WORKING PAPER

Debt-Contingent Inflation Contracts and Targeting

Edward Kutsoati
Department of Economics
Tufts University

Discussion Paper 2000-09
Department of Economics
Tufts University

Department of Economics
Tufts University
Medford, MA 02155
(617) 627-3560

Debt–Contingent Inflation Contracts and Targets

Edward Kutsoati*
Department of Economics
Tufts University
Medford, MA 02155

First version: August 1999
This version: February 2000

Abstract

This paper analyzes fiscal and monetary policy interaction in a simple policy game with debt and output shocks. Seigniorage provides revenue for the government but results in an inflation–bias. We analyze three mechanisms designed to eliminate some or all of the biases in monetary policy: an inflation performance contract, inflation target (both contingent on the stock of debt), and a zero–inflation rule. The performance contract and inflation target result in higher interest rate, remove all biases in monetary policy and achieve the pre–commitment policy, hence they are equivalent. The first two solutions also yield a higher expected welfare than a zero–inflation policy.

Keywords: Monetary policy games, Seigniorage, Inflation contracts, Inflation targets

JEL Classification: E52, E58, E61, E62

*Tel: 1-617-627-2688. E–mail address: ekutso01@emerald.tufts.edu. I am grateful to Roel Beetsma and Gregor Smith for comments on an earlier draft, and an anonymous referee for very useful suggestions. I am solely responsible for all errors.

1 Introduction

In a standard monetary policy game, a well–known result is that the time–inconsistency of monetary policy results in a positive inflation–bias. Without a proper commitment device, a pre–commitment inflation policy is not credible.[1] This is because, after inflation expectations (and, perhaps, wage contracts) have been formed by economic agents, the central bank has an incentive to renege on the pre–commitment policy in order to increase output or reduce unemployment. If economic agents are forward–looking, this leads to average inflation rates above what is desired by society.

Years after these results have been shown by Kydland and Prescott (1977) and Barro and Gordon (1983), there is still on–going research on institutional designs that can be used to improve this dynamically inconsistent monetary policy. The seminal work in this direction was by Rogoff (1985). He showed that delegating monetary policy to a central banker with a higher weight on the achievement of low inflation than the government can reduced the degree of bias in inflation. Rogoff's weight–conservative central banker solution however results in suboptimal stabilization of output shocks. Lohmann (1992) extended the analysis in Rogoff (1985) to include the possibility of the government overriding the central bank's policy, but at a cost. The threat to override causes the the bank to implement the appropriate policy so in equilibrium, the option to override is never exercised.

Recently, a solution to eliminate the bias in monetary policy was proposed by Walsh (1995) and Persson and Tabellini (1993). These authors show that an inflation–performance contract, which rewards (penalizes) the monetary authority for low (high) inflation can be used to remove the inflation–bias in monetary monetary: in effect, restoring the pre–commitment monetary policy. This contract solution has been extended to the case where there is persistence in the unemployment rate (or employment level), as in Lockwood (1997) and Svensson (1997), and to the case with uncertain central bank preferences as in Beetsma and Jensen (1997). In Lockwood (1997) and Svensson (1997), it was shown that the equivalent inflation contract must necessarily be state–contingent in order to be able to restore the pre–commitment policy.

In this paper, we explore the use of inflation performance contracts and targets in solving a similar bias in monetary policy: one that occurs due to an economy's debt problems. As noted by Sargent and Wallace (1981), fiscal deficits which result in a debt burden may lead to

[1] A pre–commitment inflation policy is one that ensures an efficient stabilization of output shocks, but at the same time results in a zero expected inflation level (see, for example, Lockwood (1997)).

monetary expansions and higher inflation rates. This is a more common problem in monetary policymaking, especially in less developed countries (LDCs), but often ignored in research aimed at institutional designs. In most LDCs, financially unsustainable budgetary policies force the monetary authorities to create money and therefore tolerate high levels of inflation.

We first show that a performance contract written for the central bank can be used to remove the biases in monetary policy that result from the incentives to monetize debt. The contract should be designed to depend on the outstanding debt level: that is, the central bank is penalized (rewarded) for high (low) levels of inflation, with the penalty increasing in the level of outstanding debt. We then analyze fiscal and monetary policies if the authorities set an inflation target that is contingent on stock of debt and show that the contract and target solutions are equivalent: they both remove all biases in inflation policy and achieve the pre–committment rule.

The latter result contrasts with Svensson (1997) who also considered performance contract and inflation target contingent on a different state variable, employment level. Svensson showed that whereas a contract contingent on employment level restores the pre–committment inflation rule, an inflation target only removes the positive inflation–bias but leaves a bias in stabilization of employment shocks. The reason for this difference is the fiscal policy reaction to our contract or target solution. In Svensson's model, only monetary policy is considered. In this paper, the resulting equilibrium with a performance contract or inflation target involves a higher interest rate on all debt, which in turn makes it costly for the government to run large deficits ensures fiscal discipline. We argue that such fiscal discipline is all that is needed to restore the pre–commitment policy. In our context, one can think of these mechanisms as explicitly shifting the debt burden from the government to the central bank, and the bank reacting with a tighter monetary policy.

Since the issue of deficit financing is one of the main reasons for making central banks more independent from fiscal authorities (especially for less developed countries), one would think that institutional reforms will be accompanied by such explicit contracts aimed at maintaining low levels of inflation. This will give the central banks more autonomy over monetary policy so as to resist attempts by the government to finance deficits by creating money. Such institutional designs can also help eliminate potential conflicts between fiscal and monetary authorities over the direction of monetary policy.[2]

[2]Conflicts between Finance Ministers and the Governors of Central Banks have been documented in many countries over time. For example, James Coyne had to resign as Governor of the Bank of Canada in 1961 over disagreement on the direction of interest rates.

However, even though they seem desirable, such monetary policy agreements are hardly observed in practice. One reason for this political: for example, a performance contract that rewards the central banker for low inflation will be politically unpopular if the same policy results in low output, high unemployment or a drastic reduction in government spending (see Goodhart and Viñals (1994)).

Another reason is the impossibility of writing contracts or having targets contingent on the realization of every state, as discussed in Persson and Tabellini (1993). Hence, more common approach in monetary policy is to set a constant inflation target or a simple inflation rule independent of output shocks, such as a zero-inflation rule.[3] We therefore compare society's welfare (*i.e,* government's dynamic loss) in the case of a zero–inflation rule to that of the game in which a debt–contingent inflation target is set or a performance contract is written for the central bank. It is shown that the performance contract or target solution results in a higher welfare.

The rest of the chapter is organized as follows. In section 2, we outline the dynamic model of the interaction between fiscal and monetary policies. We solve for a pre–commitment monetary policy and then analyze a the outcome in a zero–inflation target. We then show that there is unique inflation contract and target that achieves the pre–commitment outcome in the model, hence equivalent. In section 3, we compare the welfare levels from a zero–inflation rule and the pre–commitment inflation rule. Section 4 concludes the chapter.

2 A simple policy game with debt

We consider a dynamic policy game with monetary policy delegated to an independent central bank. The features of the model is similar to Jensen (1994), with monetary policy delegated to a central bank. Thus, the model consists of three agents: *the government*, a *central bank* and the *private sector.* We follow the literature on policy games by characterizing the private sector as a representative union whose sole objective is to achieve a target real wage through nominal wage negotiations. For simplicity, we also assume that the central bank directly sets the rate of inflation, π_t.

The government (or fiscal authority) sets the capital tax rate (τ_t) and determines the ratio

[3]In fact, Svensson (1997) shows that an appropriately chosen constant inflation target is equivalent to a designing a state–independent (or linear) performance contract that removes the average bias in monetary policy.

of government spending to output (g_t). The government has a per–period budget constraint given

$$g_t + (1 + r)d_{t-1} = \pi_t + \tau_t + d_t \tag{1}$$

where d_t is ratio of *indexed* debt to output. The government therefore finances its public expenditures (including debt servicing) through the tax revenues, seigniorage and by issuing indexed debt. The interest rate (r) on outstanding debt (d_{t-1}) is assumed to be constant and equal to the net rate of return on an outside investment opportunity available to an individual investor.[4] See the Appendix for more details and derivation of equation (1).

Production is undertaken in a competitive industry characterized by a Cobb–Douglas technology with labor as the only input. Aggregate output at time t is given by $Y_t = L_t^{\gamma} e^{a_t}$, where L_t denotes labor input and a_t is a supply shock. Firms maximize their profits taking the price level, (nominal) wage contracts and the tax rate on revenue as given. This involves maximizing a representative firm's profit function given by

$$\Pi_t = P_t L_t^{\gamma} e^{a_t}(1 - \tau) - W_t L_t,$$

where W_t is the nominal wage for period t. and L_t is the units of labor hired. Assuming the supply of labor is perfectly elastic (workers willing to work any amount of hours at the negotiated wage), then profit maximization implies that the (log of) aggregate output at time t can be normalized as

$$y_t = \alpha(p_t - w_t + log(1 - \tau_t)) + \epsilon_t$$

where p_t, w_t are the logs of price level and nominal wage at time t, $\alpha = \frac{\gamma}{1-\gamma}$ and $\epsilon_t = \frac{a_t}{1-\gamma}$. We assume ϵ_t is i.i.d with mean zero and variance σ^2.

For simplicity, we also assume that workers (or the union) adopt the following rule in their nominal wage negotiations: $w_t = E\left[p_t \mid \Omega^u_{t-1}\right]$, where $E[\,\cdot\,]$ denotes the expectation operator, conditional on the union's information set, Ω^u_{t-1}, which includes the structural parameters, state of the economy, preferences of the policymakers (see below) and the distribution of ϵ_t. Hence workers negotiate for nominal wage contracts based on their expectation of next period's price level. Since $\pi_t = p_t - p_{t-1}$ and the expected inflation $\pi^e_t = E\left[p_t \mid \Omega^u_{t-1}\right] - p_{t-1}$, we can write the aggregate output at time t as

$$y_t = \alpha(\pi_t - \pi^e_t - \tau_t) + \epsilon_t \tag{2}$$

[4]A fixed interest rate and the use of *indexed* debt rules out non–linear debt dynamics and makes the model more tractable. Furthermore, a fixed interest rate can be justified if we are assuming a small open economy.

where $log(1-\tau_t)$ has been approximated by $-\tau_t$. This represents a Lucas–type supply function augmented by taxes: higher tax rates lower output since they distort firms' labor demands and a surprise inflation increases output since it lowers the real wage.

The government, as well as the society, is assumed to have preferences defined over output, inflation and government expenditure. Specifically, the government's per–period utility is given by the quadratic loss function

$$L_t^G = \frac{1}{2}\left[(y_t - \overline{y})^2 + \delta(g_t - \overline{g})^2 + \lambda\pi_t^2\right] \tag{3}$$

where δ and λ are constants weights. The motivation for including spending in the government's loss function is the same as in Jensen (1994): it reflects the utility citizens derive from various forms of spending, *e.g,* health programmes, education, etc. Hence, the government's objective is to minimize the sum of inflation variability, output deviations from a desired level, $\overline{y} > 0$, and deviations of the ratio of spending–to–output from its target, $\overline{g} > 0$. Clearly, if $\pi_t = \pi_t^e$ and there are no output shocks, the government will have to provide a production subsidy at the rate $\tau = -\frac{\overline{y}}{\alpha}$, in order to achieve the production target.

The government seeks to minimize the infinite discounted sum of per–period loss functions given by

$$\omega = E_0\left[\sum_{t=1}^{\infty}\beta^{t-1}L_t \mid \Omega_{t-1}\right]$$

where $\beta\,(0 < \beta < 1)$ is the discount factor and Ω_{t-1} is the government's information set that t. The government is assumed to know all the structural parameters, history and state of the economy, preferences of the the central banker as well as the realization of ϵ_t.

Monetary policy (or, in this case, inflation control) is delegated to a central bank with the mandate of maintaining price stability and ensuring sufficient stabilization of output. In algebraic terms, we assume the central bank has a per–period loss function given by

$$L_t^M = \frac{1}{2}\left[(y_t - \overline{y})^2 + \lambda\pi_t^2\right]. \tag{4}$$

The central bank has the same information as the government and, for simplicity, we assume they have a common discount factor. Hence the only difference in the objectives of the two policymakers is that the central bank does not care about spending levels.[5] The central bank

[5]Even within this formulation, it can be seen that the government's spending policy indirectly affects monetary policy: revenue taxes to finance government expenditure distorts output, and since the bank cares about output stabilization, this in turn forces the bank to set positive inflation levels. Moreover, an alternate formulation in which government expenditure explicitly enters the bank's loss function (but perhaps with a lesser weight than the government's) will only lead to more seigniorage but will not alter the qualitative conclusion in this paper. See also footnote 6.

therefore chooses inflation rates to minimize the infinite discounted sum of per–period loss functions given by

$$\nu = E\left[\sum_{t=0}^{\infty} \beta^t L_t^M \mid \Omega_{t-1}\right].$$

We consider three institutional designs: a policy game with debt–contingent inflation contract or target, and one with a zero–inflation policy. The timing of events in the economy is as follows. Initially, the government decides on the institutional design; one of the above three. The union then signs a one–period nominal wage contract before the output shock is realized. After the realization of the output shock, the fiscal and monetary authorities choose their policies independently. Finally, production takes place. Hence, the union acts as a Stackelberg leader in the model, but fiscal and monetary policies are chosen in a Nash setting. See Alesina and Tabellini (1987), Debelle and Fischer (1994) and Beetsma and Bovenberg (1997a,b) for similar formulations.

Jensen (1994) analyzed a deterministic version of this economy (no output shocks) with the government as the sole policymaker conducting both fiscal and monetary policies. He then showed that it will not be advantageous for the government to give up monetary discretion for zero inflation in all periods. By introducing the central bank and analyzing a performance contract and inflation target, we able to extend his results to show that the contract achieves the pre–commitment policy and also improves upon the welfare associated with a zero–inflation target.

2.1 Pre–commitment policy

We first consider the case where the central bank is able to pre–commit to an inflation rule, call it π_t^r, before agents sign nominal wage contracts. Note that this is similar to an announcement of the direction of monetary policy, and not the actual inflation policy. Persson and Tabellini (1993) show that in this case, the central bank will effectively be choosing π_t^e subject to the *constraint* that $\pi_t^e = E_{t-1}\pi_t$.

The optimal policies under commitment can be derived from the solutions to the central bank's problem given by

$$\nu(d_{t-1}) = \min_{\pi_t, \pi_t^e} E_{t-1}\left[\frac{1}{2}\left((y_t - \overline{y})^2 + \lambda\pi_t^2\right) + \beta\nu(d_t)\right] \qquad (P.1)$$

subject to $\pi_t^e = E_{t-1}\pi_t$ and equations (2); and the solution to the government's problem given by

$$\omega(d_{t-1}) = \min_{\tau_t, d_t} E_{t-1}\left[\frac{1}{2}\left((y_t - \overline{y})^2 + \delta(g_t - \overline{g})^2 + \lambda\pi_t^2\right) + \beta\omega(d_t)\right] \qquad (P.2)$$

subject to equations (1) and (2).

The first order conditions are given by

$$\begin{aligned} \alpha(y_t - \overline{y}) + \lambda\pi_t + \theta_t &= 0 & (5)\\ \alpha E_{t-1}(y_t - \overline{y}) + \theta_t &= 0 & (6)\\ -\alpha(y_t - \overline{y}) + \delta(g_t - \overline{g}) &= 0 & (7)\\ \delta(g_t - \overline{g}) + \beta\omega'(d_t) &= 0 & (8) \end{aligned}$$

where θ_t is the Lagrange multiplier associated with the constraint $\pi_t^e = E_{t-1}\pi_t$. Eliminating θ_t from equation (5) and (6), we get

$$\alpha(y_t - E_{t-1}y_t) + \lambda\pi_t = 0 \qquad (9)$$

which says that if output is lower than expected, then the gain from an increased inflation, in terms of increased output, must equal the cost in raising the inflation rate. Equation (7) states that the marginal cost of a unit increase in taxes (in terms of lost output) must equal the marginal gain in terms of higher expenditures.[6] Equation (8) shows that the gain from increasing the debt position, in terms of higher government outlays, must be offset by the discounted future losses that arise from a constrained set of policy choices.

Substituting equation (7) into equation (9), we get

$$\pi_t = -\frac{\delta}{\lambda}[(g_t - \overline{g}) - E_{t-1}(g_t - \overline{g})].$$

Taking expectations of this equation gives the expected inflation rate, $\pi_t^e = 0$. Hence, if monetary policy is delegated to an independent central bank with no incentive to monetize debt, the pre-commitment policy will have an zero expected rate of inflation every period. This can be compared with an institution in which the government conducts both fiscal and monetary policy. In such an economy, the government can never commit to a rule that results in zero

[6]Were we to introduce government spending into the Bank's loss function with a weight of, say, δ_m (where possibly, $\delta_m < \delta$), then equation (9) will be

$$\alpha(y_t - E_{t-1}y_t) + \delta_m(g_t - E_{t-1}g_t) + \lambda\pi_t = 0.$$

The subsequent analysis will be notationally complicated without any gain in the qualitative results.

expected inflation because the government cares about expenditures and there will always be expectations of debt monetization (cf. equations (3) and (4)).

Substituting π_t and $\pi_t^e = 0$ into equation (7), we can solve for the tax rate in terms of the expected deviation of output from its target. This is given by

$$\tau_t = -\frac{\overline{y}}{\alpha} - \frac{\delta}{\lambda}[(g_t - \overline{g}) - E_{t-1}(g_t - \overline{g})] - \frac{\delta}{\alpha^2}(g_t - \overline{g}) + \frac{\epsilon_t}{\alpha}. \tag{10}$$

Differentiating the government's value function with respect to d_{t-1} and forwarding the resulting equation by one period yields the Benveniste–Scheinkman (1979) formula given by $\omega'(d_t) = -(1+r)\delta E_t(g_{t+1} - \overline{g})$. Inserting this into equation (8) gives

$$E_t(g_{t+1} - \overline{g}) = \frac{(g_t - \overline{g})}{\beta(1+r)} \tag{11}$$

Equation (11) describes the evolution of public expenditure deviations from the target level. If $\beta(1+r) > 1$, then public expenditure level is expected to converge to the target level through time. However if $\beta(1+r) < 1$, then the expected level of government spending diverges infinitely from its target level through time. This can only be sustained through infinite rounds of borrowing (or lending) which is not feasible. The model will then have an equilibrium only if $\beta(1+r) > 1$ (see also Jensen (1994)). This is guaranteed by imposing the following No–Ponzi–Game restriction on the debt level:

$$E_t\left[\lim_{j\to\infty} \frac{d_{t+j}}{(1+r)^j}\right] = 0. \tag{12}$$

This is the stochastic version of the condition in Jensen (1994), and requires that the expectation of the discounted future debt must be zero.

Now, re–write equation (1), the government's budget constraint, as

$$d_t = (g_t - \overline{g}) + \overline{g} + (1+r)d_{t-1} - \tau_t - \pi_t.$$

Forwarding this equation j times and using equations (11) and (12), we get

$$\sum_{j=0}^{\infty} E_t \frac{(g_{t+j} - \overline{g})}{(1+r)^j} + \frac{(1+r)}{r}\overline{g} + (1+r)d_{t-1} = \sum_{j=0}^{\infty} E_t \frac{(\tau_{t+j} + \pi_{t+j})}{(1+r)^j}. \tag{13}$$

Equation (13) states that the expectation of the present value of current and all future government outlays must be equal to the expectation of future stream of revenues net of production subsidies. Substituting the expression for τ_{t+j} and π_{t+j} and making use of (11), we get

$$\gamma_1 \frac{\beta(1+r)^2}{\beta(1+r)^2 - 1}(g_t - \overline{g}) + \frac{(1+r)}{r}\left(\overline{g} + \frac{\overline{y}}{\alpha}\right) + (1+r)d_{t-1} = -\frac{2\delta}{\lambda}\left((g_t - \overline{g}) - E_{t-1}(g_t - \overline{g})\right) + \frac{\epsilon_t}{\alpha} \tag{14}$$

where $\gamma_1 = 1 + \frac{\delta}{\alpha^2}$. Taking expectations through equation (14), gives the expected deviation of spending to be

$$E_{t-1}(g_t - \overline{g}) = -\frac{1}{\gamma_1}\frac{\beta(1+r)^2 - 1}{\beta(1+r)r}\left\{\overline{g} + \frac{\overline{y}}{\alpha} + rd_{t-1}\right\}. \tag{15}$$

The term in the curly brackets on the RHS of equation (15) is just the government budgetary requirement: the sum of expenditure target, and tax subsidies and current interest obligations on outstanding debt. If this sum is positive then the expected present level of the government expenditure will be below the target level; that is, the government sacrifices present spending for the future.

Substituting (15) into equation (14) gives the deviation of actual expenditure from its target level as

$$g_t - \overline{g} = -\frac{1}{\gamma_1}\frac{(\beta(1+r)^2 - 1)}{\beta(1+r)r}\left\{\overline{g} + \frac{\overline{y}}{\alpha} + rd_{t-1}\right\} + \frac{\Theta_1}{\alpha}\epsilon_t \tag{16}$$

where $\Theta_1 = \left(\frac{\beta\gamma_1(1+r)^2}{\beta(1+r)^2-1} + \frac{2\delta}{\lambda}\right)^{-1}$. Finally, inserting equation (16) and $E_{t-1}(g_t - \overline{g})$ into the expressions for π_t and d_t yields the pre–commitment inflation rule

$$\pi_t^P = -\left(\frac{\delta}{\lambda\alpha}\right)\Theta_1\epsilon_t. \tag{17}$$

It has an expected value of zero and a variance given by $\text{var}(\pi_t^P) = \left(\frac{\Theta_1\delta}{\lambda\alpha}\right)^2\sigma^2$. The comparative statics show that $\frac{\partial\text{var}(\pi_t^P)}{\partial\delta} > 0$: if δ is large, then the government will be less concerned about smooth output (relative to expenditures) and therefore τ_t will be less variable. This implies that inflation will have to be more variable in order to stabilize output from its shocks. Also, $\frac{\partial\text{var}(\pi_t^P)}{\partial\lambda} < 0$ simply because a high λ implies an aversion to inflation variability. Finally, if α is large enough $\left(\text{in particular}, \alpha > \frac{\delta}{1+\frac{2\delta}{\lambda}\frac{\beta(1+r)^2}{\beta(1+r)^2-1}}\right)$, then $\frac{\partial\text{var}(\pi_t^P)}{\partial\alpha} < 0$. This is because for a large enough α, a little inflation will have a large effect of output so that is is relatively easier to smooth output with monetary policy. Consequently, inflation is less variable.

The evolution of debt is then given by

$$d_t = \frac{1}{\beta(1+r)}d_{t-1} - \frac{\beta(1+r)-1}{\beta(1+r)r}\left(\overline{g} + \frac{\overline{y}}{\alpha}\right) - \frac{\Theta_1\gamma_1}{(\beta(1+r)^2-1)\,\alpha}\epsilon_t. \tag{18}$$

From the debt dynamics in equation (18), we can calculate the steady states in the pre–commitment policy game. In the steady state, there are no shocks to the economy and $d_t = d_{t-1} = d^{ss}$. Solving for d^{ss} in equation (18) with $\epsilon_t = 0$, gives $d^{ss} = -\frac{1}{r}\left(\overline{g} + \frac{\overline{y}}{\alpha}\right) < 0$. The model has steady–state properties similar to Jensen (1994); that is, the economy becomes a net creditor in the long–run. In the steady state, all tax distortions would be eliminated: inflation is reduced to $\pi^{ss} = 0$ and the government provides firms with a subsidy at the rate of $\tau^{ss} = -\frac{\overline{y}}{\alpha}$. Hence, the government achieves its spending and output targets through the revenue from its lending program.

For purposes of welfare comparison in section 3, we find the expected dynamic loss under the pre–commitment policy. This will be given by

$$\omega_P(d_{t-1}) = E_{t-1}\left[\sum_{j=0}^{\infty} \frac{\beta^j}{2}\gamma_1\delta\left((g_{t+j} - \overline{g})^2 + \lambda\pi_{t+j}^2\right)\right]$$

Using equations (16) and (18), and after some fair amount of algebra, we get

$$\omega_P(d_{t-1}) = \frac{1}{2}\left[\frac{\delta}{\gamma_1}\frac{\beta(1+r)^2 - 1}{\beta r^2}\left\{\overline{g} + \frac{\overline{y}}{\alpha} + rd_{t-1}\right\}^2 + \frac{\delta}{1-\beta}\left(\frac{\Theta_1}{\alpha}\right)^2\left(\frac{1}{\Theta_1} - \frac{\delta}{\lambda}\right)\sigma^2\right] \tag{19}$$

2.2 Discretionary monetary policy with inflation contract

As mentioned earlier, although the policy rule under commitment yields zero expected inflation and sufficient stabilization of output shocks, it will be difficult to implement it without a proper commitment device. The temptation to generate a "surprise" inflation after nominal wage contracts have been signed, means that the pre–commitment inflation policy is time–inconsistent. This is taken into account by the union when signing their wage contracts and results in a positive bias in the inflation rate as well as an inefficient stabilization of output shocks (see Kydland and Prescott (1977), Barro and Gordon (1983), Svensson (1997)).

In this section, we assume that the central bank cannot commit to π_t^r and therefore has to resort to a discretionary monetary policy. However, following the work of Walsh (1995), Persson and Tabellini (1993) and others, we investigate whether the government can design a performance contract for the central bank that can achieve the pre–commitment policy in the discretionary game. Since the state of the economy is characterized by the debt level, such a contract will be contingent on the outstanding debt level, as shown Lockwood (1997) and Svensson (1997).

Now, suppose at the beginning of every period the government offers the central bank a contract $\{w_0, c_t\}$ in which the bank receives some payoff in terms of utility given by $w_t = w_0 - c_t\pi_t$ and $c_t = c_0 + c_1 d_{t-1}$, where w_0, c_0 and c_1 are constants. The central bank thus faces the inter–temporal problem given by

$$\nu(d_{t-1}) = \min_{\pi_t} E_{t-1}\left[\frac{1}{2}\left(y_t^2 + \lambda\pi_t^2\right) - w_0 + c_t\pi_t + \beta\nu(d_t)\right] \qquad (P.3)$$

subject to equations (2), taking agents expectation of inflation, π_t^e, as given. The government's problem remains the same, as in (P.2)

The first order conditions from minimization of the loss functions in the contract game are given by equations (7), (8) and

$$\alpha(y_t - \overline{y}) + \lambda\pi_t + c_t = 0. \qquad (20)$$

Equations (7) and (20) yields

$$\pi_t = -\frac{\delta}{\lambda}(g_t - \overline{g}) - \frac{c_t}{\lambda}.$$

The expected inflation rate will then be given by

$$\pi_t^e = -\frac{\delta}{\lambda}E_{t-1}(g_t - \overline{g}) - \frac{1}{\lambda}\left(c_0 + c_1 d_{t-1}\right).$$

If there is no contract, $c_0 = c_1 = 0$, then as as long as spending is below its desired level, inflation is expected to be positive. In the discretionary policy game with no contract, the central bank finances part of the shortfall of government spending by creating money. As agents recognize this, $\pi_t^e > 0$. This is the positive inflation–bias. If δ is large, relative to λ, then the bias is larger since the government cares more about achieving the spending target than maintaining a stable price level. Clearly, a necessary condition for removing all biases in discretionary monetary policy is to find some pair $\{c_0, c_1\}$ such that $(c_0 + c_1 d_{t-1}) = -\delta E_{t-1}(g_t - \overline{g})$.

Substituting the expressions for π_t and π_t^e into equation (7), after some simplification, yields the same expression for tax rate as in equation (10). Inserting the expressions for π_t and τ_t into the budget constraint (equation (1)), we get

$$d_t = \gamma_2(g_t - \overline{g}) + \overline{g} + \frac{\overline{y}}{\alpha} + \frac{c_0}{\lambda} + (1+\hat{r})d_{t-1} + \frac{\delta}{\lambda}\left((g_t - \overline{g}) - E_{t-1}(g_t - \overline{g})\right) - \frac{\epsilon_t}{\alpha}$$

where $\gamma_2 = 1 + \frac{\delta}{\alpha^2} + \frac{\delta}{\lambda}$, and $\hat{r} = r + \frac{c_1}{\lambda}$ becomes the *net* rate of interest on outstanding debt. Due to this new debt dynamics and the higher interest paid on outstanding debt, the No–Ponzi–Game restriction in the case of performance contracts will be given by

$$E_t\left[\lim_{j\to\infty}\frac{d_{t+j}}{(1+\hat{r})^j}\right] = 0. \qquad (21)$$

Applying this restriction to future debt, and making use equation (11), gives

$$\gamma_2 \frac{\beta(1+r)(1+\hat{r})}{\beta(1+r)(1+\hat{r})-1}(g_t-\overline{g}) + \frac{1+\hat{r}}{\hat{r}}\left(\overline{g}+\frac{\overline{y}}{\alpha}+\frac{c_0}{\lambda}\right) + (1+\hat{r})d_{t-1} = -\frac{\delta}{\lambda}((g_t-\overline{g}) - E_{t-1}(g_t-\overline{g})) + \frac{\epsilon_t}{\alpha}$$

and taking expectations through this equation gives the expected expenditure deviation as

$$E_{t-1}(g_t-\overline{g}) = -\frac{1}{\gamma_2}\frac{\beta(1+r)(1+\hat{r})-1}{\beta(1+r)\hat{r}}\left\{\overline{g}+\frac{\overline{y}}{\alpha}+\frac{c_0}{\lambda}+\hat{r}d_{t-1}\right\}. \tag{22}$$

and the actual deviation of spending from its target level to be

$$g_t-\overline{g} = -\frac{1}{\gamma_2}\frac{\beta(1+r)(1+\hat{r})-1}{\beta(1+r)\hat{r}}\left\{\overline{g}+\frac{\overline{y}}{\alpha}+\frac{c_0}{\lambda}+\hat{r}d_{t-1}\right\}+\frac{\Theta_2}{\alpha}\epsilon_t$$

where $\Theta_2 = \left(\frac{\beta\gamma_2(1+r)(1+\hat{r})}{\beta(1+r)(1+\hat{r})-1}+\frac{\delta}{\lambda}\right)^{-1}$. The inflation policy will then be

$$\pi_t^c = -\frac{\delta}{\lambda}(g_t-\overline{g}) - \frac{c_t}{\lambda} - \frac{\delta}{\lambda}\left(\frac{\Theta_2}{\alpha}\right)\epsilon_t. \tag{23}$$

It is easy to see that if the central bank is not offered a performance contract, that is $c_0 = c_1 = 0$, the resulting inflation policy from the discretionary game will be

$$\pi_t^d = \frac{\delta}{\lambda\gamma_2}\frac{\beta(1+r)^2-1}{\beta(1+r)r}\left\{\overline{g}+\frac{\overline{y}}{\alpha}+rd_{t-1}\right\} - \frac{1}{\frac{\beta\gamma_2(1+r)^2}{\beta(1+r)^2-1}+\frac{\delta}{\lambda}}\left(\frac{\delta}{\lambda\alpha}\right)\epsilon_t. \tag{24}$$

Equation (24) shows that if no contract is offered, the discretionary game results in a positive bias and a stabilization bias in the inflation policy. The positive inflation–bias (first term on the RHS of equation (24)) consists of an average inflation bias given by $\frac{\delta}{\lambda\gamma_2}\frac{\beta(1+r)^2-1}{\beta(1+r)r}\left(\overline{g}+\frac{\overline{y}}{\alpha}\right)$, and a debt–contingent bias given by $\frac{\delta}{\lambda\gamma_2}\frac{\beta(1+r)^2-1}{\beta(1+r)}d_{t-1}$. Furthermore, we have

$$\left(\frac{\beta\gamma_1(1+r)^2}{\beta(1+r)^2-1}+\frac{2\delta}{\lambda}\right) - \left(\frac{\gamma_2\beta(1+r)^2}{\beta(1+r)^2-1}+\frac{\delta}{\lambda}\right) = -\frac{\frac{\delta}{\lambda}}{\beta(1+r)^2-1} < 0,$$

since $\gamma_1 = 1+\frac{\delta}{\alpha^2} < \gamma_2 = 1+\frac{\delta}{\alpha^2}+\frac{\delta}{\lambda}$. Hence, the discretionary policy without contract, π_t^d involves an inefficient stabilization of output shocks. This is the stabilization bias (see also Lockwood (1997)).

The first objective of the paper is to investigate whether a government will be able to design a performance contract that will eliminate these biases and restore the pre–commitment outcome. Recall that to be able to remove the biases associated with a discretionary policy, it is necessary that the contract $\{c_0, c_1\}$ be designed such that $c_0 + c_1 d_{t-1} = -\delta E_{t-1}(g_t - \overline{g})$. Our first result (below) shows that such a contract can be designed in this economy and it can also eliminate the stabilization bias.

Proposition 1 *There is a unique debt–contingent inflation contract,* $w_t^* = w_0 - (c_0^* + c_1^* d_{t-1})\pi_t$, *where*

$$c_1^* = \frac{\delta}{\gamma_1}\frac{(\beta(1+r)^2-1)}{\beta(1+r)} \qquad \text{and} \qquad c_0^* = \frac{c_1^*}{r}\left(\overline{g} + \frac{\overline{y}}{\alpha}\right),$$

which achieves the pre–commitment inflation policy in the monetary discretionary game.

Proof: By setting $c_0 + c_1 d_{t-1} = \delta E_{t-1}(g_t - \overline{g})$, which is given in equation (22), it is clear that the contract eliminates the state–contingent bias if

$$c_1 = \frac{\delta}{\gamma_2}\frac{\beta(1+r)(1+\hat{r})-1}{\beta(1+r)}.$$

With $\hat{r} = r + \frac{c_1}{\lambda}$, solving for c_1 gives

$$c_1 = c_1^* = \frac{\delta}{\gamma_1}\frac{\beta(1+r)^2-1}{\beta(1+r)}.$$

Secondly, the average–bias can be eliminated if

$$\begin{aligned} c_0 &= \frac{\delta}{\gamma_2}\frac{\beta(1+r)(1+\hat{r})-1}{\beta(1+r)\hat{r}}\left\{\overline{g} + \frac{\overline{y}}{\alpha} + \frac{c_0}{\lambda}\right\} \\ &= \frac{c_1^*}{\hat{r}}\left\{\overline{g} + \frac{\overline{y}}{\alpha} + \frac{c_0}{\lambda}\right\} \end{aligned}$$

Solving for c_0, gives

$$c_0 = \frac{c_1^*}{r}\left(\overline{g} + \frac{\overline{y}}{\alpha}\right) = c_0^*$$

Thus, $\{c_0^*, c_1^*\}$ eliminates the average and state–contingent bias in the discretionary inflation policy. It remains to show that the same pair $\{c_0^*, c_1^*\}$ can also eliminate the stabilization bias. But using $c_1 = \frac{\delta}{\gamma_2}\frac{\beta(1+r)(1+\hat{r})-1}{\beta(1+r)}$ in equation (23) gives

$$\begin{aligned} \pi_t^c &= -\left(\frac{1}{\frac{\delta(1+\hat{r})}{c_1} + \frac{\delta}{\lambda}}\right)\left(\frac{\delta}{\lambda\alpha}\right)\epsilon_t \\ &= -\left(\frac{1}{\frac{\beta\gamma_1(1+r)^2}{\beta(1+r)^2-1} + \frac{2\delta}{\lambda}}\right)\left(\frac{\delta}{\lambda\alpha}\right)\epsilon_t = -\left(\frac{\delta}{\lambda\alpha}\right)\Theta_1\epsilon_t \end{aligned}$$

where we make use $\hat{r} = r + \frac{c_1^*}{\lambda}$ and the expression for c_1^* in the second equality. The last equation is the same as the pre-commitment policy in equation (17). □

Proposition 1 shows that the government can offer a performance contract to the central bank that achieves the pre–commitment outcome at all times. Since $c_1^* > 0$, the inflation contract rewards (penalizes) the central bank for lower (higher) rates of inflation. As in Lockwood

(1997), the inflation contract is also contingent on the state of the economy (which is the debt level in this economy) because it should be able to eliminate the debt–contingent inflation bias as well.

With this inflation contract, the government shifts the debt burden explicitly onto the central bank: the higher the debt level, the more severe is the penalty for bad inflation performance precisely because the temptation to monetize is greater with a large debt. The central bank therefore reacts with a tight monetary policy which results in a high interest rate, $\hat{r} = r + \frac{c_1^*}{\lambda}$. Hence, this contract is equivalent to a discrete jump in the interest rate on outstanding debt. This increases the cost of borrowing by the government and serves to ensure fiscal discipline. It can easily be shown that $\frac{\partial c_1^*}{\partial \delta} > 0$, so that, with a performance–contract, monetary policy will be tighter if δ is high. Intuitively, a high δ implies that the government is relatively more concerned with smooth expenditures and there is a larger incentive to create money to finance spending.

2.3 Discretionary monetary policy with inflation target

Next, we analyze the possibility of using a debt–contingent inflation target to remove the biases in inflation in a discretionary game. Suppose that the government sets a target for inflation contingent on outstanding debt. That is, $\pi_t^{\text{targ}} = \kappa_0 + \kappa_1 d_{t-1}$.

The central bank's problem will then be given by

$$\nu(d_{t-1}) = \min_{\pi_t} E_{t-1} \left[\frac{1}{2} \left(y_t^2 - \overline{y} \right) + \lambda \left(\pi_t - (\kappa_0 + \kappa_1 d_{t-1}) \right)^2 + \beta \nu(d_t) \right] \qquad (P.4)$$

subject to equation (2), and taking agents expectation of inflation, π_t^e, as given. The government's problem also becomes

$$\omega(d_{t-1}) = \min_{\pi_t} E_{t-1} \left[\frac{1}{2} \left(y_t^2 - \overline{y} \right) + \delta(g_t - \overline{g}) + \lambda \left(\pi_t - (\kappa_0 + \kappa_1 d_{t-1}) \right)^2 + \beta \omega(d_t) \right] \qquad (P.5)$$

subject to equation (1) and (2).[7]

The first order conditions from minimization of the loss functions are given by equations (7), (8) and

$$\alpha(y_t - \overline{y}) + \lambda(\pi_t - \kappa_0 - \kappa_1 d_{t-1}) = 0 \qquad (25)$$

[7] We assume both authorities share the same concern of minimizing the variation of actual inflation around the target, hence the difference in objectives continues to be the absence of government spending in the bank's loss function.

In addition, the Benveniste–Scheinkman equation is

$$g_t - \overline{g} = \beta(1+r)E_t(g_t - \overline{g}) + \frac{\kappa_1 \lambda}{\delta} E_t[\pi_{t+1} - (\kappa_0 + \kappa_1 d_t)].$$

Since we seek a solution that eliminates positive inflation–bias, it must be that $E_t[\pi_{t+1} - (\kappa_0 + \kappa_1 d_t)] = 0$ if such a κ_0 and κ_1 exist. With this solution, the above Benveniste–Scheinkman equation will be just as in equation (11). Equations (7) and (25) yields

$$\pi_t = -\frac{\delta}{\lambda}(g_t - \overline{g}) + \kappa_0 + \kappa_1 d_{t-1}.$$

and the expected inflation rate will then be given by

$$\pi_t^e = -\frac{\delta}{\lambda} E_{t-1}(g_t - \overline{g}) + \kappa_0 + \kappa_1 d_{t-1}.$$

As before, a necessary condition for removing all biases in discretionary monetary policy is to find some pair $\{\kappa_0, \kappa_1\}$ such that $\kappa_0 + \kappa_1 d_{t-1} = \frac{\delta}{\lambda} E_{t-1}(g_t - \overline{g})$.

Substituting the expressions for π_t and π_t^e into equation (7) yields the tax policy in equation (10). Inserting the expressions for π_t and τ_t into the budget constraint (equation (1)), we get

$$d_t = \gamma_2(g_t - \overline{g}) + \overline{g} + \frac{\overline{y}}{\alpha} - \kappa_0 + (1+\tilde{r})d_{t-1} + \frac{\delta}{\lambda}\left((g_t - \overline{g}) - E_{t-1}(g_t - \overline{g})\right) - \frac{\epsilon_t}{\alpha}$$

where $\tilde{r} = r - \kappa_1$ becomes the *net* rate of interest on outstanding debt. This debt dynamics has the same form as found under the inflation contract, except the government's budgetary requirement is now given by $\left(\overline{g} + \frac{\overline{y}}{\alpha} - \kappa_0\right)$ and the *effective* gross rate on outstanding is $(1+\tilde{r})$. Following the analysis in the previous section, we get the No–Ponzi–Game restriction to be

$$E_t\left[\lim_{j\to\infty} \frac{d_{t+j}}{(1+\tilde{r})^j}\right] = 0 \tag{26}$$

and the expected expenditure deviation to be

$$E_{t-1}(g_t - \overline{g}) = -\frac{1}{\gamma_2}\frac{\beta(1+r)(1+\tilde{r}) - 1}{\beta(1+r)\tilde{r}}\left\{\overline{g} + \frac{\overline{y}}{\alpha} + \kappa_0 + \tilde{r} d_{t-1}\right\}. \tag{27}$$

The the actual deviation of spending from its target level is then given by

$$g_t - \overline{g} = E_{t-1}(g_t - \overline{g}) + \frac{\Theta_3}{\alpha}\epsilon_t$$

where $\Theta_3 = \left(\frac{\beta\gamma_2(1+r)(1+\tilde{r})}{\beta(1+r)(1+\tilde{r})-1} + \frac{\delta}{\lambda}\right)^{-1}$, and the inflation policy is

$$\pi_t^{\text{targ}} = -\frac{\delta}{\lambda}E_{t-1}(g_t - \overline{g}) + \kappa_0 + \kappa_1 d_{t-1} - \frac{\delta}{\lambda}\left(\frac{\Theta_3}{\lambda}\right)\epsilon_t. \tag{28}$$

The next proposition shows that the inflation target can be designed to eliminate the stabilization bias. As noted, a necessary condition for this is to have $\kappa_0 + \kappa_1 d_{t-1} = \frac{\delta}{\lambda} E_{t-1}(g_t - \overline{g})$.

Proposition 2 *There is a debt–contingent inflation target* $\pi_t^{T*} = \kappa^*0 + \kappa_1^* d_{t-1})$, *where*

$$\kappa_1^* = -\frac{\delta}{\gamma_1}\frac{(\beta(1+r)^2 - 1)}{\beta(1+r)} \qquad \textit{and} \qquad \kappa_0^* = \frac{\kappa_1^*}{r}\left(\overline{g} + \frac{\overline{y}}{\alpha}\right),$$

which achieves the pre–commitment inflation policy in the monetary discretionary game.

Proof: By setting $\kappa_0 + \kappa_1 d_{t-1} = \frac{\delta}{\lambda} E_{t-1}(g_t - \overline{g})$, which is given in equation (27), it is clear that the inflation target the state–contingent bias if

$$\kappa_1 = \frac{\delta}{\lambda\gamma_2}\frac{\beta(1+r)(1+\tilde{r}) - 1}{\beta(1+r)}.$$

With $\tilde{r} = r - \kappa_1$, solving for κ_1 gives

$$\kappa_1 = \kappa_1^* = -\frac{\delta}{\lambda\gamma_1}\frac{\beta(1+r)^2 - 1}{\beta(1+r)}.$$

Secondly, the average–bias can be eliminated if $\kappa_0 = \frac{\kappa_1^*}{\tilde{r}}\left\{\overline{g} + \frac{\overline{y}}{\alpha} - \kappa_0\right\}$ which implies that

$$\kappa_0 = \frac{\kappa_1^*}{r}\left(\overline{g} + \frac{\overline{y}}{\alpha}\right) = \kappa_0^*$$

Thus, $\{\kappa_0^*, \kappa_1^*\}$ eliminates the average and state–contingent bias in the discretionary inflation policy. Finally, we show that κ_1^* can also eliminate the stabilization bias. Using the expression κ_1^* and $1 + \tilde{r} = 1 + r - \kappa_1^*$ into equation (28) gives

$$\begin{aligned}
\pi_t^{\text{targ}} &= -\left(\frac{1}{-\frac{\delta}{\lambda}\frac{(1+\tilde{r})}{\kappa_1} + \frac{\delta}{\lambda}}\right)\left(\frac{\delta}{\lambda\alpha}\right)\epsilon_t \\
&= -\left(\frac{1}{-\frac{\delta}{\lambda}\frac{(1+r)}{\kappa_1} + \frac{2\delta}{\lambda}}\right)\left(\frac{\delta}{\lambda\alpha}\right)\epsilon_t \\
&= -\left(\frac{1}{\frac{\beta\gamma_1(1+r)^2}{\beta(1+r)^2-1)} + \frac{2\delta}{\lambda}}\right)\left(\frac{\delta}{\lambda\alpha}\right)\epsilon_t
\end{aligned}$$

which is the same as the pre-commitment policy in equation (17) □

The debt–contingent inflation target with $\kappa_0 = \kappa_0^*$ and $\kappa_1 = \kappa_1^*$ removes all biases in monetary policy and achieves the pre–commitment inflation rule. An examination of the inflation contract and target shows that both solutions result in a higher and equal interest rate on the stock of debt since $\kappa_1 = -\frac{c_1}{\lambda}$. It therefore follows that, with debt monetization problems, a simple solution to the inflation–bias problem is a hike in the rate of interest to ensure fiscal discipline, hence restoring the pre–commitment rule.

In spite of the positive appeal of the above inflation contract and target, they are rarely observed in practice. Whereas it more common these days to observe explicit constant inflation targets or rule, inflation performance contracts are almost non–existence: not even simple (and linear) performance contracts independent of a state variable. This is partly because any such contracts may be too sophisticated to implement and subject to political criticisms, especially if other state variables (*e.g.,* employment and output level) have to be taken into account. For example, a widely cited form of an inflation contract is the one proposed in New Zealand in which the Governor of the Reserve Bank is rewarded (or penalized) according to inflation performance. But even then, this contract was rejected by government officials on the grounds that it would invoke headlines in the press such as "Governor makes \$500,000 by taking action to throw 500,000 out of work" (see Goodhart (1994)). Moreover, they are totally non–existent in countries with debt problems.

In the next section, we analyze the game with a zero–inflation rule and then compare welfare under the diferrent regimes in section 3.

2.4 Zero Inflation Policy

We now suppose that the central bank follows a zero inflation rule all periods. This is equivalent to a zero inflation announcement which is believed and implemented at all times.

The optimal fiscal policies under this monetary policy can be derived from the first order conditions to the government's maximization problem given in equations (7) and (8). Substituting $\pi_t = \pi_t^e = 0$ into equation (7), we can solve for the optimal tax rate in terms of the deviation of output from its target. This is given by

$$\tau_t = -\frac{\overline{y}}{\alpha} - \frac{\delta}{\alpha^2}(g_t - \overline{g}) + \frac{\epsilon_t}{\alpha}.$$

and the per–period debt level will be

$$d_t = \gamma_1(g_t - \overline{g}) + \left(\overline{g} + \frac{\overline{y}}{\alpha}\right) - \frac{\epsilon_t}{\alpha}$$

Using the evolution of public expenditure deviation derived in equation (11), and applying equation (13), we get the deviation of actual expenditure from its target level to be

$$g_t - \overline{g} = -\frac{1}{\gamma_1}\frac{(\beta(1+r)^2-1)}{\beta(1+r)r}\left\{\overline{g} + \frac{\overline{y}}{\alpha} + rd_{t-1}\right\} + \frac{\Theta_4}{\alpha}\epsilon_t \tag{29}$$

where $\Theta_4 = \left(\gamma_1 \frac{\beta(1+r)^2}{\beta(1+r)^2-1}\right)^{-1}$. Finally, the level of debt in the zero–inflation regime will evolve as follows:

$$d_t = \frac{1}{\beta(1+r)}d_{t-1} - \frac{\beta(1+r)-1}{\beta(1+r)r}\left(\overline{g} + \frac{\overline{y}}{\alpha}\right) - \frac{\Theta_4\gamma_1}{(\beta(1+r)^2-1)\,\alpha}\epsilon_t. \tag{30}$$

To complete the analysis under the zero–inflation target policy, we find the the government's expected dynamic loss function. This is given by

$$\begin{aligned}\omega_Z(d_{t-1}) &= E_{t-1}\left[\sum_{j=0}^{\infty}\frac{\beta^j}{2}\left[(y_{t+j}-\overline{y})^2 + \delta(g_{t+j}-\overline{g})^2 + \lambda\pi_{t+j}^2\right]\right] \\ &= E_{t-1}\left[\sum_{j=0}^{\infty}\frac{\beta^j}{2}\left[\gamma_1\delta(g_{t+j}-\overline{g})^2\right]\right]\end{aligned}$$

Using equations (29) and (30), and after some little algebra, we get

$$\omega_Z(d_{t-1}) = \frac{1}{2}\left[\frac{\delta}{\gamma_1}\frac{\beta(1+r)^2-1}{\beta r^2}\left\{\overline{g} + \frac{y}{\alpha} + rd_{t-1}\right\}^2 + \frac{\delta}{(1-\beta)}\left(\frac{\sigma}{\alpha}\right)^2\Theta_4\right] \tag{31}$$

The zero–inflation rule is simpler and much more feasible in practice. More generally, constant inflation targets and rules (or a target range) have become increasingly common in several countries (*e.g.*, Canada and New Zealand). But as shown by Svensson (1997) and in this paper, if there is persistent in a state variable, such targets can only eliminate some but not all biases in monetary policy: for example, the zero–inflation rule does not involve stabilization of output shocks.

In the next section, we show that the optimal contract $\{c_0^*, c_1^*\}$ in Proposition 1 or optimal target $\{\kappa_0^*, \kappa_1^*\}$ in Proposition 2 results in a higher expected welfare.

3 Welfare analysis

In this section we compare the government's dynamic loss (or welfare) under an inflation–performance contract or target with welfare under a zero inflation rule. Since the contract and target solutions achieve the same outcome as the pre–commitment policy, the welfare levels are equal. Hence, the analysis reduces to comparing the dynamic losses in equation (19) (contract or target) and (31) (zero–inflation rule).

Both dynamic loss functions consists of two terms, a state–contingent term given by the first term and a time–invariant term given by the second. The first terms are the same and vanishes in the steady state since all distortions are removed from the economy and the government is able to subsidize output to its desired level. However, there is an additional loss that comes from the disturbance term, ϵ_t, and is captured in the second term. This reflects the loss arising from the aggregate uncertainty in the economy, irrespective of the debt position.

Proposition 3 *Given any debt level, the government will better off offering the performance contract* $\{c_0^*, c_1^*\}$ *or setting the inflation target* $\{\kappa_0^*, \kappa_1^*\}$ *than adopting the zero–inflation policy.*

Proof: To prove this, we show that $\omega_P(d_{t-1}) < \omega_Z(d_{t-1})$: that is, the expected dynamic loss from a performance contract is strictly less than the dynamic loss with zero inflation policy. But this is straight–forward by comparing the second terms in $\omega_P(d_{t-1})$ and $\omega_T(d_{t-1})$ (NOTE that the first terms are the same). We therefore have

$$\begin{aligned}\omega_P(d_{t-1}) - \omega_Z(d_{t-1}) &= \frac{\delta}{2(1-\beta)}\left(\frac{\sigma}{\alpha}\right)^2\left(\Theta_1 - \frac{\delta}{\lambda}\Theta_1^2 - \Theta_4\right) \\ &< \frac{\delta}{2(1-\beta)}\left(\frac{\sigma}{\alpha}\right)^2(\Theta_1 - \Theta_4) < 0\end{aligned}$$

since $\Theta_1 - \Theta_4 < 0$. Hence, $\omega_P(d_{t-1}) < \omega_Z(d_{t-1})$. □

The government has a smaller expected dynamic loss if it offers an inflation performance contract to the central bank. This is true even in the steady state. This is because, a zero–inflation policy leads to higher variation in fiscal policies (and subsequently, higher output variance) which results in higher expected losses. In contrast, a state–contingent contract or target allows for optimal stabilization of output shocks and reduces the variation in output and public expenditure levels.

4 Conclusion

Following the work of Walsh (1995), recent research on monetary policy has focused on how performance contract may be design to rid monetary policy of its inflation bias. In particular, Svensson (1996) and Lockwood (1997) analyzed how an inflation contract can be used to resolve the biases in monetary discretion when unemployment is persistent. These authors show that the bias in monetary policy can be removed, and the pre–commitment policy restored, with a state–contingent inflation performance contract written for the central bank. Such a contract rewards the bank for keeping inflation low.

In this paper we extend the contract analysis to the problem of debt. With a high debt level, agents expectation of debt monetization leads to a similar inflation–bias in monetary discretion. It is shown that it is possible to achieve the pre–commitment policy rule with a debt–contingent inflation contract or target. The two solutions explicitly shifts the debt burden from the government to the central bank, and the bank reacts by tightening monetary policy. The resulting equilibrium yields a higher interest rate on outstanding debt. This mimics the fact that agents will always demand a higher interest rate on government debt to account for the risk of debt monetization.

It is also shown that, in this model, the debt–contingent performance contract or target results in a higher welfare level than if the central bank were to follow a zero–inflation policy at all times. This shows that, though it may be difficult to implement, a well–designed performance contract can enhance monetary policy, ensure fiscal discipline and improve upon welfare, especially in indebted countries. Finally, it must be emphasized that such contracts must be accompanied by the necessary institutional arrangements that increases commitment else it would be open to McCallum's (1995) critique: that is, the government will have the incentive to renege on the contract so that the time–inconsistent problem still remains.

Appendix

Derivation of equation (1):

The derivation of the government's budget constraint (equation (1)) follows Beetsma and Bovenberg (1997a). Nominal money at time t is assumed to be given by $M_t = P_t\overline{Y}$, where $\overline{Y}$ is the real output level in the absence of any distortions in the economy (the anti–log of $\overline{y}$). This is the desired level of output. The change in nominal money supply will then be

$$M_t - M_{t-1} = (P_t - P_{t-1})\,\overline{Y}. \qquad (A.1)$$

We first write the government's budget constraint in nominal terms as

$$P_tG_t + (1+r)P_tD_{t-1} = \tau_tP_tY_t + (M_t - M_{t-1}) + P_tD_t \qquad (A.2)$$

where G_t is total expenditure, D_t is amount of *indexed* debt issued by the government at time t, M_t is money supply and r is the (fixed) net nominal interest rate. The debt is indexed in the sense that it is issued at price P_{t-1} but redeemed at price P_t. The interest r is assumed to equal the rate of return on an outside investment opportunity available to the individual investor. Hence, such an investor will be willing to invest in the government bonds if its rate of return is at least equal to r. Since the government tries to borrow at the minimum costs, it offers the rate r on its debt. Dividing equation (A.2) by $P_t\overline{Y}$ and using (A.1), the budget constraint can be written as

$$g_t + rd_{t-1} = \tau_t\frac{Y_t}{\overline{Y}} + \pi_t(1+\pi_t)^{-1} + d_t \qquad (A.3)$$

where g_t and d_t are ratios of expenditure and debt to the desired nominal output respectively. Finally, approximating $\pi_t(1+\pi_t)^{-1}$ by π_t and Y_t by $\overline{Y}$, we get equation (1) in the text.

References

[1] Alesina, Alberto and Guido Tabellini (1987), "Rules and Discretion with Noncoordinated Monetary and Fiscal Policies" *Economic Inquiry,* 25 (4), 619–630.

[2] Barro, Robert and David Gordon (1983), "Rules, Discretion and Reputation in a Model of Monetary Policy" *Journal of Monetary Economics,* 12, 101–121.

[3] Beetsma Roel and A. Lans Bovenberg (1997a), "Central Bank Independence and Public Debt Policy", *Journal of Economic Dynamics and Control,* 21, 873–94.

[4] — (1997b), "Designing Fiscal and Monetary Institutions in a Second–Best World", Independence and public debt policy", *European Journal of Political Economy,* 13, 53–79.

[5] — and Henrik Jensen (1998), "Inflation Targets and Contracts with Uncertain Central Banker Preferences," *Journal of Money, Credit and Banking,* 30 (3), 384–403

[6] Benveniste, L. M. and Jose Scheinkman (1979), "On the Differentiability of the Value Function in Dynamic Models of Economics," *Econometrica,* 47, 727–32.

[7] Buiter, William (1981), "The Superiority of Contingent Rules over Fixed Rules in Models with Rational Expectations," *Economic Journal,* 91, 647–70.

[8] Debelle, Guy and Stanley Fischer (1996), "How Independent should a Central Bank Be?" in *Goals, Guidelines and Constraints facing Monetary Policy Makers,* Jeffrey C. Fuhrer (ed.), Federal Reserve, Boston.

[9] Goodhart, Charles (1994), "What Should Central Banks Do? What Should Be Their Macroeconomic Objectives and Operations?", *Economic Journal*, 104, 1424–36.

[10] — and José Viñals (1994), "Strategies and Tactics of Monetary Policy: Examples from Europe and the Antipodes," in *Goals, Guidelines and Constraints facing Monetary Policy Makers,* Jeffrey C. Fuhrer (ed.), Federal Reserve, Boston.

[11] Jensen, Henrik (1994), "Loss of Monetary Discretion in a Simple Dynamic Policy Game" *Journal of Economic Dynamics and Control,* 18 (3),763–79.

[12] Kydland, F. E. and E. Prescott (1977), "Rules Rather than Discretion: The Inconsistency of Optimal Plans," *Journal of Political Economy,* 85, 473–491.

[13] Lockwood, Ben (1997), "State–Contingent Inflation Contracts and Unemployment Persistence," *Journal of Money, Credit and Banking*, 29 (3), 286–99

[14] Lohmann, Sussanne (1992), "Optimal Pre-commitment in Monetary Policy: Credibility Versus Flexibility," *American Economic Review*, 82, 273–86

[15] McCallum, Bennet (1995), "Two Fallacies concerning Central Bank Independence," NBER working paper #5075.

[16] Persson, Torsten and Guido Tabellini (1993), "Designing Institutions for Monetary Stability," *Carnegie–Rochester Conference Series on Public Policy*, 39, 53–84.

[17] Rogoff, Kenneth (1985), "The Optimal Degree of Commitment to an Intermediate Monetary Target", *Quarterly Journal of Economics*, 110, 1169–90.

[18] Sargent, Thomas and Neil Wallace (1981), "Some Unpleasant Monetarist Arithmetic", Quarterly Review, Federal Reserve Bank of Minneapolis.

[19] Svensson, Lars (1997), " Optimal Inflation Targets, 'Conservative' Central Banks, and Linear Inflation Contracts," *American Economic Review,* 87 (1), 98–114

[20] Tabellini, Guido (1986), "Money, Debt and Deficits in a Dynamic Game" *Journal of Economic Dynamics and Control,* 10, 427–442.

[21] Walsh, Carl (1995), "Optimal Contracts for Central Banks," *American Economic Review,* 85, 150–67

TUFTS UNIVERSITY
ECONOMICS DEPARTMENT

DISCUSSION PAPERS SERIES 2000

2000-09 Edward KUTSOATI; Debt-Contingent Inflation Contracts and Targeting

2000-08 Yannis M. IOANNIDES and George PETRAKOS; Regional Disparities in Greece and The Performance of Crete, Peloponnese and Thessaly.

2000-07 Hans H. HALLER and Yannis M. IOANNIDES; Propaedeutics of Strategic Theories of Economic Integration.

2000-06 Yannis M. IOANNIDES and Henry G. OVERMAN; Zipf's Law For Cities: An Explanation.

2000-05 Drusilla K. BROWN; International Trade And Core Labor Standards A Survey Of The Recent Literature.

2000-04 Gilbert E. METCALF; Environmental Levies and Distortionary Taxation: Pigou, Taxation, and Pollution.

2000-03 Drusilla K. BROWN; International Labor Standards in the World Trade Organization and the International Labor Organization.

2000-02 Alan V. DEARDORFF, Drusilla K. BROWN, and Robert M. STERN; Computational Analysis of the Government Of India’s Market Opening Initiatives.

2000-01 Drusilla K. BROWN and Robert M. STERN; Measurement and Modeling of the Economic Effects of Trade and Investment Barriers in Services.

Discussion Papers are available on-line at

http://ase.tufts.edu/econ/papers