discretion:

The problem with the pre-commitment equilibrium is that it is time inconsistent (e.g., Kydland and Prescott [1977]; Barro and Gordon [1983]). Once nominal wages have been set, the government has the incentive to raise the inflation rate in order to stimulate output. Therefore, it is more realistic to assume, as we will do from now on, that the monetary policymaker is not able to bind itself to its announcements.

The discretionary equilibrium in the absence of delegation is found by minimising (2.2) subject to (2.1), taking inflation expectations, $\mathrm{E}[\pi]$, as given. This yields:

$$\begin{aligned} \mathrm{E}[\pi] &= \bar{\pi} + \lambda\bar{y}, \qquad \sigma_\pi^2 = \frac{\lambda^2}{(1+\lambda)^2}\sigma_\epsilon^2, \qquad \sigma_y^2 = \frac{1}{(1+\lambda)^2}\sigma_\epsilon^2, \\ L^G &= \frac{\lambda(1+\lambda)}{2}\bar{y}^2 + \frac{\lambda}{2(1+\lambda)}\sigma_\epsilon^2. \end{aligned} \tag{2.4}$$

Expected inflation exceeds the socially optimal inflation rate by $\lambda\bar{y}$ because of the incentive to create a surprise inflation in order to bring output closer to its target, $\bar{y} > 0$. Clearly, the welfare loss is higher under discretion than under pre-commitment. Hence, the government may seek to improve upon (2.4) by delegating monetary policy to an independent central banker.

2.2. Delegation of Monetary Policy

For the remainder of the paper we assume that monetary policy is delegated to a central banker with full instrument independence. However, in contrast to the existing literature, its preferences are *uncertain* at the moment of delegation. This uncertainty is modelled following Srensen [1991] and is "pure" in two respects: (i) the central banker's preferences will on average coincide with society's preferences, and (ii) monetary policy will on average (for given delegation parameters) coincide with policy in the absence of uncertainty about the central banker's preferences. More specifically, we assume that the central bank has the following loss function:

$$L^{CB} = \frac{1}{2}\left[(\lambda - \alpha)(y - \bar{y})^2 + (1+\alpha)(\pi - \bar{\pi})^2\right], \tag{2.5}$$

[6] Given that expected output is zero independent of the monetary regime, we will neither here, nor in the following, state expected output.

where α is a stochastic parameter unobserved by the government and the private sector. We assume that $\mathrm{E}[\alpha] = 0$ and $\mathrm{E}[\alpha^2] = \sigma_\alpha^2$. Moreover, it is assumed that α is independent of ϵ, hence $\mathrm{E}[\alpha\epsilon] = 0$, and that $-1 < \alpha < \lambda$ with probability one.

Specification (2.5) may be motivated by the assumption that the distribution of preferences of individuals in society is determined by α according to (2.5). An (equally-weighted) aggregation of individuals' preferences over α then yields the welfare loss function (2.2). Monetary policy can thus be thought of as being delegated to an individual who is randomly selected from society. Specification (2.5) has the appealing property that inflation expectations for any given monetary regime are independent of σ_α^2 , as we will see below. This allows us to derive closed-form solutions for the model and ensures that any effects of σ_α^2 will be due to the risk-aversion of the government only.[7]

The timing of events becomes as follows: First, monetary policy is delegated to the central bank. Then, inflation expectations are formed. Next, the supply shock, ϵ, hits the economy and, finally, monetary policy is conducted. We will consider two forms of delegation: A (non-state-contingent) linear inflation contract in the sense of Walsh [1995a] and Persson and Tabellini [1993], and an inflation target in the sense of Svensson [1996].

3. The optimal linear inflation contract

Under a linear inflation contract, the central bank incurs an additional penalty if the inflation rate exceeds the socially desired inflation rate $\bar{\pi}$. The central banker therefore faces the following loss function:

$$L^{CB} + f\,(\pi - \bar{\pi}), \tag{3.1}$$

where f is the size of the penalty for each unit that inflation is above its social optimum. Parameter f thus characterises the contract.

Under this contract, the discretionary central bank chooses inflation so as to minimise (3.1) subject to (2.1), having observed the shock and taking as given inflation expectations. From the first-order condition we obtain the following reaction function:

$$\pi = \frac{\lambda - \alpha}{1 + \lambda}\left(\mathrm{E}\left[\pi\right] + \bar{y} + \epsilon\right) + \frac{1 + \alpha}{1 + \lambda}\bar{\pi} - \frac{1}{1 + \lambda}f. \tag{3.2}$$

[7] This is in sharp contrast to the papers of Nolan and Schaling [1996], who allow for a central banker whose weight on inflation stabilisation is uncertain and who examine the implications for expected inflation, and Lossani, Natale and Tirelli [1996], who use the same modeling strategy within a Lohmann [1992] type of model. Apart from the fact that the focus of their analyses is very different from ours, we note that the way uncertainty is incorporated in their models implies that average policy outcomes differ from those prevailing in the absence of central banker uncertainty. Inflation expectations thus respond to uncertainty even though the private sector is risk neutral. In consequence, central bank uncertainty affects both the first and the second moment of inflation. The interpretation of welfare losses from such uncertainty is therefore problematic, as some of the losses are due to the government's risk aversion and others not. This confusion is avoided in our set up.

Inflation increases with $\mathrm{E}[\pi]$, $\overline{y}$ and ϵ, because each of these variables raises the marginal gain of higher output (remember that $\lambda - \alpha > 0$ for all α), while it decreases with f, because an increase in f raises the central banker's marginal loss of inflation. Inflation expectations follow from (3.2) as

$$\mathrm{E}[\pi] = \bar{\pi} + \lambda\overline{y} - f. \tag{3.3}$$

Hence, inflation is expected to exceed its social optimum whenever $\lambda\overline{y} > f$, in which case the traditional inflation bias dominates the disciplining effect of the contract. Also note that uncertainty about the central banker's preferences does not affect inflation expectations.

Insert (3.3) back into (3.2) in order to write realised inflation as:

$$\pi = \mathrm{E}[\pi] - \alpha\left(\overline{y} - \frac{1}{1+\lambda}f\right) + \frac{\lambda - \alpha}{1+\lambda}\epsilon. \tag{3.4}$$

Combining (3.4) with (2.1) and (3.3) yields realised output:

$$y = -\alpha\left(\overline{y} - \frac{1}{1+\lambda}f\right) - \frac{1+\alpha}{1+\lambda}\epsilon. \tag{3.5}$$

Inflation and output deviate from their expected values when either α or ϵ differ from their expected values of zero.

For the moment, suppose that the supply shock is zero. We see that the contract affects the extent to which a preference shock is translated into an inflation surprise. To understand the intuition for this effect, consider the case of $\alpha > 0$, i.e., the central banker turns out to be more "conservative" than expected. In the absence of a contract (i.e., $f = 0$), inflation and output will be lower than expected. Equation (3.2) shows that inflation expectations have a positive effect on actual inflation because of the need to protect output. However, the incentive to raise inflation in response to higher expected inflation is weakened if $\alpha > 0$. Suppose now that a contract is in place ($f > 0$). As this reduces inflation expectations, it reduces the "inflation-lowering" effect of an unexpectedly conservative central banker (i.e., $\alpha > 0$). For "mild" contracts though ($0 < f < (1+\lambda)\overline{y}$), realised inflation will still be below expected inflation when $\alpha > 0$. But for "strict" contracts ($f > (1+\lambda)\overline{y}$), the "inflation-lowering" effect is reversed such that inflation will be unexpectedly high, cf. (3.4) and (3.5). The reason is that a "strict" contract lowers inflation expectations by so much that output is perceived as being too high. As a result, the central bank has the incentive to reduce inflation. If it cares less about output than expected ($\alpha > 0$), it therefore reduces inflation by less than expected, i.e., it enacts an inflation surprise. Note that for a given realisation of α, it follows that if $f = (1+\lambda)\overline{y}$, a preference shock creates no inflation surprise at all.

Now, consider the effects of a supply shock. The transmission of this shock to inflation and output is influenced by the preference shock. A positive realisation of

α, for example, increases the reluctance of the central banker to use inflation as an instrument for stabilising output. Hence, if α is larger, the effect of a given supply shock on inflation becomes weaker, while the effect on output becomes stronger. Note that the inflation contract has no effect, however, on the interaction between α and ϵ, as it is unable to affect the way in which a shock is transmitted into monetary policy, cf. (3.2).

Because the government is risk averse, it may be instructive to state the variances of inflation and output for a given contract. Using (3.4) and (3.5) together with the assumption that α and ϵ are independent, one has:

$$\sigma_\pi^2 = \sigma_\alpha^2 \left(\overline{y} - \frac{1}{1+\lambda} f\right)^2 + \frac{\lambda^2 + \sigma_\alpha^2}{(1+\lambda)^2}\sigma_\epsilon^2, \tag{3.6}$$

$$\sigma_y^2 = \sigma_\alpha^2 \left(\overline{y} - \frac{1}{1+\lambda} f\right)^2 + \frac{1 + \sigma_\alpha^2}{(1+\lambda)^2}\sigma_\epsilon^2. \tag{3.7}$$

Hence, through the first term on the right hand sides on (3.6) and (3.7) the contract affects the variation in inflation and output arising from uncertain preferences. Because in absence of supply shocks both inflation and output surprises disappear when $f = (1+\lambda)\,\overline{y}$, a contract with this value for f will minimise the variances of both inflation and output.

The government's objective, however, is not to minimise the variance of output and inflation, but to minimise the expected value of its loss function. Therefore, the government chooses f so as to minimise $E[L^G]$ subject to (3.3), (3.4) and (3.5). Using the first-order condition, the optimal value for f, denoted by f^*, is given by:

$$f^* = \frac{(1+\lambda)\,(\lambda + \sigma_\alpha^2)}{1 + \lambda + \sigma_\alpha^2}\overline{y}. \tag{3.8}$$

Insert (3.8) into (3.4) and (3.5), and use the resulting expressions for realised inflation and output to obtain the following characterisation of the equilibrium under the optimal contract:

$$\begin{aligned} \mathrm{E}\,[\pi] &= \overline{\pi} - \frac{\sigma_\alpha^2}{1+\lambda+\sigma_\alpha^2}\overline{y}, \qquad \sigma_\pi^2 = \frac{\sigma_\alpha^2}{(1+\lambda+\sigma_\alpha^2)^2}\overline{y}^2 + \frac{\lambda^2+\sigma_\alpha^2}{(1+\lambda)^2}\sigma_\epsilon^2, \\ \sigma_y^2 &= \frac{\sigma_\alpha^2}{(1+\lambda+\sigma_\alpha^2)^2}\overline{y}^2 + \frac{1+\sigma_\alpha^2}{(1+\lambda)^2}\sigma_\epsilon^2, \\ L^G &= \frac{(1+\lambda)\,(\lambda+\sigma_\alpha^2)}{2\,(1+\lambda+\sigma_\alpha^2)}\overline{y}^2 + \frac{\lambda+\sigma_\alpha^2}{2(1+\lambda)}\sigma_\epsilon^2. \end{aligned} \tag{3.9}$$

Expression (3.8) reveals that it is optimal to offer a contract to the central banker which depends on the degree of uncertainty about its preferences. To understand this result, consider the case where $\sigma_\alpha^2 \to 0$, so that $f^* = \lambda\overline{y}$. This yields Walsh's [1995a] result that a contract should be offered that eliminates the expected inflation bias ($\lambda\overline{y}$) arising from discretion [see (3.9) for $\sigma_\alpha^2 \to 0$], while preserving efficient stabilisation of supply shocks. Hence, the optimal contract produces the outcomes of the pre-commitment equilibrium [compare (3.9) with (2.3) for $\sigma_\alpha^2 \to 0$]. However, when $\sigma_\alpha^2 > 0$, one has that $f^* > \lambda\bar{y}$. The reason is that, by raising f above $\lambda\bar{y}$, the government is able to reduce some of the inflation and output variability arising from uncertain central banker preferences [see (3.6) and (3.7)]. Although expected inflation is reduced to below its target, the associated loss is of a second-order magnitude, whereas the gain in terms of lower macroeconomic variability is of a first-order magnitude. A higher variance of α therefore requires a higher value for f^*. Note also that if σ_α^2 becomes unbounded, the gains from reducing macroeconomic variability become so large that f^* approaches $(1+\lambda)\,\bar{y}$, the value that minimises the variances of inflation and output, as discussed above.[8]

The way in which the optimal policy choice of the government depends on uncertainty is analogous to Brainard's [1967] early results on policymaking in an uncertain environment. He found that uncertainty about the effects of policy variables on target variables implies that policy choices affect the shape of the distributions of the target variables. Clearly, a risk-averse government must take this into account when making its optimal policy choices. Indeed, the same problem arises in selecting the optimal contract, because the effects of the instrument f on the governments targets are uncertain, as is clear from (3.4) and (3.5).

Brainard also showed that the optimal policy is independent of uncertainty when transmission from policy instruments to target variables is deterministic. The reason is that the policy choice only shifts the locations of the target variables' distributions — but not their shape. This is also reflected in the optimal inflation contract considered here, which is independent of the variance of the supply shock, even though the uncertainty about the central banker's preferences magnifies the macroeconomic variability due to supply shocks. However, as is clear from (3.6) and (3.7), the transmission from the supply shocks to the target variables is unaffected by the government's choice of f.

4. The optimal inflation target

Having characterised the optimal inflation contract, we turn now to the case where delegation takes the form of imposing an inflation target. The central bank is no longer goal independent as the government chooses a particular inflation target, π^b, to be pursued by the central bank. Its loss function therefore becomes:

$$L^{CB'} = \frac{1}{2}\left[(\lambda - \alpha)\,(y - \bar{y})^2 + (1+\alpha)\left(\pi - \pi^b\right)^2\right]. \tag{4.1}$$

[8] Using (3.8), one has that $\lim_{\sigma_\alpha^2 \to \infty} f^* = (1+\lambda)\,\bar{y}^2$. Note, however, that the argument is purely illustrative, because $\sigma_\alpha^2 \to \infty$ could be inconsistent with the requirement that $-1 < \alpha < \lambda$ for all α.

The central bank chooses inflation so as to minimise (4.1) subject to (2.1), having observed the shock and taking as given inflation expectations. The first-order condition implies the following reaction function:

$$\pi = \frac{\lambda - \alpha}{1+\lambda}\left(\mathrm{E}\left[\pi\right] + \overline{y} + \epsilon\right) + \frac{1+\alpha}{1+\lambda}\pi^{b}. \tag{4.2}$$

Hence, expected inflation is given by:

$$\mathrm{E}\left[\pi\right] = \pi^{b} + \lambda\overline{y}. \tag{4.3}$$

Expected inflation is the sum of the inflation target imposed by the government and the inflation bias arising from discretion in monetary policymaking. Realised inflation under a given target follows upon inserting (4.3) back into (4.2):

$$\pi = \mathrm{E}\left[\pi\right] - \alpha\overline{y} + \frac{\lambda - \alpha}{1+\lambda}\epsilon. \tag{4.4}$$

Combining (2.1), (4.3) and (4.4) yields:

$$y = -\alpha\overline{y} - \frac{1+\alpha}{1+\lambda}\epsilon. \tag{4.5}$$

As under a contract, realisations of α and/or ϵ different from their expected values cause an inflation surprise and thus a deviation of output from the natural rate. But compared with (3.4) and (3.5), the solutions for inflation and output differ in an important aspect: the delegation parameter, π^b, has no effect on how a shock to the central banker's preferences feeds into inflation and output. For example, an increase in π^b raises the marginal gain from inflation both directly, which is captured by the second term on the right hand side of (4.2), and indirectly through a proportional increase in inflation expectations [see (4.3)], which is captured by the first term on the right hand side of (4.2). The sum of the weights attached to these two effects is independent of α and, in fact, equals unity. Hence, actual inflation increases one for one with the inflation target.

As is clear from (4.4) and (4.5), the choice of the inflation target does not affect the variance of inflation and output,[9] while the uncertainty arising from the supply shocks has the same implications for macroeconomic variability as in the case of an inflation contract. In particular, the transmission from supply shocks to target variables is independent of the inflation target. Thus,

$$\sigma_{\pi}^{2} = \sigma_{\alpha}^{2}\overline{y}^{2} + \frac{\lambda^{2} + \sigma_{\alpha}^{2}}{(1+\lambda)^{2}}\sigma_{\epsilon}^{2}, \tag{4.6}$$

$$\sigma_{y}^{2} = \sigma_{\alpha}^{2}\overline{y} + \frac{1 + \sigma_{\alpha}^{2}}{(1+\lambda)^{2}}\sigma_{\epsilon}^{2}, \tag{4.7}$$

[9] In Brainard's [1967] terminology, the government's policy instrument does not affect the shape of the target variables' distribution, as its effects on these variables are certain.

and these expressions therefore coincide with (3.6) and (3.7), respectively, if $f = 0$.

To find the optimal inflation target, the government chooses the value of π^b that minimises $E[L^G]$ subject to (4.4) and (4.5). The optimal inflation target, denoted by π^{b*}, is:

$$\pi^{b*} = \overline{\pi} - \lambda \overline{y}. \tag{4.8}$$

Substitute π^{b*} into (4.4) and (4.5) to give realised inflation and output under the optimal target. Hence, the optimal target implies that:

$$\begin{aligned} \mathrm{E}[\pi] &= \bar{\pi}, \qquad \sigma_\pi^2 = \sigma_\alpha^2 \overline{y}^2 + \frac{\lambda^2 + \sigma_\alpha^2}{(1+\lambda)^2}\sigma_\epsilon^2, \qquad \sigma_y^2 = \sigma_\alpha^2 \overline{y}^2 + \frac{1 + \sigma_\alpha^2}{(1+\lambda)^2}\sigma_\epsilon^2, \\ L^G &= \frac{\lambda + (1+\lambda)\sigma_\alpha^2}{2}\overline{y}^2 + \frac{\lambda + \sigma_\alpha^2}{2(1+\lambda)}\sigma_\epsilon^2. \end{aligned} \tag{4.9}$$

Note that the optimal inflation target (4.8) does not depend on the variances of the shocks, which follows immediately from the fact that the inflation target does not affect the variances of inflation and output. Hence, its optimal value is determined exclusively by its effects on the means of the target variables. Given that expected output cannot be affected in this natural rate model, the inflation target is chosen such that the expected inflation rate coincides with the socially optimal inflation rate. Therefore, as far as the optimal inflation target is concerned, certainty equivalence holds, and, hence, π^{b*} corresponds to the optimal target derived by Svensson [1996] in the absence of uncertainty about central bank preferences.

5. Comparison of the optimal contract with the optimal target

In line with Svensson's [1996] results, it clear from (4.9) with (3.9) that in the absence of uncertainty about preferences, both the optimal linear inflation contract and the optimal inflation target imply the pre-commitment solution discussed in Section 2. However, because in general the optimal inflation contract is affected by preference uncertainty, and the optimal inflation target is not, it is clear that the means and variances of the policy targets will differ under the two delegation arrangements when $\sigma_\alpha^2 > 0$.

Comparing (4.9) with (3.9), we see that the variances of inflation and output are *highest* under the optimal inflation target. This follows from the fact that, in contrast to the inflation contract, the inflation target is not able to stabilise (partly) the effects of the preference shocks. As noted earlier, such stabilisation in the case of the optimal contract is at the cost of expected inflation being below the socially optimal inflation rate. These costs and benefits are the only relevant ones when deciding which form of delegation is preferred; the effects of supply shocks on inflation and output are the same in both cases.

A comparison of the government's expected losses under each form of delegation [see (3.9) and (4.9)] shows that the optimal inflation contract is superior to the optimal inflation target if and only if:

$$\frac{(1+\lambda)\left(\lambda+\sigma_{\alpha}^{2}\right)}{2\left(1+\lambda+\sigma_{\alpha}^{2}\right)}\overline{y}^{2} < \frac{\lambda+(1+\lambda)\sigma_{\alpha}^{2}}{2}\overline{y}^{2}.$$

It is straightforward to verify that this inequality always holds if $\sigma_{\alpha}^{2} > 0$ (note that, in accordance with the above discussion, the comparison is independent of σ_{ϵ}^{2}).[10] Also, it is easy to establish that the difference in losses between the two delegation arrangements is increasing in σ_{α}^{2}.

Thus, the lower variability of inflation and output under the optimal inflation contract dominates the welfare loss arising from average inflation being too low. The reason is that the deviation of expected inflation from its target causes only a second-order welfare loss, whereas the gain in terms of lower variability of inflation and output is of first-order magnitude. Thus, the superiority of the optimal inflation contract arises from the fact that a positive value of f both stabilises the direct effects of uncertainty about the central banker's preferences on the target variables and reduces the average inflation bias (although too much). The inflation target, on the other hand, only eliminates the average inflation bias but does not help in reducing the effects of uncertainty about the central banker's type on output and inflation variability.

6. The optimal combination of a contract and a target

Given that the optimal linear inflation contract and the optimal inflation target yield different results, one wonders whether there exists a combination of the two arrangements that delivers *strictly* lower welfare losses than each of them in isolation.[11] Below, we show that this is indeed the case.

The timing is as before and starts with the government choosing the optimal combination of (f, π^{b}). Then expectations are formed, followed by a realisation of the supply shock. Finally, the central banker chooses the inflation rate which minimises

$$L^{CB'} + f(\pi - \overline{\pi}), \tag{6.1}$$

[10] After completing the first draft of this paper, we became aware of Muscatelli [1995] who devotes a section to the issue of inflation targets versus inflation contracts in a model which is somewhat similar to ours. In line with our findings, his results suggest that a contract is superior to a target. This conclusion, however, is rather speculative in nature, because it is based on the assumption that the optimal delegation arrangements are certainty equivalent (which is in general not the case). Moreover, the expressions for the welfare losses are, in our opinion, invalid in his paper. This precludes a proper welfare comparison between a contract and a target.

[11] This would be in sharp contrast to Svensson's [1996] model (without unemployment persistence), where there exists an infinite number of combinations of a target and a contract which all establish the same, optimal equilibrium. In his model, either the target or the contract is redundant in achieving the optimum.

subject to (2.1), taking inflation expectations as given. The first-order condition can be rewritten to give the central bank's reaction, from which we derive expected inflation:

$$\mathrm{E}[\pi] = \pi^b + \lambda\overline{y} - f, \tag{6.2}$$

If we insert (6.2) back into the reaction function we can obtain the following expressions for realised inflation and output, respectively:

$$\pi = \mathrm{E}[\pi] - \alpha\left(\overline{y} - \frac{1}{1+\lambda}f\right) + \frac{\lambda-\alpha}{1+\lambda}\epsilon, \tag{6.3}$$

$$y = -\alpha\left(\overline{y} - \frac{1}{1+\lambda}f\right) - \frac{1+\alpha}{1+\lambda}\epsilon. \tag{6.4}$$

Note that these outcomes are the same as (3.4) and (3.5), respectively, with the only difference being that π^b replaces $\overline{\pi}$ as a component of expected inflation. This, however, has no implications for the variances of inflation and output, so that these are still given by (3.6) and (3.7).

Simultaneously minimising $E[L^G]$ with respect to f and π^b subject to (6.3), (6.4) and (6.2) yields two first-order conditions from which we obtain the optimal combination of a contract and a target. We denote this combination by (f^{**}, π^{b**}), where

$$f^{**} = (1+\lambda)\,\overline{y}, \qquad \pi^{b**} = \overline{\pi} + \overline{y}. \tag{6.5}$$

Substitute these values into (6.3) and (6.4) to give realised inflation and output. The equilibrium under (6.5) is then characterised by:

$$\begin{aligned} \mathrm{E}[\pi] &= \overline{\pi}, \qquad \sigma_\pi^2 = \frac{\lambda^2+\sigma_\alpha^2}{(1+\lambda)^2}\sigma_\epsilon^2, \qquad \sigma_y^2 = \frac{1+\sigma_\alpha^2}{(1+\lambda)^2}\sigma_\epsilon^2, \\ L^G &= \frac{1}{2}\lambda\overline{y}^2 + \frac{\lambda+\sigma_\alpha^2}{2(1+\lambda)}\sigma_\epsilon^2. \end{aligned} \tag{6.6}$$

Compared with the outcomes under a contract or target only, (3.9) and (4.9), respectively, we see from (6.6) that the optimal combination of a target and a contract completely eliminates both the average inflation bias and the stochastic part of inflation and output which arises from uncertainty about the central banker's preferences only. The way supply shocks are transmitted to inflation and output is the same as before. Therefore, the variances of these variables in (6.6) coincide with the terms involving σ_ϵ^2 in the corresponding expressions in (3.9) and (4.9).

These results are very intuitive: as is clear from (6.2), for a given contract the inflation target can always be chosen so as to produce an expected inflation rate which is equal to the socially optimal rate. Hence, the contract can be chosen freely with concern for macroeconomic variability only. We saw in Section 3 that $f = (1+\lambda)\,\overline{y}$ is the contract which minimizes the variances of inflation and output [see also (6.3) and (6.4)]. Therefore, optimal delegation involves a contract with $f = (1+\lambda)\,\overline{y}$ and an inflation target which is then adjusted so as to eliminate the inflation bias.

Of course, in terms of the expected welfare loss, the optimal delegation combination (f^{**}, π^{b**}) outperforms both the arrangement with a contract only and with a target only. Compared to a contract only, variability is reduced and average performance is improved; compared to a target only, variability is reduced. Nevertheless, the arrangement with the optimal delegation combination is inferior to the pre-commitment solution. The reason is that preference uncertainty affects the transmission from supply shocks towards inflation and output. Therefore, macroeconomic variability is still suboptimally high [compare (6.6) with (2.3)]. The Appendix discusses a contract which leads the economy to the pre-commitment solution. However, this contract depends on the realisations of the shocks and may therefore be difficult to implement in practice.

Expression (6.5) reveals that the optimal inflation target exceeds the socially optimal inflation rate. This is in sharp contrast with Svensson's [1996] possibly unrealistic finding that the inflation target should be set below the socially optimal rate in order to provide the monetary authority with the appropriate incentive to eliminate the inflation bias (on average). In practice, countries that have adopted an inflation targeting regime do not seem to set their inflation targets below the desired inflation rate. In fact, our combination-delegation arrangement may well represent the most important features of New Zealand's monetary arrangements: an inflation target combined with a dismissal rule for the central banker. The additional punishment imposed by the contract when inflation exceeds its optimal rate could be interpreted as the utility loss from dismissal.

7. Is delegation preferable?

Even though the optimal delegation combination (f^{**}, π^{b**}) eliminates the inflation bias, when compared with the case of discretion without delegation, stabilisation of supply shocks is suboptimal, because the transmission from the shocks to the target variables is affected by the uncertainty about the central banker's preferences. Hence, the delegation of monetary policy to a central bank which has instrument independence involves a trade-off between reducing the effects of discretion in monetary policymaking and introducing additional variability in output and inflation. Formally, comparing (2.4) and (6.6), we find that delegation is preferable if and only if

$$\sigma_\alpha^2 \sigma_\epsilon^2 < \lambda^2(1+\lambda)\bar{y}^2.$$

Delegation is more likely to be preferred if the degree of uncertainty about the central banker's preferences is lower, because then the additional uncertainty in inflation and output arising from uncertain preferences is less. If $\sigma_\epsilon^2 \to 0$, however, uncertainty about preferences plays no role, and delegation is always preferred. Similarly, if $\sigma_\alpha^2 \to 0$, which yields the standard case considered in the literature, the variance of the supply shock does not affect the desirability of delegation. Delegation is also more likely to be preferable if $\bar{y}$ or λ are higher, because then the incentive, which is futile in equilibrium, to raise output through unanticipated inflation is stronger. Therefore, the gain from eliminating the inflation bias is more likely to dominate the loss arising from less efficient stabilisation.

This suggests that societies with relatively high macroeconomic variability (high σ_ϵ^2) would be reluctant to hand over the conduct of monetary policy to an independent central banker. This rather intuitive prediction does not feature in existing models, where optimal delegation *always* improves upon discretion in the absence of delegation (and in some cases yields the pre-commitment solution). It is worth stressing that this result is not due to the fact that, as in the original Rogoff [1985] model, an independent central bank conducts insufficient output stabilisation. In our model the result is due to the risk that stabilisation policy can deviate in any direction from the socially optimal stabilisation policy (that is, output stabilisation may be suboptimally low or suboptimally high, depending on the realisation of α). As such, our results are also in accordance with the empirical absence of correlation between central bank independence and output variability (see, e.g., Grilli, Masciandaro and Tabellini [1991]): in our set-up, countries with independent central bankers will *ex post* either show too high or too low output variability compared to those without.

8. Concluding comments

This paper has discussed the consequences of uncertain central banker preferences for the delegation of monetary policy by means of an inflation contract, an inflation target, or a combination of both. We found that, while delegation helps in reducing the inflation bias from discretion, it also leads to inefficient stabilisation, because the transmission from supply shocks to target variables becomes uncertain. In terms of welfare, the optimal linear inflation contract outperforms the optimal targeting arrangement. Given that both types of arrangements yield different outcomes when implemented separately, there exists an optimal combination of a target and a contract which performs *strictly* better than either a contract or a target only. This combination arrangement eliminates all the variability not associated with economic shocks and has the empirically appealing property that it involves a target which exceeds the socially optimal inflation rate, thereby resembling existing monetary arrangements.

The choice to delegate or not involves a trade-off between eliminating the inflation bias and less efficient stabilisation. The desirability of delegation increases when preference uncertainty, the variability of the supply shock, the output target and the relative weight attached to the output target are all lower.

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Appendix: State-Contingent Contracts

Below we show that the pre-commitment solution can be attained by offering the central banker a state-contingent linear contract, i.e., a contract that depends on the realisations of the supply shock and the preference shock. Of course, in practice such contracts are difficult to implement because they rely on the assumption that it is possible to somehow identify these realisations. In principle, information about the shocks may be extracted from realisations of inflation and output. However, the extraction problem is complicated by the fact that these realisations depend on the contract itself, which, on its turn, depends on the shocks. Therefore, we assume here that the shocks can be observed just before the contract is carried out.

The central banker is offered a linear contract, such that it faces the following loss function:

$$L^{CB} + (f_0 + f_1\alpha + f_2\epsilon + f_3\alpha\epsilon)(\pi - \overline{\pi}). \tag{A.1}$$

Then the following vector (f_0, f_1, f_2, f_3) of contract parameters is optimal and yields the pre-commitment solution:

$$(f_0^*, f_1^*, f_2^*, f_3^*) = (\lambda\overline{y}, -\overline{y}, 0, -1). \tag{A.2}$$

Optimality is easily established if we consider the first-order condition for the central bank in the absence of a contract, i.e. $(f_0, f_1, f_2, f_3) = (0, 0, 0, 0)$:

$$(\lambda - \alpha)(\pi - \mathrm{E}[\pi] - \epsilon - \overline{y}) + (1 + \alpha)(\pi - \overline{\pi}) = 0. \tag{A.3}$$

However, the pre-commitment solution can be attained if the central bank has the following first-order condition:

$$\lambda(\pi - \mathrm{E}[\pi] - \epsilon) + (\pi - \overline{\pi}) = 0.$$

Hence, the following marginal loss of inflation must be added to the central bank's first-order condition (A.3) in order to get the appropriate first-order condition:

$$\alpha(\pi - \mathrm{E}[\pi] - \epsilon - \overline{y}) + \lambda\overline{y} - \alpha(\pi - \overline{\pi}).$$

However, because $\mathrm{E}[\pi] = \overline{\pi}$ in the pre-commitment solution, this reduces to:

$$-\alpha(\epsilon + \overline{y}) + \lambda\overline{y}.$$

Hence, to ensure the appropriate first-order condition for the central banker requires a contract such that

$$(f_0 + f_1\alpha + f_2\epsilon + f_3\alpha\epsilon) = -\alpha(\epsilon + \overline{y}) + \lambda\overline{y},$$

which coincides with the combination in (A.2).

To verify its optimality, impose the suggested contract and solve for the central banker's reaction function. Taking expectations shows that $\mathrm{E}[\pi] = \overline{\pi}$ indeed holds. Combining this with the reaction function, we obtain the outcomes for inflation and output which indeed coincide with the outcomes for the pre-commitment solution.

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