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SIGNALLING, WAGE CONTROLS AND MONETARY DISINFLATION POLICY

by

Torsten Persson and Sweder van Wijnbergen

INSTITUTE FOR INTERNATIONAL ECONOMIC STUDIES

University of Stockholm
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Institute for International Economic Studies
S-106 91 Stockholm
Sweden
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by

Torsten Persson
Institute for International Economic Studies and RCER

and

Sweder van Wijnbergen
World Bank, CEPR and NBER

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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 Argentina, Brazil and Israel used extensive wage-price controls as part of more comprehensive disinflation programs in 1985 and 1986. 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.

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, which would 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 Drifill (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 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 show under which conditions a
separating equilibrium exists, and when it will involve wage controls. Controls are more
likely to be useful, the larger the desired reduction in inflation, and the more serious the
credibility problem is. 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 explain when signalling is necessary and discuss the separating
equilibria that emerge in this incomplete information game between wage setters and the
public sector. We argue that when separating equilibria exist, there is a natural unique
signalling equilibrium. We characterize this signalling equilibrium and analyze under
which conditions it involves the use of wage controls. Section 4 concludes.

¹ Persson (1987) gives a general survey of recent work on credibility problems in
macroeconomic policy, while Driffield (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.
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 have chosen to work with the simplest macro-model we could think of. 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 two time periods, labeled 1 and 2.

Capital is fixed and the marginal productivity of labor a declining function of labor use. Labor demand \( \ell_t \) 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:

\[
(1) \quad \ell_t = - (w_t - p_t).
\]

Formally, 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 \( \ell_t \) from full employment \( \ell^* \). Using (1), we can thus formulate the unions’ objective at \( t \) as:

\[
(2) \quad \max_{w_t} U_t^u = - (p_t^e - w_t - \ell^*)^2 / 2,
\]

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

\[
(3) \quad w_t = p_t^e - \ell^*
\]

\[
(4) \quad \ell_t = \ell^* + (p_t - p_t^e).
\]

Consumers hold money balances, with velocity increasing as nominal interest rates rise. There are no stochastic elements in the money demand function, so the government can control actual prices \( p_t \) exactly through its control of the money supply. Nothing is
lost therefore by our assumption 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.

Real interest rates are zero by assumption, so the distortionary costs of inflation, \( \pi_t = p_t - p_{t-1} \), 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, \( \pi_t^e \), 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; the extra revenue involved is valued in line with future revenue requirements, which we simplify to either one of two types, High or Low. These considerations alone, would imply a government objective function \( \tilde{U}_t^i \)

\[
\tilde{U}_t^i = -\pi_t^2/2 - (\pi_t - \pi_t^e)^2/2 + b_i(\pi_t - \pi_t^e), \quad \text{for } i = H, L.
\]

In addition to controlling the price level through monetary policy, the government can, at a cost, impose wage controls in the form of an upward bound on wages, \( \tilde{w}_t \). If it does so, wages do not equal \( w_t = p_t^e - \ell^* \), but min \( (w_t, \tilde{w}_t) \). When controls are binding, \( \tilde{w}_t = p_t^e - \ell^* < w_t \), where \( p_t^e \) is the "price expectation equivalent" embodied in the controls. Define \( \delta_t = p_t^e - \tilde{p}_t = \pi_t^e - \tilde{\pi}_t^e \), as a measure of the tightness of wage controls.

Since actual real wages with binding controls--that is, with \( \delta_t > 0 \)--are \( \tilde{w}_t - p_t \), deviations from full employment are given by \( \pi_t - \tilde{\pi}_t^e = \pi_t - \pi_t^e + \delta_t \). Thus, (binding) wage controls can potentially alleviate the underemployment of negative surprise inflation associated with 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 (\( \delta_t \) increases). Assume for simplicity that
the costs go up in proportion to $\delta_t$, with proportionality factor "$c_t$". Adding these costs and the effects of wage controls on employment to (5), yields the final form of the government objective:

\[
U_t^1 = -\frac{\pi_t^2}{2} - [\pi_t - \pi_t^e + \max(\delta_t, 0)]^2/2 + b_i(\pi_t - \pi_t^e) - c_t\max(\delta_t, 0).
\]

We will now assume that the 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 what we need for this is the following assumption

\[
(7a) \quad c_1 \geq q b_L + (1-q) b_H \quad \text{and}
\]

\[
(7b) \quad c_2 \geq b_H,
\]

where $q$ is defined in equation (8) below. We make assumption (7) to highlight the potential signalling function of wage controls, not because of any strong empirical views.

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.

The unions do not, at the time wages have to be negotiated for period 1, know what the revenue requirements of the government are. That is, $b_i$ can be either $b_L$ or $b_H$, with $b_h > b_L$. The unions enter period 1 with a prior distribution on the government's "type" $i$, determined by past information:

\[
(8) \quad \text{Prob} \, (i = L: t = 1) = q.
\]

The posterior distribution at the end of this period forms the prior for the next, 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.

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3 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 equilibrium 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.
2.2 Incentives to Mimic and Signal

Let us now consider the solutions in period 2 under different assumptions regarding the unions' beliefs about the government's type. Define the within-period payoff of the government, \( v_t \), having as arguments: true type, private beliefs as to the government's type, and the policy instruments used:

\[
v_t = v_t(i; j; \pi_t, \delta_t)
\]

with \( t = 1, 2 \) and \( i, j = H, L \).

Consider first the solutions for period 2 if private beliefs are correct. Then, straightforward optimization of (5) holding \( \pi_2^e \) fixed, together with assumption (7), yields:

\[
\pi_2(i; i) = (\pi_2^e + b_i)/2
\]

\[
= b_i; \quad \text{for } i = H, L,
\]

where the second line imposes rational expectations. Inserting (10) into (5) yields:

\[
v_2(i; i; \pi_2(i; i), 0) = -(b_i^2)/2.
\]

In a signalling equilibrium, private beliefs in period 2 will indeed be correct and (11) therefore gives the appropriate payoff for type \( i \) in a signalling equilibrium.

However, when establishing the existence (and uniqueness) of a signalling equilibrium, we shall have to look at deviations from the proposed equilibrium. Such deviations will lead the private sector to mistakenly take type \( i \) for type \( j \) (\( i \neq j \)) with probability one. It is therefore relevant to ask about the outcome in period 2 when the private sector mistakenly takes type \( i \) for type \( j \), and hence mistakenly expect \( b_j^* \) as period 2 inflation. In that case, it is easy to show that the optimal inflation rates and associated payoffs are:

\[
\pi_2(i; j) = (b_i + b_j)/2,
\]

and

\[
v_2(i; j; \pi_2(i; j), 0) = (b_i^2)/2 - ((b_i + b_j)/2)^2; \quad \text{for } i \neq j.
\]

Notice by comparing equations (11) and (13) that
\begin{equation}
(14) \quad v_2(H; L; \pi_2(H; L), 0) - v_2(H; H; \pi_2(H; H), 0) = \\
= (b_H^2) - ((b_H + b_L)/2)^2 > 0.
\end{equation}

Hence, a high-inflation government gains from being taken for a low-inflation one. The reason is that when the public is mistaken rather than correct in its beliefs, the optimal credible inflation rate is lower and there is positive surprise inflation yielding additional revenue and overemployment. The net effect is a higher period 2 payoff. The high-inflation government therefore wants to mimic the low-inflation government if this can induce the private sector to believe that it is indeed a low-inflation type.

Also, by comparing (11) and (13), we get
\begin{equation}
(15) \quad v_2(L; H; \pi_2(L; H), 0) - v_2(L; L; \pi_2(L; L), 0) = \\
= (b_L^2) - ((b_H + b_L)/2)^2 < 0.
\end{equation}

Hence, a low-inflation government loses out on being taken for a high-inflation one in period 2. The reason is that when the private sector is mistaken rather than correct in its beliefs, inflation is higher and there is negative surprise inflation which is costly in terms of both revenue and employment. To avoid these future costs, the low-inflation government clearly wants 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 quantified in equation (14). But following low-inflation policies in period 1 is 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 indeed desirable, we have a signalling equilibrium.

These comments set the stage for the next steps in our analysis. In Section 3.1, we analyze whether mimicking pays off for the high-inflation government even in the absence of strategic behavior by the low-inflation government; if it does not, there is no need to signal for the latter one. In Section 3.2, we first analyze whether signalling pays off for the low-inflation government if it needs to do so. We can then go on to discuss the existence of a signalling equilibrium. To avoid possible confusion, we stress that it is only in this second half of Section 3.2 that we get to the point of considering a full equilibrium. In the preceding discussion about the two governments' incentives to act strategically, we to a large extent deal with (hypothetical) deviations from equilibrium.

3. Incomplete information and the signalling problem.

3.1 Is signalling necessary?

This question can be answered by comparing the H-type's payoff when mimicking the L-type's non-strategic optimum with what the H-type obtains if it simply plays its own non-strategic optimum. Let $V(i; j; q; \pi, \delta)$ denote the total payoff when the government's true type is $i$; the public perceives the government to be of type $j$ in period 2; the unions' prior in period 1 is $q$; and the period 1 policy instruments are set at $\pi$ and $\delta$. It is obtained by adding the period 1 payoff $v_1(\cdot)$ and the period 2 payoff $v_2(\cdot)$, discounting the latter by the discount factor $d_1$.

Suppose now (hypothetically) that the high-inflation government would always mimic the low-inflation government's choice of policy in period 1, and consider the low-inflation government's non-strategic optimum. In analogy with (10), period 1 inflation of the low-inflation government equals:
\[
\pi_1(L; q) = (\pi_1^e + b_L)/2 = b_L.
\]

Since both types play the same inflation rate, rational expectations imply the second equality. (Wage controls \(\delta_1\) are 0 by assumption (7a).) From (16) and (13), the high-inflation government's payoff is:

\[
V(H; L; q; b_L,0) = -(b_L^2)/2 + d_H[(b_H^2)/2 - ((b_H + b_L)/2)^2].
\]

However, without mimicking, the high-inflation government plays

\[
\pi_1(H; q) = (\pi_1^e + b_H)/2,
\]

while the low-inflation government plays the first line of (16). Simple calculations show that in this case rational expectations implies:

\[
\pi_1^e = qb_L + (1 - q)b_H.
\]

Hence, (18) becomes:

\[
\pi_1(H; q) = b_H - q(b_H - b_L)/2,
\]

and, taking (10) into account, the resulting payoff to the high-inflation government is:

\[
V(H; H; q; \pi_1,0) = (b_H^2)/2 - [b_H - q(b_H - b_L)/2]^2 - d_H(b_H^2)/2.
\]

The difference between (17) and (21) cannot be signed unambiguously, so we cannot claim that mimicking will always (nor, for that matter, never) pay. This is, of course, as one should expect. Simple differentiation shows that the difference increases with \(d_H\) and \((b_H - b_L)\), the latter for given \((b_H + b_L)\), and that it decreases with \(q\).

Mimicking is more likely to pay, the more pronounced the difference between the two actors and the higher the valuation of future benefits (the higher \(d_H\)). This accords well with intuition. A higher prior on the government being of type L lowers the unions' inflationary expectations. This lowers the optimal period 1 inflation rate without mimicking. It also lowers the period 1 inflationary surprise without mimicking, which decreases overemployment and the revenue from surprise inflation. The net effect is to lower the incentive to mimic.

A simple diagram clarifies our discussion further, and can be used in the
subsequent analysis. Figure 1 is drawn in "instrument space", \((\pi, \delta)\). Both \(\pi\) and \(\delta\) refer to period 1 values. On the horizontal axis, we illustrate the two full-information equilibria, \(b_H\) and \(b_L\), for each type of government. In the absence of mimicking and thus with fully revealed types in period 2, \(H\) plays according to (20), \(\pi(H; q)\), in between \(b_L\) and \(b_H\).

Clearly, being mistaken for \(L\) would raise \(H\)'s total payoff. We can therefore define a region around \(b_H\) within which \(H\)'s payoff, if mistaken to be type \(L\) in period 2, exceeds \(V(H; H; q; \pi(H; q), 0)\). Its boundary is given by:

\[
V(H; L; q; \pi, \delta) = V(H; H; q; \pi(H; q), 0).
\]

Equation (22) describes an elliptic "indifference curve", which always cuts the \(\pi\)-axis to the left and right of \(\pi(H; q)\)--the line ABC in Figure 1.\(^4\) Below ABC, we have \(V(H; L; q; \pi, \delta) > V(H; H; q; \pi(H; q), 0)\).

To assess whether signalling is necessary, is equivalent to assessing whether the indifference curve that cuts through \(b_L\) lies inside of the boundary defined in (22), that is whether \(b_L > \pi_A\) in Figure 1. If \(b_L > \pi_A\), \(H\) would mimic \(L\) at his unconstrained optimum \((b_L, 0)\). In that case signalling becomes potentially attractive for \(L\).

3.2 Existence of Signalling Equilibria.

We showed in section 3.1 that if \(L\) is mistaken for \(H\) (and mimicked by \(H\), so this does not presume private sector irrationality), \(L\) will play \((b_L, 0)\). This is also his full-information optimum choice of policy instruments. But as we demonstrated in equation (15), not being mistaken for \(H\) would raise \(L\)'s period 2 payoff \(v_2\), so \(L\) would be willing to move away from \((b_L, 0)\) if that could convince the private sector of his true type. But moving away from \((b_L, 0)\) obviously lowers \(L\)'s period 1 payoff \(v_1\), so we can define a border line below which the benefits of being believed in period 2 outweigh the

\(^4\) The indifference curve is elliptic since the total payoff is quadratic in \(\pi_1\) and \(\delta_1\).
\[ V(H; L; \phi; \pi, \delta) = V(H; H; \phi; \pi(H, \theta), 0) \]
costs in period 1. This curve, FGH in Figure 2, is defined by

\[(23) \quad V(L; L; q; \xi, \delta) = V(L; H; q; b_L, 0).\]

From the definition of FGH it is clear that L prefers any point below FGH (provided he is believed to be L) over being mistaken for H. However, below ABC it is in H's interest to mimic L's policies, so any point L chooses below ABC will lead to mimicking and hence to being mistaken for H. Thus FGBA is the set of potential policy choices of L in a signalling equilibrium. Within FGBA it does not pay for H to mimic L, but L is better off than it would be if mistaken for H.

Clearly, if it could, L would want to minimize the costs of signalling by choosing a policy as close to \((b_L, 0)\) as the no-mimicking constraint permits. However, the now standard equilibrium concept for incomplete information games—Kreps and Wilson's (1982) \textit{sequential equilibrium}—does not rule out any of the points within FGBA as candidates for equilibrium. But, as is further discussed in Appendix 1, with plausible restrictions on the private sector's off-equilibrium beliefs we can rule out all potential equilibria except those on the boundary ABC. Formally, we find a single candidate for our signalling equilibrium by solving the following Lagrangean problem:

\[(24) \quad \max_{\pi, \delta, \lambda, \mu} \min_{\lambda, \mu} Z(\pi, \delta, \lambda, \mu) = V(L; L; q; \pi, \delta) - \lambda[V(H; L; q; \pi, \delta) - V(H; H; q; \pi(H; q)0)] + \mu \delta.\]

The term "\(\mu \delta\)" reflects the non-negativity constraint on the wage controls variable \(\delta_1\); as discussed in Section 2.1, controls are not operative if they are set above desired wages \((\bar{\pi}_t > \pi^e_t)\).\(^5\) The first order conditions to (24) are:

\[(25a) \quad Z_\pi = (-2\pi_S + \pi^e_S + b_L - \delta_S)(1 - \lambda_S) - \lambda_S(b_H - b_L) = 0\]

\[(25b) \quad Z_\delta = -(\pi_S - \pi^e_S + \delta_S + c_1)(1 - \lambda_S) + \mu = 0\]

\[(25c) \quad Z_\lambda = V(H; L; q; \pi_S, \delta_S) - V(H; H; q; \pi(H; q)0) = 0 \text{ or } \lambda_S = 0\]

\(^5\) When solving the problem (24) formally, we substitute \(\delta_t\) for \(\max(\delta_t, 0)\) in the government objective (6) and instead impose the inequality constraint by way of the multiplier \(\mu\).
$V(L; l; q; \pi, \delta) = V(L; H; q; b_L; 0)$
(25d) \[ Z_\mu = \delta_S = 0 \ or \ \mu_S = 0, \]

where the subscript S denotes values associated with L's policy choices in the signalling equilibrium. Conditions (25) imply

(26) \[ V_\delta(H; L; \cdot)/V_\pi(H; L; \cdot) = V_\delta(L; L; \cdot)/V_\pi(L; L; \cdot). \]

What (26) says is that, at the suggested equilibrium choice for L--point S in Figure 2--L's and H's indifference curves are tangents. This is intuitive: if the equilibrium were at a point--like R, say--where L's indifference curve cuts ABC, L could raise its payoff by rearranging the use of \( \delta \) and \( \pi \) while remaining on ABC. (However intuitive, this argument still implies a restriction on the private sector's off-equilibrium beliefs, as explained in Appendix 1.) It is conceivable, however, that the tangency point occurs at negative \( \delta \), such as point S' in Figure 2. In that case the second inequality constraint becomes operative, \( \delta_S = 0 \), and a corner solution at A obtains (see Section 3.3 for a further discussion of this case).

A final issue needs to be discussed before we can establish that point S for L--together with point \((\pi(H; q), 0)\) for H--is indeed a signalling equilibrium. Does L, at S, have an incentive to deviate, for given inflationary expectations in period 1, even if that would lead to mistakenly being taken for H in period 2.\(^6\) 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 from S of L, \( \tilde{\pi}(L; q) \), when the deviation results in him being taken for H. In analogy with (16), the optimal inflation rate is

(27) \[ \tilde{\pi}(L; q) = (b_L + \pi^e_S)/2, \]

where \( \pi^e_S \) are the inflationary expectations in the suggested signalling equilibrium (\( \delta_L \) is

\(^6\) Notice that this is not quite the same as asking whether S is in FGH. The difference lies in the assumption that \( \pi^e_1 \) is constant across this experimental deviation from the suggested equilibrium.
optimally set to 0, by the assumed lower bound on $c_1$. This leads to the payoff

$$V(L; H; q; \pi(L; q), 0) = -\left(\pi_S^e + \frac{(b_L - \pi_S^e)}{2}\right)^2 +$$

$$+ d_L[(b_L)^2/2 - ((b_L + b_H)/2)^2].$$

L's payoff in (28) should be compared to the payoff in the suggested signalling equilibrium $V(L; L; q; \pi_S, \delta_S)$. To do that, we first solve (25) for L's equilibrium policy choices $\delta_S$ and $\pi_S$; see (31) below. Then we can calculate the appropriate value of $\pi_S^e$, given that H sets $\pi_1$ according to (18). After straightforward but tedious substitutions and manipulations, the condition for existence of a signalling equilibrium can finally be expressed as

$$V(L; L; q; \pi_S, \delta_S) - V(L; H; q; \pi(L; q), 0) =$$

$$= \left[\frac{1}{1+q}\right]^2\left\{q[\lambda_S/(1-\lambda_S)+1/2](b_H-b_L) + [c_1-(b_H-b_L)]\right\}^2$$

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

This condition is expressed in terms of the model's parameters, with one exception; $\lambda_S$ is itself a complicated second order function of the parameters. Condition (29) is likely, but not certain, to hold. It can be seen that the likelihood of existence increases in $c_1$---the cost of controls---and in $d_L$---the low-inflation government's discount factor---which are both intuitive results. In Appendix 2, we derive (an example of) a set of relatively weak sufficient conditions for (29) to be fulfilled, namely

$$q \leq 3/4 + b_L/(b_H-b_L)$$

and

$$d_Lb_L \geq d_Hb_H.$$ 

Thus, if the initial credibility problem, as parameterized by $q$, is serious 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.

3.3 Characterization of signalling equilibria
The first-order conditions (25) yield intuitive solutions for \( \pi_S \) and \( \delta_S \). Consider the case where both instruments are used; we shall later on in this section discuss under which circumstances the use of wage controls is not part of the solution. The solution for \( \pi_S \) is:

\[
(31a) \quad \pi_S = b_L + c_1 - (b_H - b_L)\lambda_S/(1 - \lambda_S).
\]

The signalling value of \( \pi_1 \) 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 \( b_L \). On the other hand, high gains from signalling (a large difference \( b_H - b_L \)) tend to call for tighter monetary policy (lower inflation).\(^7\)

The signalling value for the wage control parameter \( \delta \) is

\[
(31b) \quad \delta_S = (\pi_S - c_1).
\]

Substituting this into the definition of \( \delta \) and evaluating the employment consequences yields an interesting result:

\[
(32) \quad \pi_S^e - \pi_S = (\ell^* - \ell_1) = c_1 > 0.
\]

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 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 \( \delta = 0 \) imposed (no wage controls allowed). The first-order condition for inflation then simplifies to yield:

\[\ldots\]

\(^7\) The argument is not entirely rigorous: \( \lambda/(1 - \lambda) \) also depends on \( b_H - b_L \). The preceding argument assumes implicitly that \( \lambda < 1 \) and hence that \( \lambda/(1 - \lambda) > 0 \). 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 \( \lambda < 1 \).
(33) \( \hat{\pi}_1(L; q) = (b_L + \pi^e_1)/2 - \lambda(b_H - b_L)/2(1 - \lambda) \)

and \( H \)'s choice remains

(34) \( \pi_1(H; q) = (b_H + \pi^e_1)/2. \)

Imposing rational expectations then yields

(35) \( \pi^e_1 = b_H - q(b_H - b_L)/(1 - \lambda). \)

Combining (33) and (35) gives the recessionary impact of the disinflation program

(36) \( \pi^e_1 - \hat{\pi}_1(L; q) = (1 - q)(b_H - b_L)/2(1 - \lambda) > 0. \)

Consider now whether it is optimal to use wage controls or not in the signalling equilibrium. This can be assessed by evaluating \( Z_\delta \) at \( \hat{\pi}_1(L; q) \); this corresponds to point \( A \) in Figure 3. Clearly, at that corner, \( \mu \) is just equal to zero too, so the derivative \( Z_\delta \) evaluated at \( A \) becomes

(37) \( Z_\delta = -(\pi_1 - \pi^e_1 + c_1)(1 - \lambda) \geq 0, \)

which, using (33) and (35) can be rewritten as follows:

(38) \( Z_\delta = -(1 - \lambda)[c_1 - (1 - q)(b_H - b_L)/2(1 - \lambda)]. \)

If \( Z_\delta > 0 \) at \( A \), tangency occurs at positive \( \delta \) and wage controls are part of the signalling equilibrium. If \( Z_\delta < 0 \) at \( A \), the tangency point occurs at negative \( \delta \) and hence controls will not be used.

Since \( \lambda < 1 \) from the second order conditions, whether wage controls will be used depends on the sign of the term in square brackets in (38). This term has an intuitive interpretation. From (32) and (36) it simply measures the difference in unemployment when controls are or are not part of the signalling equilibrium. Thus equation (38) tells us that wage controls will be part of the signalling equilibrium if they lower the recessionary impact of the disinflation program. 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; $x_A < 0$.\(^8\)

With the caveat that we are only looking at the direct effect of parameters and ignoring the indirect effects through $\lambda$, the comparative statics on condition (38) yield intuitive results. We see that wage controls are more likely to be used the lower their cost (lower $c_1$), the more serious is the low-inflation government's credibility problem (lower $q$) 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 may 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 and Brazil—that once in place, controls are harder to change in the short run than monetary policy. Thus controls may, at least temporarily, commit the government to a certain course of action, which might be infeasible for monetary policy. To capture such aspects, we would have to change the formalism of our model, however. Wages and

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\(^8\) To see this, note that (since $\lambda < 1$) (7b) implies the inequality $c_1 > b_H - q(b_H - b_L)/(1 - \lambda)$, where the RHS is the value of $\pi_1^6$ in (35). Thus it follows from (37) that $Z_\delta > 0$ is possible only if $\pi_1 < 0$. 
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 signalling, or 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.9 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 assuming 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

\[ 9 \text{ These facts are documented in Kiguel, Montiel and van Wijnbergen (1987).} \]
explain the use of controls by high-inflation governments without any instantaneous
effect on the black market premium on foreign exchange, like in Argentina.

Finally, 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 1

This appendix discusses how one can rule out all but one of the potential Separating Sequential Equilibrium (SE) points in the area FGBA in Figure 2 by plausible restrictions on private beliefs. Without further restrictions, any point in the range FGBA could be part of a SE. For L, none of these points is dominated by the payoff L obtains under the assumption that he will be mistaken for H; also, all points would be too costly to mimic for the H government. It is then clearly possible to construct private beliefs that would support any point in FGBA as a SE-move for L. If, for example, private beliefs are such that all points to the south-east of say $\tilde{S}$ but within FGBA in Figure 2 would be associated with mimicking, but all other points in FGBA not, $\tilde{S}$ would be a SE.

However, these beliefs are possible to rule out by the following argument. It is clear that the policy for H implicit in the beliefs supporting $\tilde{S}$ are dominated by not mimicking for all points to the south-east of $\tilde{S}$ but within FGBA. For all these points, H would in fact prefer not to mimic by construction of the curve ABC. (At the same time, $\tilde{S}$ is dominated by all the points south-east of it for L, provided he is believed to be L.) Elimination of dominated strategies thus rules out such private beliefs that assume out-of-equilibrium behavior by H that is in fact not optimal for H to follow would the situation arise.\(^1\)

This argument limits the set of feasible equilibrium moves for L to the line segment AB. We could still construct private beliefs that would support other points along AB than the one that maximizes Z in equation (25). Take for example point R in Figure 2. Private beliefs that would associate any point on AB except R with mimicking by H could support R and rule out S. Once again, however, this requires implausible

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10 Note that sequential equilibrium does not rule this out. We are not discussing what H would in fact do at say Y, but what wage setters think H would do. Sequential equilibrium puts restrictions on what actions and beliefs can constitute an equilibrium, but puts no restrictions, a priori, on beliefs outside of equilibrium.
beliefs. By construction, H is indifferent between R and S, while L would prefer S; to therefore associate S with H but R with L is arbitrary and requires actions from H that do not follow from maximization. We therefore rule out such beliefs too. Then R cannot be an equilibrium policy: H is indifferent between S and R, but L has an incentive to move from R to S. In summary, we assume that the private sector associates all points in the area FGBA with L, and does so with probability one.\footnote{Formally, the above argument corresponds to a criterion that is commonly applied in the game theory literature to reduce the number of equilibria; Cho and Kreps (1987) label it "sequential elimination of (weakly) dominated strategies". We refer the reader to that paper for a discussion--with special reference to signalling games--about refinements of Nash and Sequential Equilibrium.}

A final question about out-of-equilibrium beliefs is how the private sector interprets a policy within the intersection of ABC and FGH. This area, ABH, is one where L would go if that would convince the public about its true type. But at the same time, H has an incentive to mimic L's policy in this area. For L staying in the area FGBA and being perceived as L dominates going to the area ABH and being mistaken for H. We therefore assume that private beliefs associate any point in ABH with H, not with L, and does so with probability one.

\section*{Appendix 2}

In this Appendix we rewrite the condition (29) for existence of a signalling equilibrium. For convenience we reproduce the condition here:

\begin{align}
\text{V}(L; L; q; \pi_S, \delta_S) - \text{V}(L; H; q; \tilde{\pi}(L; q), 0) &= \\
= &\left[1/(1+q)\right]^2\{q[\lambda_S/(1-\lambda_S)+1/2](b_H^{-}b_L) + [c_L^{-}(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.
\end{align}

To make further progress in signing this expression, it is useful to exploit the condition (25c); 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

\[
V(H; L; q; \pi_S, \delta_S) - V(H; H; q; \pi(H; q), 0) =
\]

\[
(A2) \\
- \frac{(b_H - b_L)/[(1 - \lambda_S)]^2}{2} + \frac{(b_H - \pi_S)^2}{2 + c_1} + \\
+ d_H[(b_H)^2 - ((b_H - b_L)/2)^2] = 0.
\]

Using (18) and (31a) the value for \( \pi_S^e \) is

\[
(A3) \\
\pi_S^e = \{(1-q)b_H + 2q[b_L + c_1 - \lambda_S(b_H - b_L)/(1 - \lambda_S)]\}/(1+q).
\]

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

\[
V(L; L; q; \pi_S, \delta_S) - V(L; H; q; \pi(L; q), 0) =
\]

\[
(A4) \\
(1 - \lambda^2)(b_H - b_L)/2(1 - \lambda)^2 + \\
+ \frac{\lambda q^2}{(1 - \lambda)} + (2 - q)(b_H - b_L)[c_1 - (b_H - b_L)/4]/(1 + q)^2 + \\
+ (d_L - d_H)[(b_L)^2 - (b_L)^2]/4 + (d_L b_H - d_H b_H)(b_H - b_L)/2 > 0.
\]

The first of the four terms in the condition is always positive, but the other terms are ambiguous. However, by (7a) \( c_1 > q b_L + (1-q)b_H \). Therefore, if (30a) is fulfilled the second term is positive. If (30b) is fulfilled the third and the fourth terms are both positive, and consequently our existence condition is satisfied.
References


