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ABSTRACT

Wage and price controls have a long and somewhat disreputable history, presumably because of their frequent use in many countries as short run substitutes for measures with more lasting effects on the inflation rate. But, in 1985 and 1986, Argentina, Brazil, and Israel used extensive wage-price controls as part of more comprehensive disinflation programs, often labeled "heterodox" stabilization programs. To date, the Israeli stabilization seems to have succeeded, while the Argentinean and Brazilian stabilizations have clearly ended in failure. This experience raises many questions. One view is that controlling one nominal variable, namely the money supply, is enough to bring down inflation provided that sound fiscal policies are also adopted. Therefore, wage and price controls should be avoided, because of their microeconomic costs. It is clear that controls do have microeconomic costs, but can they also have macroeconomic benefits? Under which circumstances do controls help in bringing down inflation, and when do they just suppress it temporarily? What is the required supporting role of fiscal and monetary policy while they are in place? These are the issues addressed in this paper.

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1. Introduction

Wage and price controls have a long and somewhat disreputable history. Their frequent use in many countries as short run substitutes for measures with more lasting effect on the inflation rate presumably explains that disrepute. But in 1985 and 1986 Argentina, Brazil and Israel used extensive wage-price controls as part of more comprehensive disinflation programs, often labelled "heterodox" stabilization programs. In each case, the controls were intended to counteract the "inertial component" in inflation. To date, the Israeli stabilization seems to have succeeded at only minimal costs in terms of transitional output losses and increased unemployment. The Argentinean and Brazilian stabilizations have clearly ended in failure.

This experience with wage and price controls raises many questions to which the literature provides no answer. Indeed, the prevailing view--at least among neoclassically oriented economists such as Sargent (1982)--is that controlling one nominal variable, namely the money supply, is enough when bringing down inflation provided that sound fiscal policies are also adopted. Therefore, wage and price controls should be avoided, because of their microeconomic costs. It is clear that controls do have microeconomic costs, but can they also have macroeconomic benefits? Under which circumstances do controls help in bringing down inflation, and when do they just suppress it temporarily? What is the required supporting role of fiscal and monetary policy while they are in place? These are the issues we address in this paper.

Incomes policies are often defended because of proclaimed inertia in the inflationary process. Inflation inertia must unavoidably be associated with price setting. This strongly suggests that non-competitive market structures should be incorporated in the analysis. In fact, Helpman (1987) provides evidence that the actual output response to price controls in Israel and Brazil contradicts the prediction of models based on competitive markets. He also shows that the output response accords well with the predictions of a small macro- model incorporating non- competitive markets. A similar approach is followed by Dornbusch and Simonsen (1986) and Simonsen (1986). They explain inflation inertia as a consequence of a coordination failure between wage and price setters in the economy after an observed change in economic policy. Wage- price controls can be used to resolve this coordination failure. Van Wijnbergen (1987) introduces a different mechanism through which inflation inertia emerges. In his analysis the lack of credibility of monetary policy and the price setting behavior of forward looking firms is shown to lead to inflation inertia. which potentially extends well beyond the price setting period.

Credibility problems arise naturally with incomplete private information about future public sector revenue requirements. A government with high revenue requirements has a strong incentive not to announce them. If the private sector would believe announced low revenue requirements and the attendant reduced reliance on the inflation tax, it would increase its holding of monetary balances. This would, in turn, offer a low- distortion base for tax revenue through surprise inflation. A corollary of this argument is, however, that a low revenue requirement government cannot credibly announce its low inflation targets; the incentive for high- inflation governments to do likewise discredits mere announcements of low inflation.

The above information problem, and the lack of credibility it leads to, naturally suggest the analysis of signalling equilibria. The early literature on reputation and inflation- - such as Backus and Driffill (1985)- - showed the incentives for a high- inflation government to mimic a low- inflation policy maker. In that literature, the low- inflation government does not behave strategically by assumption. However, one can reasonably ask whether the low- inflation government could not try to establish credibility by deviating from its full information optimal policy in a way that would be more costly to a high- inflation government than to itself, and so make mimicking unprofitable. Vickers (1986) shows that such signalling equilibria may indeed exist. He demonstrates that a recessionary monetary policy can serve to separate a low- inflation government from its high-inflation predecessors. For a separating equilibrium to exist. the aversion of unemployment relative to inflation needs to be sufficiently diverse between the two types of policy makers. The temporary recession is what is necessary to establish beyond doubt that the policy maker indeed is of the "low-inflation type".[1]

The signalling approach is also the line taken in this paper. In a nutshell, we demonstrate that the use of wage controls, in combination with restrictive monetary policy, may allow a low-inflation government to signal its type at lower cost than through the use of monetary policy alone.[2] However, wage controls cannot substitute for restrictive macro policies; a contractionary monetary policy should also be used. although to a lesser extent than in no-controls equilibria. We demonstrate that it is never optimal to use wage controls without restrictive monetary policy; however it is sometimes optimal to use restrictive monetary policy without wage controls. We show under which conditions a separating equilibrium exists, and when it will involve wage controls. Controls are more likely to be useful, the larger is the desired reduction in inflation. and the more serious is the credibility problem. The latter is parameterized by the wage setters' prior on the likelihood that the government has high revenue requirements and thus is likely to need high inflation tax revenues.

The remainder of the paper is organized as follows. Section 2 sets up the basic model and explains the incentives for mimicking and signalling in the context of the model. In Section 3 we discuss the separating equilibria that emerge in this incomplete information game between private agents and the government. We argue that there is a natural unique candidate for signalling equilibrium and discuss the conditions for such a signalling equilibrium to exist. We characterize this signalling equilibrium and analyze under which

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1 Persson (1987) gives a general survey of recent work on credibility problems in macroeconomic policy, while Driffill (1987) specifically surveys the work that applies incomplete information games to the analysis of monetary policy. See Rodrik (1987) for a recent application of signalling games to trade policy reforms.

2 Formally our model is thus a multiple signalling game. Our analysis is related to Milgrom and Roberts' (1986) work on pricing and advertising, and to Rogoff's (1987) work on political budget cycles.

conditions it involves the use of wage controls. Section 4 concludes.

2. The Basic Model and the Incentives to Mimic and Signal

2.1 Model Structure

For better focus on the informational and incentive problems discussed in the Introduction, we formulate the simplest possible macro model. Since resolution of uncertainty over time is at the core of much of the analysis, we need an intertemporal structure. For simplicity we assume there are only two time periods, labeled 1 and 2.

Capital is fixed and the marginal productivity of labor a declining function of labor use. Labor demand ℓ_t is therefore a negative function of the real wage $w_t - p_t$ (lower-case letters indicate logarithms). For notational convenience and without much loss of generality we choose a particular functional form and particular parameter values:

(1) $$\ell_t = -(w_t - p_t).$$

We assume that unions set the nominal wage at the same time as the government sets its policy instruments, but without knowing the values of these instruments. Thus we can think of unions setting wages before actual prices are known. The nominal wage in each period is set to minimize the squared value of the expected deviation of ℓ_t from full employment ℓ^*. Using (1), we can thus formulate the unions' objective at t as:

(2) $$\max_{w_t} U_t^u = -(\ell_t^e - \ell^*)^2/2 = -(p_t^e - w_t - \ell^*)^2/2,$$

where p_t^e is the expected price level in period t. Solving (2) leads to the simple expressions:

(3) $$w_t = p_t^e - \ell^*$$

(4) $$\ell_t = \ell^* + (p_t - p_t^e).$$

Rational wage setting in this framework thus coincides with forming price, or inflationary expectations rationally.

Consumers hold money balances, with velocity increasing as nominal interest rates rise. Nominal interest rates are equal to expected inflation since we assume that the real interest is constant at zero. There are no stochastic elements in the money demand function. Rational private behavior in the money market therefore coincides with forming inflationary expectations rationally. Consumers and wage setters' inflationary expectations coincide.

Because money demand is non-stochastic, the government can control actual prices p_t exactly through its control of the money supply. Therefore nothing is lost by assuming that the government controls the price level directly: we simply substitute whatever policy rule the government decides on into the money demand function. Money markets always clear.

Inflation is given by $\pi_t = p_t - p_{t-1}$. Real interest rates are zero by assumption, so the distortionary costs of inflation go up with the square of inflation. In addition, the government is concerned about actual deviations from full employment, $(\ell_t - \ell^*)$, which by (4) depend only on price level surprises, or equivalently on inflationary surprises $(\pi_t - \pi_t^e)$. (Expected inflation, π_t^e, is given by $p_t^e - p_{t-1}$.) In line with standard welfare triangle calculations--and in line with the union objective in (1)--the welfare costs of such deviations are proportional to their squared value. Finally, inflation surprises act as a capital levy on money holders.[3] The extra revenue involved is valued in line with future revenue requirements. We simplify by making these requirements either one of two types, High or Low. These considerations imply one component of the within-period government objective function $\bar{U}_t^i$:

(5) $$\bar{U}_t^i = -\pi_t^2/2 - (\pi_t - \pi_t^e)^2/2 + b_i(\pi_t - \pi_t^e), \quad \text{for } i = H, L \text{ and } t = 1, 2.$$

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3 For given beginning-of-period money stock (the tax base), inflation tax revenues depend on the actual inflation rate (the tax rate). However, the tax base depends on expected rather than actual inflation. Thus higher inflation will raise revenue for given expected inflation and thus for given tax base. Similarly, higher expected inflation will lower the tax base and hence tax revenue for given actual inflation rate. The formulation in (5) assumes, as an approximation, that the marginal effects on inflation tax revenue of an increase in actual and a decrease in expected inflation are the same. Willem Buiter has pointed out that this approximation is in fact exact for unit-elastic money demand functions.

In addition to controlling the price level through monetary policy, the government can, at a cost, impose wage controls in the form of an upper bound on wages, $\bar{w}_t$. If it does so, wages do not equal $w_t = p_t^e - \ell^*$, but min $(w_t,\bar{w}_t)$. When controls are binding, one can define $\bar{p}_t^e$ from: $\bar{w}_t \equiv \bar{p}_t^e - \ell^* < w_t$, where $\bar{p}_t^e$ is the "price expectation equivalent" embodied in the controls. Define $\delta_t \equiv p_t^e - \bar{p}_t^e = \pi_t^e - \bar{\pi}_t^e$, as a measure of the tightness of wage controls. Since actual real wages with binding controls--that is, with $\delta_t > 0$--are $\bar{w}_t - p_t$, deviations from full employment are given by $\pi_t - \bar{\pi}_t^e = \pi_t - \pi_t^e + \delta_t$. Thus, (binding) wage controls can potentially alleviate the underemployment of negative surprise inflation that results from a low-inflation government's attempts to signal its type by pursuing a contractionary monetary policy.

However, wage controls also have microeconomic costs. We assume that these costs go up if the controls become more binding (δ_t increases). Assume for simplicity that the costs go up in proportion to δ_t, with proportionality factor "c_t"[4]. Adding these costs to (5), and substituting in the effects of wage controls on employment, yields the within-period government objective:

(6) $$U_t^i = -\ \pi_t^2/2 - [\pi_t - \pi_t^e + \max(\delta_t,0)]^2/2 + b_i(\pi_t - \pi_t^e) - c_t\max(\delta_t,0).$$

We furthermore assume that the microeconomic costs of controls are so high that they will never be used for non-strategic purposes; in particular they will never be used in period 2 (where, by construction, they cannot have any signalling value). It turns out that what we need for this is the following assumption

(7a) $$c_1 \geq q_1 b_L + (1-q_1)b_H \text{ and}$$

(7b) $$c_2 \geq b_H,$$

[4] Suppose, for instance, that there was a large number of sectors that were subject to idiosyncratic and (to the government) unobservable productivity shocks, and that these shocks were normally distributed with mean zero. That would warrant an equlilibrium wage dispersion across sectors. But wage controls would limit wage increases in all sectors, which would lead to a misallocation of resources by not allowing wage increases in high productivity sectors. The misallocation would be more severe, the tighter the wage controls.

where q_1 is defined in equation (9) below. We make assumption (7) to highlight the potential signalling function of wage controls, not because of any strong empirical view. If condition (7) does not hold, high-inflation governments may also use controls in signalling equilibria. We discuss this issue further in the concluding section.

U_t^i are the within-period government objective functions; the over-all government objective function in period one equals the discounted value of the two within-period objective functions:

$$W^i = U_1^i + d_i U_2^i. \tag{8}$$

We allow the discount factor to be different for each type of government. A natural assumption would be to assume that $d_H < d_L$. Of course the overall objective function coincides with the within-period objective function once period two has arrived, since there is no third or later period.

Private agents do not know what the revenue requirements of the government are, at the time when wages are negotiated and money demand formulated in period 1. That is, b_i can be either b_L or b_H, with $b_H > b_L$. The private sector enters period 1 with a prior distribution on the government's "type" i, determined by past information. The posterior distribution at the end of period 1 forms the prior for period 2, and is formed in accordance with Bayes' law. There is no regime switch between period 1 and 2, so the outcome in period 1 has potential information value for period 2. We let q_t denote the private sectors prior on the government's type in period t

$$q_t = \text{Prob}(i = L \text{ at } t). \tag{9}$$

2.2 Incentives to Mimic and Signal

Let us look at the policy each type of government would choose if it disregarded the influence of the policy on private sector beliefs about its type. Denote the "non-strategic" optimal policies of type i in period t by π^{*i}_t and δ^{*i}_t. To derive these policies, we just maximize myopically the period t objective in (6) with respect to π and δ. This yields

(10a) $$\pi^{*i}_t = (b_i + \pi^e_t)/2$$

(10b) $$\delta^{*i}_t = 0,$$

where (10b) follows because of our assumption (7).

To illustrate the incentives for mimicking and signalling, we now consider the optimal policies in period 2 for an arbitrary value of q_2, the private sector beliefs about the government's type. Since there are no incentives to signal or mimic in the last period, both types of governments will choose their non-strategic policies. Rational expectations implies that private inflationary expectations satisfy

(11) $$\pi^e_2 = q_2\pi^{*L}_2 + (1 - q_2)\pi^{*H}_2 = b_H - q_2(b_H - b_L),$$

where the last equality follows from (10a). We can then determine the optimal monetary policies of both types of governments:

(12) $$\pi^{*L}_2 = b_L + (1 - q_2)(b_H - b_L)/2$$

(13) $$\pi^{*H}_2 = b_H - q_2(b_H - b_L)/2.$$

The payoff to government i when pursuing this policy is given by

(14) $$U^i_2(q_2) = -(\pi^{*i}_2)^2/2 - (\pi^{*i}_2 - \pi^e_2)^2/2 + b_i(\pi^{*i}_2 - \pi^e_2),$$

where we have written U^i_2 as a function of q_2.

We can now make precise the value of having a reputation as a low-inflation government. Evaluate (14) for each type of government by substituting from (11) - (13) and differentiate the resulting expressions to get

(15) $$dU^L_2/dq_2 = (b_H - b_L)[b_L + (1 - q_2)(b_H - b_L)/2] > 0$$

(16) $$dU^H_2/dq_2 = (b_H - b_L)[b_H - q_2(b_H - b_L)/2] > 0.$$

Both types of governments thus gain from an increased private perception that the government is indeed a low-inflation one.

Consider first a high-inflation government. As long as q_2 is above zero, its optimal policy in period 2 leads to surprise inflation, which yields overemployment and extra revenue. A higher value of q_2 decreases inflationary expectations. This leads to a lower credible inflation rate, to higher overemployment and to higher revenue. As expressed in

(16), the net result--with the utility function we have assumed--is a higher period 2 payoff. The high-inflation government therefore has an incentive to mimic the low-inflation government in period 1 if this can induce the private sector to believe that it is indeed a low-inflation type.

What about the low-inflation government? As long as q_2 is below unity, its optimal policy leads to surprise deflation, which gives underemployment and a loss of revenue. A higher q_2, leading to lower expected inflation, decreases the optimal inflation rate and decreases the costs associated with underemployment and loss of revenue. To diminish these future costs, the low-inflation government clearly has an incentive to convey, or signal, its true type to the private sector already in period 1.

However, both mimicking and signalling can only be done at a cost, and may therefore not always take place. The high-inflation government would mimic by following the low-inflation government's policies in period 1, to reap the period 2 benefits of a higher q_2. But following low-inflation policies in period 1 is obviously suboptimal for the high-inflation government apart from its strategic benefits; whether to mimic or not then boils down to trading off period 1 costs against period 2 benefits.

The low-inflation government, in turn, would try to make such mimicking unprofitable by deviating from its non-strategic period 1 optimal policies in ways that are sufficiently more costly to the high-inflation government. A situation where mimicking is made unprofitable is a candidate for a signalling equilibrium. But even if it is possible to signal by policy, it may not be desirable; the costs of signalling may exceed the cost of being mistaken for a high-inflation government. If signalling is not only possible, but also desirable, we have a signalling equilibrium.

3. Incomplete information and the signalling problem.

3.1 Sequential equilibria

Our basic equilibrium concept is Kreps and Wilsons' (1982) sequential equilibrium: a now standard equilibrium concept for incomplete information games. To see what this concept means in our model, define the strategy profile σ by

(17) $$\sigma \equiv (\sigma^P, \sigma^L, \sigma^H) \equiv [\{\sigma_t^P\}_{t=1}^2, \{\sigma_t^L\}_{t=1}^2, \{\sigma_t^H\}_{t=1}^2],$$

where the private sector's period t strategy is $\sigma_t^P \equiv \pi_t^e$, and the government i period t strategy is $\sigma_t^i \equiv (\pi_t^i, \delta_t^i)$. A strategy profile $\hat{\sigma}$ is a sequential equilibrium if, in addition to the usual Nash conditions, the following conditions hold:

(D1a) $\hat{\sigma}^P$ is optimal for any q_t

(D1b) q_t is revised according to Bayes' Law, when it applies

(D1c) $\hat{\sigma}_t^L$ and $\hat{\sigma}_t^H$ are chosen optimally for any q_t.

There are two types of pure-strategy sequential equilibria in our model:[5] Separating equilibria, in which the period 1 policy programs of the two types of governments are different $\hat{\sigma}_1^L \neq \hat{\sigma}_1^H$, and pooling equilibria, in which the policy programs are the same, $\hat{\sigma}_1^L = \hat{\sigma}_1^H$. (In period 2 the policy programs are always different as explained in Section 2.2.) We shall be mostly concerned with separating equilibria. In the remainder of the paper the term "equilibrium" is taken to mean sequential equilibrium.

Notice that according to (D1a) inflationary expectations in period t are formed as

(18) $$\pi_t^e = q_t \hat{\pi}_t^L + (1 - q_t)\hat{\pi}_t^H.$$

Also, the private learning process implicit in (D1b) implies that

(19a) When $\hat{\sigma}_1^L \neq \hat{\sigma}_1^H$

$$q_2 = 1 \text{ if } (\pi_1, \delta_1) = \hat{\sigma}_1^L \text{ and } q_2 = 0 \text{ if } (\pi_1, \delta_1) = \hat{\sigma}_1^H,$$

(19b) When $\hat{\sigma}_1^L = \sigma_1^H$

$$q_2 = q_1 \text{ if } (\pi_1, \delta_1) = \hat{\sigma}_1^H.$$

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[5] We do not consider mixed strategies.

The definition of sequential equilibrium specifies only how beliefs are revised in equilibrium, since Bayes' Law does not apply for zero-probability, out-of-equilibrium events. But how beliefs are revised in those circumstances actually helps determine the equilibrium. We must therefore make some auxiliary assumptions about how beliefs would be revised should an out of equilibrium policy be observed in period 1. Section 3.2 shows how to determine the optimal policies required by (D1c) for an arbitrary out-of-equilibrium updating rule for q_2. Not surprisingly, a large number of separating equilibria exist, depending on which out-of-equilibrium updating rule is chosen. In Section 3.3 we use recent developments in game theory to show that plausible restrictions on the out-of-equilibrium updating rule eliminate all separating equilibria but one.

3.2 Separating equilibria

Now consider a candidate for separating equilibrium $(\hat{\sigma}^P, \hat{\sigma}^L, \hat{\sigma}^H)$. We already know from above how $\hat{\sigma}^P$, $\hat{\sigma}_2^L$, and $\hat{\sigma}_2^H$ are determined. Therefore, we have to discuss only what characterizes the equilibrium policy programs in period 1: $\hat{\sigma}_1^L$ and $\hat{\sigma}_1^H$, $\hat{\sigma}_1^L \neq \hat{\sigma}_1^H$. As mentioned before, we must make some assumption about how beliefs are revised for off-equilibrium events. We will return to this issue in the next subsection. For now, let us just make the assumption that any policy in period 1, except the equilibrium policy of the low-inflation government, is associated with the high-inflation government with probability one. Formally,

(20) $$q_2 = 1 \text{ if } (\pi_1, \delta_1) = \hat{\sigma}_1^L \text{ and } q_2 = 0 \text{ otherwise.}$$

As a last preliminary, we need some new notation. Let $V(i; j; \pi_1, \delta_1)$ denote the total payoff to government i as a function of its period 1 policies given that it is perceived to be of type j in period 2. Thus, $V(i; j; \pi_1, \delta_1)$ is calculated from (11)-(14), setting $q_2 = 0$ if j = H and $q_2 = 1$ if j = L.

What is the optimal policy for a high-inflation government in a separating equilibrium? The answer is simple. If $\hat{\sigma}_1^H$ is an equilibrium policy, it must be the high-inflation government's non-strategic optimum:

(21) $$\hat{\sigma}_1^H = (\hat{\pi}^{*H}_1, 0),$$

with $\hat{\pi}^{*H}_1$ defined by (10a) and (18). This conclusion follows because of (20): If the high-inflation government does not mimic the low-inflation government's policy, the private sector believes that it is a high-inflation government with probability one. Therefore, the best it can do is to pursue its non-strategic optimal policy. For $\hat{\sigma}_1^H$ to indeed be an equilibrium, the resulting payoff must not fall short of the payoff when mimicking the policy of the low-inflation government:

(22) $$V(H;\ H;\ \hat{\pi}^{*H}_1, 0) \geq V(H;\ L;\ \hat{\pi}^L_1, \hat{\delta}^L_1).$$

A simple diagram illustrates the discussion and can be used in the subsequent analysis. Figure 1 is drawn in "policy space" (π_1, δ_1). We have plotted $\hat{\pi}^{*H}_1$ on the horizontal axis. Leaving aside for a moment how private beliefs about the government's type are actually formed, we can illustrate the incentives for the high-inflation government to mimic the low-inflation government's policy. We have already seen that being mistaken for L would raise H's payoff. Therefore there is a set of points $\mathcal{H}$ around the point $(\hat{\pi}^{*H}_1, 0)$ where H's payoff, if mistaken for L, exceeds $V(H;\ H;\ \hat{\pi}^{*H}_1, 0)$. The boundary of $\mathcal{H}$ is given by

(23) $$V(H;\ L;\ \pi_1, \delta_1) = V(H;\ H;\ \hat{\pi}^{*H}_1, 0).$$

Equation (23) describes an elliptic "indifference curve", which always cuts the π-axis to the left and right of $\hat{\pi}^{*H}_1$ -- the line ABC in Figure 1.[6] Outside of ABC, we have $V(H;\ L;\ \pi_1, \delta_1) < V(H;\ H;\ \hat{\pi}^{*H}_1, 0)$; inside of ABC the opposite holds.

Now clearly, to ask whether $\hat{\sigma}_1^H$ is indeed an equilibrium, is equivalent with asking whether $\hat{\sigma}_1^L$ is outside of $\mathcal{H}$ in Figure 1. In that case, mimicking (playing $\hat{\sigma}_1^L$ instead of $\hat{\sigma}_1^H$) would be too costly. As we have drawn the figure, the condition obviously holds.

Consider instead the incentives of a low-inflation government. In particular, what is the best alternative to following our proposed equilibrium policy $\hat{\sigma}_1^L$? This question also

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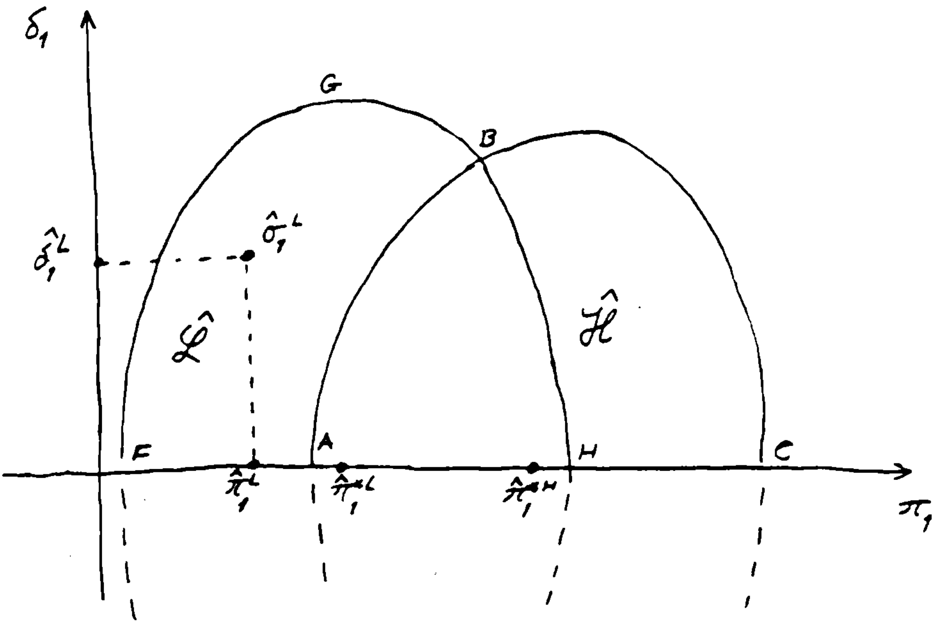
6 The indifference curve is elliptic since the total payoff is quadratic in π_1 and δ_1.



δ_1
G
B
$\hat{\delta}_1^L$
$\hat{\sigma}_1^L$
$\hat{\mathcal{L}}$
$\hat{\mathcal{H}}$
F
A
H
C
$\hat{\pi}_1^L$
$\hat{\pi}_1^{*L}$
$\hat{\pi}_1^{*H}$
π_1

Figure 1

has a simple answer because of (20). All other policies than $\dot{\sigma}_1^L$ make the private sector set $q_2 = 0$. Therefore, the only alternative to $\dot{\sigma}_1^L$ must be to pursue the non-strategic optimal policy $(\dot{\pi}^{*L}_1, 0)$. So $\dot{\sigma}_1^L$ is an equilibrium only if

(24) $$V(L; H; \dot{\pi}^{*L}_1, 0) \leq V(L; L; \dot{\pi}_1^L, \dot{\delta}_1^L).$$

Again, Figure 1 serves as an illustration. In the Figure we have plotted $\dot{\pi}^{*L}_1$ on the horizontal axis. Around that point is a set of points $\dot{\mathscr{L}}$, where L's payoff if recognized as L exceeds $V(L; H; \dot{\pi}^{*L}_1, 0)$. The boundary of $\dot{\mathscr{L}}$ is given by the indifference curve FGH which is defined by

(25) $$V(L; H; \dot{\pi}^{*L}_1, 0) = V(L; L; \pi_1, \delta_1).$$

Outside of FGH, $V(L; H; \dot{\pi}^{*L}_1, 0) > V(L; L; \pi_1, \delta_1)$, inside of FGH the opposite holds. To ask whether $\dot{\sigma}_1^L$ is an equilibrium is equivalent with asking whether $\dot{\sigma}_1^L$ is within $\dot{\mathscr{L}}$. As we have drawn the figure, the condition is satisfied making the incentives to signal its type strong enough for L.

In summary, the policies in a separating equilibrium must satisfy the two conditions (22) and (24). Figure 1 illustrates such a separating equilibrium. But it should be clear that there are many possible separating equilibria. The root of the non-uniqueness is essentially the arbitrariness in how private beliefs are revised out of equilibrium. In the next subsection we show how plausible restrictions on private beliefs can single out a unique candidate for equilibrium, however.

3.3 Signalling Equilibrium.

In Figure 1, the high-inflation government would clearly be better off if the separating equilibrium were a little farther to the south-east, since that would put it closer to the non-strategic optimum. What prevents L from moving in this direction is that he would then be tainted as type H, according to our assumption (20). But we see from the figure that this assumption is not particularly plausible: Government H would never want to choose a point south-east of $\dot{\sigma}_1^L$, as long as the point was outside of $\dot{\mathscr{H}}$. What prevents the low-inflation government from signalling his type at lower cost is thus private beliefs about the H government. But these beliefs are implausible, in the sense that they are inconsistent with rational behavior of the high-inflation government.

Borrowing from the game-theoretic literature on equilibrium refinements, we can rule out such beliefs by a formal argument known as "elimination of dominated strategies".[7] In our context a policy $(\bar{\pi}_1, \bar{\delta}_1)$ is <u>dominated</u> for government i if, for i ≠ j,

(26) $$V(i; j; \bar{\pi}_1, \bar{\delta}_1) < V(i; i; \hat{\pi}^{*i}_1, 0),$$

where $\hat{\pi}^{*i}_1$ is the non-strategic optimum associated with the equilibrium policy that we are considering. In figure 1, for example, all the points that do not belong to $\hat{\mathscr{H}}$ are dominated for H, while all points that do not belong to $\hat{\mathscr{L}}$ are dominated for L.

We use this definition to rule out beliefs that rely on dominated policies having been carried out. More precisely, we shall assume

(27) $$q_2 = 1 \text{ if (26) holds for H but not for L}$$
$$q_2 = 0 \text{ if (26) holds for L but not for H.}$$

From now on we shall use the term "signalling equilibrium" to mean an undominated separating equilibrium:

(D2) σ_S is a signalling equilibrium if it satisfies (D1) given (27).

It follows from our discussion that the low-inflation government's policy in a signalling equilibrium allows it to signal its policy at lowest possible cost. That is, the no-mimicking constraint (22) should just be binding. A signalling equilibrium $(\sigma^L_{s1}, \sigma^H_{s1})$ is illustrated in Figure 2, where the points $(\pi^{*L}_{s1}, 0)$ and $(\pi^{*H}_{s1}, 0)$ are the non-strategic optimum policies of the two governments that correspond to the points $(\hat{\pi}^L_1, 0)$ and $(\hat{\pi}^H_1, 0)$ in Figure 1. Similarly, the regions $\mathscr{H}_s$ and $\mathscr{L}_s$ have been constructed in an analogous way

[7] In a highly recommendable paper, Cho and Kreps (1987) discuss refinements of Nash and Sequential equilibrium that impose restrictions on off-equilibrium beliefs to reduce the number of equilibria in incomplete information games. They label the refinement we use here "sequential elimination of dominated strategies".

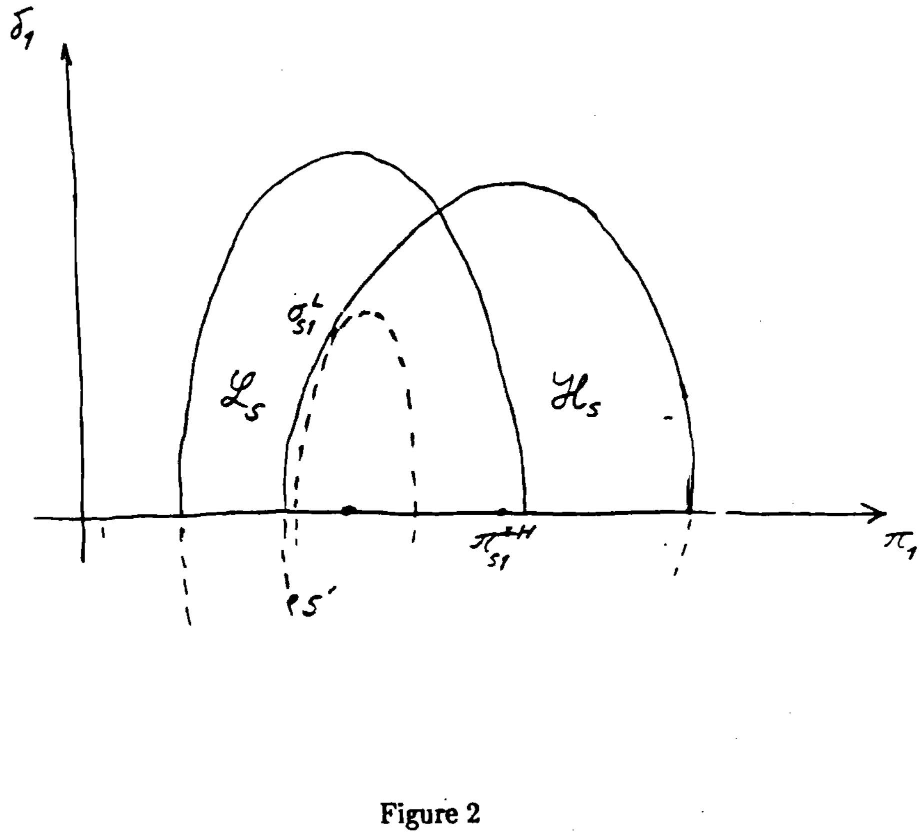


Figure 2

as the regions $\dot{\mathscr{H}}$ and $\dot{\mathscr{L}}$ in Figure 1.[8] Note that the L-government's policy lies at the boundary of $\mathscr{H}_s$, so that (22) just binds. Further, at the equilibrium point an indifference curve of the L-government, marked by a dotted line, is tangent to the boundary. In that way, signalling indeed takes place at lowest possible cost.

The discussion around Figure 2 suggests that we can find the single candidate for signalling equilibrium by solving the following Lagrangean problem:

(28) $$\underset{\pi,\delta}{\text{Max}}\ \underset{\lambda,\mu}{\text{Min}}\ Z(\pi,\delta,\lambda,\mu) = V(L; L; \pi_1, \delta_1) - \lambda[V(H; L; \pi_1, \delta_1) - V(H; H; \pi^{*H}_{s1}, 0)] + \mu\delta$$

The term "$\mu\delta$" reflects the non-negativity constraint on the wage controls variable δ_1: as discussed in Section 2.1, controls are not operative if they are set above desired wages ($\bar{\pi}_t > \pi^e_t$).[9] The first order conditions to (28) are:

(29a) $$Z_\pi = (-2\pi^L_{s1} + \pi^e_{s1} + b_L - \delta^l_{s1})(1 - \lambda_s) - \lambda_s(b_H - b_L) = 0$$

(29b) $$Z_\delta = -(\pi^L_{s1} - \pi^e_{s1} + \delta^L_{s1} + c_1)(1 - \lambda_s) + \mu_s = 0$$

(29c) $$Z_\lambda = V(H; L; \pi^L_{s1}, \delta^L_{s1}) - V(H; H; \pi^{*H}_{s1}, 0) = 0 \text{ or } \lambda_s = 0$$

(29d) $$Z_\mu = \delta^L_{s1} = 0 \text{ or } \mu_s = 0,$$

where the subscript s denotes values in the signalling equilibrium. It is conceivable, however, that the tangency point occurs at negative δ_1, such as point S' in Figure 2. In that case the second inequality constraint becomes operative, $\delta^L_{s1} = 0$, and a corner solution at A obtains (see Section 3.4 for a further discussion of this case).

A final issue needs to be discussed before we can establish that our candidate for signalling equilibrium $(\sigma^L_{s1}, \sigma^H_{s1})$ is indeed a signalling equilibrium. Does L have an incentive to deviate to his non-strategic optimum at $(\pi^{*L}_{s1}, 0)$, even if this implies being

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8 We have indexed the non-strategic inflation rates π^{*H}_{s1} and π^{*L}_{s1} and the regions $\mathscr{H}_s$ and $\mathscr{L}_s$ by s to emphasize that they are dependent on the equilibrium that we are considering. Thus, the region $\mathscr{L}_s$, say, in Figure 2 does not exactly coincide with the region $\dot{\mathscr{L}}$ in Figure 1.

9 When solving the problem (24) formally, we substitute δ_t for $\max(\delta_t,0)$ in the government objective (6) and instead impose the inequality constraint by way of the multiplier μ.

mistaken for H in period 2. If the answer is yes, no signalling equilibrium exists. We shall confine our attention to those parameter constellations where the answer is no.

To see what restrictions this implies, consider the optimal deviation σ^{L}_{s1} of L. In analogy with (10a), the optimal inflation rate is

(30) $$\pi^{*L}_{s1} = (b_L + \pi^e_{s1})/2,$$

where π^e_{s1} are the inflationary expectations in the suggested signalling equilibrium, formed as in (18). The optimal deviation leads to the payoff

(31) $$V(L; H; \pi^{*L}_{s1}, 0) = - (\pi^e_{s1})^2/2 + ((b_L - \pi^e_{s1})/2)^2 + d_L[(b_L)^2/2 - ((b_L + b_H)/2)^2].$$

L's payoff in (31) should be compared to the payoff in the suggested signalling equilibrium $V(L; L; \pi^L_{s1}, \delta^L_{s1})$. To do that, we first solve (29) for L's equilibrium policy choices π_{s1} and δ_{s1}; see (35) below. Then we can calculate the appropriate value of π^e_{s1}, given that H sets $\bar{\pi}_1$ according to (10a). After straightforward but tedious substitutions and manipulations, the condition for existence of a signalling equilibrium can finally be expressed as

(32) $$V(L; L; \pi^L_{s1}, \delta^L_{s1}) - V(L; H; \pi^{*L}_{s1}, 0) = [1/(1+q_1)]^2\{q_1[\lambda_s/(1-\lambda_s)+1/2](b_H - b_L) + [c_1 - (b_H - b_L)]\}^2 - [\lambda_s(b_H - b_L)/(1-\lambda_s)]^2/2 + d_L[((b_L+b_H)/2)^2 - (b_L)^2] > 0.$$

This condition is expressed in terms of the model's parameters, with one exception; λ_s is itself a complicated second-order function of the parameters. Condition (32) is likely, but not certain, to hold. It can be seen that the likelihood of existence increases in $\bar{c}_1$-- the cost of controls--and in d_L--the low-inflation government's discount factor--which are both intuitive results. In the Appendix, we derive (an example of) a set of relatively weak sufficient conditions for (32) to be fulfilled, namely

(33a) $$q_1 \leq 3/4 + b_L/(b_H - b_L) \text{ and}$$

(33b) $$d_L b_L \geq d_H b_H.$$

Thus, if the initial credibility problem is serious enough (that is, if q_1 is low enough) and the low-inflation government's discount factor is high enough relative to the discount factor of the high-inflation government, a signalling equilibrium exists.

3.4 Characterization of signalling equilibria

The first-order conditions (29) yield intuitive solutions for π^L_{s1} and δ^L_{s1}. Consider first a program where both policy instruments are used; later on in this section we discuss under which circumstances wage controls are not part of the program. The solution for π^L_{s1} is:

(34a) $$\pi^L_{s1} = b_L + c_1 - (b_H - b_L)\lambda_s/(1 - \lambda_s).$$

The signalling value of π_1 can be either smaller or larger than b_L. High marginal costs of imposing controls (high c_1) work towards inflation in excess of the full-information solution b_L. (If $q_1 = 1$ so the private sector had complete information about the L-governments type, (10a) yields $\pi^L_1 = b_L$.) On the other hand, high gains from signalling (a large difference $b_H - b_L$) tend to call for tighter monetary policy (lower inflation).[10]

The signalling value for the wage control parameter δ_1 is

(34b) $$\delta^L_{s1} = (\pi^e_{s1} - \pi^L_{s1} - c_1).$$

Substituting (34b) into the definition of δ_1 and evaluating the employment consequences yields an interesting result:

(35) $$\bar{\pi}^e_{s1} - \pi^L_{s1} = (\ell^* - \ell_{s1}) = c_1 > 0.$$

If controls are part of the signalling equilibrium, wages will be cut, but monetary policy is used in such a way that a recession still results. This is very important: it means that in a signalling equilibrium where wage controls are used, monetary policy should also be restrictive. A recession is still part of the first period optimum and both signalling instruments (wage controls and monetary policy) are used in conjunction. Controls are

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10 The argument is not entirely rigorous: $\lambda_s/(1 - \lambda_s)$ also depends on $b_H - b_L$. The preceding argument assumes implicitly that $\lambda_s < 1$ and hence that $\lambda_s/(1 - \lambda_s) > 0$. This is the case for those solutions where the first-order conditions indeed describe a maximum of Z. This can be seen by inspecting the second order conditions; these require $\lambda_s < 1$.

thus complements, not substitutes for conventional restrictive demand management policies.

As a step towards analyzing when controls are likely to be part of the signalling equilibrium, consider what the signalling equilibrium looks like with $\delta_I = 0$ imposed (no wage controls allowed). The first-order condition for inflation then simplifies to yield:

(36) $$\pi^L_{r1} = (b_L + \pi^e_{r1})/2 - \lambda_r(b_H - b_L)/2(1 - \lambda_r)$$

and H's choice remains

(37) $$\pi^{*H}_{r1} = (b_H + \pi^e_{r1})/2,$$

where the r-subscript denotes values in this restricted signalling equilibrium. These two points are illustrated in Figure 3. Imposing rational expectations yields

(38) $$\pi^e_{r1} = b_H - q_1(b_H - b_L)/(1 - \lambda_r).$$

Combining (36) and (38) gives the recessionary impact of the disinflation program:

(39) $$\pi^e_{r1} - \pi^L_{r1} = (\ell^* - \ell_{r1}) = (1 - q_1)(b_H - b_L)/2(1 - \lambda_r) > 0.$$

Consider now whether it is optimal to use wage controls or not in the signalling equilibrium. This can be assessed by evaluating Z_δ at π^L_{r1}. Clearly, at that corner, μ is just equal to zero too, so the derivative Z_δ becomes

(40) $$Z_\delta = -(\pi^L_{r1} - \pi^e_{r1} + c_1)(1 - \lambda_r) \gtrless 0,$$

If $Z_\delta > 0$, tangency occurs at positive δ and wage controls are part of the signalling equilibrium. If $Z_\delta < 0$, the tangency point occurs at negative δ and hence controls will not be used. From the second-order conditions $\lambda_r < 1$, so whether wage controls will be used depends on the sign of the first bracket in (40). But using (35), (36), (38) and (39), (40) can be rewritten as follows:

(41) $$Z_\delta = -(1 - \lambda_r)[c_1 - (1 - q_1)(b_H - b_L)/(2(1 - \lambda_r))] = (1 - \lambda_r)(\ell_{s1} - \ell_{r1})$$

The condition for whether wage controls will be used or not is thus very intuitive. Equation (41) tells us that wage controls will be part of the signalling equilibrium only if they lower the recessionary impact of the disinflation program.

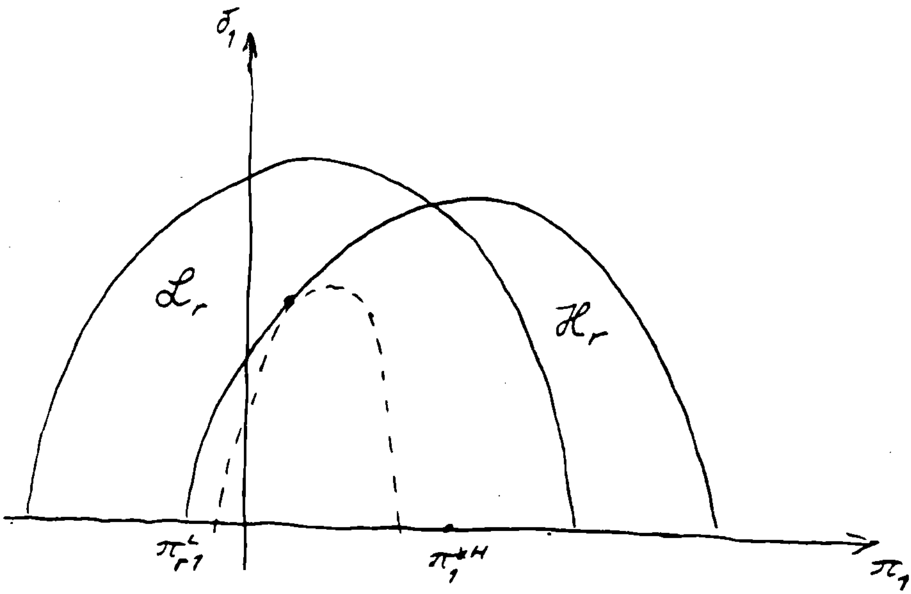

Figure 3

This would be the case when signalling with monetary policy alone would be very recessionary. In fact, under our assumption (7a)--that c_1 is high enough not to be used for non-strategic purposes--wage controls will only be part of L's disinflation policy program when signalling without them would actually result in deflation: $\pi_{r1}^{L} < 0$.[11]

With the caveat that we are only looking at the direct effect of parameters and ignoring the indirect effects through λ_r, the comparative statics on condition (41) yield intuitive results. We see that wage controls are more likely to be used the lower their microeconomic cost (lower c_1), the more serious is the low-inflation government's credibility problem (lower q_1) and the larger the incentive for the high-inflation government to mimic (higher $b_H - b_L$).

4. Concluding Remarks

We have discussed the design of a policy package that would help establish credibility of a monetary disinflation program. Our results indicate that wage controls <u>may</u> be part of such a program if they lower the recessionary impact of the program. However, we also showed that wage controls need to be backed up by restrictive use of more conventional policies such as monetary policy, contrary to what part of the literature suggests.

There is another aspect of wage and price controls that might be relevant in this context, which we have not discussed. It may be--particularly when controls are negotiated at an economy wide level with centralized unions and employer organizations, as in Israel--that once in place, controls are harder to change in the short run than monetary

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[11] To see this, note that (since $\lambda_r < 1$) (7) implies the inequality $c_1 > b_H - q_1(b_H - b_L)/(1 - \lambda_r)$, where the RHS is the value of π_{r1}^{e} in (38). Thus it follows from (40) that $Z_\delta > 0$ is possible only if $\pi_{r1}^{L} < 0$.

policy. Controls may therfore, at least temporarily, commit the government to a certain course of action, while even short-run commitments may be infeasible for monetary policy. To capture such aspects, we would have to change the formalism of our model, however. Wages and wage controls would have to be set before monetary policy, and the setting of controls would be allowed to influence the private sectors prior about the government's type.

In our discussion we have focused on separating equilibria. Our model also has pooling equilibria, where both types of policy makers choose the same policy in period 1 (but not in period 2). In particular, when no signalling equilibrium exists, all equilibria must be pooling. But when signalling equilibria do exist, we think that the pooling equilibria may be ruled out by plausible restrictions on the private sector's (off-equilibrium) beliefs.

A strong implication of our model is that only low-inflation governments will in fact use wage controls. This would seem counterfactual. In Israel the black market premium for foreign exchange disappeared at the implementation of the disinflation program, which fits our predictions. However, in Brazil the black market premium doubled instantaneously from 20% to 40% in February 1986 and continued to climb to around 100% as time went by. In Argentina, the premium did not increase or decrease initially, but moved up later on as the program ran into increasing trouble. In the context of our model. suppose that the cost of controls, c_1, were so low that controls would also be part of the signalling equilibrium solution for the high-inflation government. That would explain the use of controls combined with expansionary monetary policy and an immediate decline in credibility, like in Brazil. We have ruled this out by <u>assuming</u> that c_1 is so high that this would never occur. We have also loaded the dice against the use of wage controls for other purposes than signalling, by assuming that the government accepts the private employment target. A government employment target above the private one might also lead to wage controls being used even by high-inflation governments.

Alternatively, pooling equilibria could exist, although such equilibria should, by construction, not lead to an instantaneous rise in a credibility indicator like the black market premium on foreign exchange. Pooling equilibria might, however, conceivably explain the use of controls by high-inflation governments without any instantaneous effect on the black market premium on foreign exchange, like in Argentina.

The recent literature on stabilization programs in high-inflation countries--see Helpman and Leiderman (1987) for a recent survey--has so far treated policy as exogenous, at least when it comes to formal analysis. Our analysis extends that literature, by endogenizing government policy and by explicitly addressing the credibility problems associated with a stabilization of inflation. Clearly, this paper is but a first step, however. More research should follow.

Appendix

In this Appendix we rewrite the condition (32) for existence of a signalling equilibrium. For convenience we reproduce the condition here:

$$V(L;\, L;\, \pi^{L}_{s1},\, \delta^{L}_{s1}) - V(L;\, H;\, \pi^{*L}_{s1},0) =$$

$$(A1) \qquad = [1/(1+q_1)]^2\{q_1[\lambda_s/(1-\lambda_s)+1/2](b_H-b_L) + [c_1-(b_H-b_L)]\}^2$$

$$- [\lambda_s(b_H-b_L)/(1-\lambda_s)]^2/2 + d_L[((b_L+b_H)/2)^2-(b_L)^2] > 0.$$

To make further progress in signing this expression, it is useful to exploit the condition (29c); at the signalling equilibrium the high-inflation government is just as well off as in his non-strategic optimum. After some manipulations this condition can be rewritten as

$$V(H;\, L;\, \pi^{L}_{s1},\delta^{L}_{s1}) - V(H;\, H;\, \pi^{*H}_{s1},\, 0) =$$

$$(A2) \qquad - [(b_H-b_L)/(1-\lambda_s)]^2/2 + [(b_H-\pi^{e}_{s1})/2+c_1]^2 +$$

$$+ d_H[(b_H)^2-((b_H-b_L)/2)^2] = 0.$$

Using (18) and (34a) the value for π^{e}_{s1} is

$$(A3) \qquad \pi^{e}_{s1} = \{(1-q_1)b_H + 2q_1[b_L+c_1-\lambda_s(b_H-b_L)/(1-\lambda_s)]\}/(1+q_1).$$

Substituting (A3) into (A2), deducting the resulting expression from (A1), and simplifying, the existence condition can be rewritten as

$$V(L;\, L;\, \pi^{L}_{s1},\, \delta^{L}_{s1}) - V(L;\, H;\, \pi^{*L}_{s1},0) =$$

$$(A4) \qquad (1-\lambda_s^2)(b_H-b_L)/2(1-\lambda_s)^2 +$$

$$\{\lambda q_1^2/(1-\lambda_s) + (2-q_1)(b_H-b_L)[c_1-(b_H-b_L)/4]\}/(1+q_1)^2 +$$

$$(d_L-d_H)[(b_H)^2-(b_L)^2]/4 + (d_Lb_L-d_Hb_H)(b_H-b_L)/2 > 0.$$

The first of the four terms in the condition is always positive, but the other terms are ambiguous. However, by (7a) $c_1 > q_1b_L + (1-q_1)b_H$. Therefore, if (33a) is fulfilled the second term is positive. If (33b) is fulfilled the third and the fourth terms are both positive, and consequently our existence condition is satisfied.

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