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A Model of Inflation and Reputation with Wage Bargaining

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Abstract

This paper investigates the issue of reputation in a model of monetary policy with imperfect information. The private sector is described by a wage formation mechanism which incorporates the actions of two parties: a trade union and a firm. They set wages by solving a bargaining problem, taking into account the effect of their action on government incentives. Unlike in the standard literature, the equilibrium has the feature that as the distortion of the economy gets bigger, namely as the bargaining power of the union increases, the reputational equilibrium with low inflation becomes more likely to occur. This finding is consistent with the observation that higher levels of the labor cost are not typically associated with higher levels of inflation.

1. Introduction

Economists have speculated for years about the source of the apparent inflationary bias of market economies. The question is why governments are usually willing to tolerate persistent high rates of inflation if systematic expansionary policies are known to fail to raise output. One answer is that zero inflation is not a credible policy if the government is known to care about output. This is what has arisen as "dynamic inconsistency" in Kydland and Prescott (1977) and as inferiority of Nash solutions in Barro and Gordon (1983), but generally reflects the fact that noncooperative equilibria, in which the government cannot precommit to a zero inflation policy, need not be Pareto optimal. If, however, the private sector is incompletely informed about the nature of its opponent, reputational effects provide an incentive for the government to choose a noninflationary monetary policy. Backus and Driffill (1985), Barro (1986), and Tabellini (1988), among others, analyzed this setting. Following the same line of research, this paper investigates the issue of whether reputational incentives can be strong enough to induce the authorities to abide by their announcements and hence refrain from creating unexpected inflation.

One central feature distinguishes the present model from those already analyzed on this topic. In the standard literature the public is described by an expectation formation mechanism which is supposed to portray the preferences of a single representative agent of the economy. Such a not clearly specified description of the behavior of the public delivers, among others, the result that the incentive of the government to pursue inflationary policy is increasing in the degree of distortion in the economy, where by distortion is meant any occurrence which causes natural output to be different from what would be optimal for the government. Hence, highly distorted economy should exhibit higher levels of inflation. The absence of a competitive labor market is one typical example. The evidence, however, does not suggest that higher levels of the cost of labor are systematically associated to higher levels of inflation.

This paper analyzes the consequences of the introduction of a more complex structure for the private sector in the standard models of inflation and reputation. Specifically, I assume that the public is made up by two agents, a trade union and a firm, who bargain over the nominal wage in order to maximize their utility functions, given the expected

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behavior of the government. The game is analyzed under the hypothesis that the government and the public move simultaneously as well as in the case where the public has the first move in each period. The simultaneous moves setup intends to describe an economy with decentralized labor markets. Under this setup nominal wages just reflect inflationary expectations, since each individual agent cannot do better than forecast inflation as accurate as possible. However, under the institutional setting prevailing in most industrial countries wages are more likely to be determined by negotiation processes between centralized labor unions and coordinated business associations. Further wages are controlled by binding labor contracts lasting some specific interval of time, whereas policy-makers enjoy a large degree of flexibility and, at each stage of the game, can deviate at their discretion from previous announcements. This scenario is best captured by a repeated game in which the public has the first move in each period. Here, private agents have an active strategic role, since they can set nominal wages so as to influence monetary policy.

Perhaps surprisingly, the result is that a relatively higher weight assigned to the union in the wage negotiation process makes the reputational equilibrium with low inflation more likely to occur. This finding is coherent with the evidence that highly inflationary countries are not those where labor's share are higher. Furthermore, the range of parameter values for which a reputational equilibrium occurs is not affected by the specification of the game. As long as both parties take part to the wage setting process, providing the private sector with the first move does not actually improve its active strategic role. The reason is that the firm and the union exhibit opposite preferences over the inflationary policy implemented by the government. Consequently, each party acts so as to create opposite incentives for the government and the potential strategic role of the private sector, as a whole, turns out to be strongly weakened. In contrast, if the union is allowed to set wages unilaterally (i.e. if the bargaining power of the firm is pushed to zero) the qualitative feature of the equilibrium will change and the set of parameter values which sustains a zero-inflation outcome results to be enlarged even further.

Section 2 of this paper presents the macroeconomic model.

Section 3 analyzes the bargaining game and computes the equilibrium nominal wage under the hypothesis that there is uncertainty

about the inflationary policy implemented by the government.

Section 4 examines the optimal monetary policy, given that the behavior of the private sector is described by the wage formation process analyzed in the previous section. Section 4.1 computes the equilibrium with monetary policy precommitments; section 4.2 derives the "one-shot" discretionary equilibrium when the players move simultaneously; section 4.3 characterizes the reputational equilibrium of the repeated game under the hypothesis that the private sector is incompletely informed about the government's preferences over the trade-off between inflation and output.

Section 5 analyzes the game with the private sector having the first move. The equilibrium under the limit case in which the union is allowed to set wages unilaterally (i.e. the firm has zero bargaining power) is described in section 5.1.

Section 6 presents some evidence.

Finally, section 7 concludes.

2. The Model

The macroeconomy is described by two simple equations; an aggregate demand function:

$$M_t/P_t = y_t,$$ (1)

where M_t is the money supply, p_t is the price level and y_t is the real output; and an aggregate supply function:

$$y_t = 2L_t^{1/2}[1],$$ (2)

which relates employment to output. The government sets M_t to maximize:

$$u^g = \sum_{t=0}^{T} \delta_g^t \; [-(1/2)\Pi_t^2 + \tau y_t], \qquad 0<\delta_g<1$$ (3)

where $\Pi_t = p_t - p_{t-1}$ is the rate of inflation in period t. Equation (3)

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[1] The production function is a standard Cobb-Douglas: $y=(1/\alpha)L^{\alpha}$. The choice of $\alpha=1/2$ is just due to computational convenience. The results obatained hold for any $\alpha\in(0,1)$.

simply says that the government wants to keep inflation close to zero and to increase employment above its current level. The parameter τ indicates the relative weight assigned by the government to the employment objective.

The firm and the union negotiate each period over the nominal wage, taking into account the inflationary policy that they expect to be implemented by the government in that period. The firm then takes nominal wages as given by the bargaining outcome and sets employment and output, once the price level has become observable. Each party bargains so as to maximize its own payoff.

The firm is characterized by a profit function, $y(L)-wL$, where w is the real wage, defined as the nominal wage W deflated by the price level $(w=W/p)$. The firm is a profit maximizer; therefore, it chooses L_t by solving $y'(L_t)=w_t$. Given my specification of the production function, the demand for labor is simply:

$$L_t = 1/w_t^2. \qquad (4)$$

Profit is then $1/w_t$. The total payoff of the firm is the discounted sum of its future profits:

$$u^f = \sum_{t=0}^{T} \delta_f^t \, [1/w_t], \qquad\qquad 0<\delta_f<1, \qquad (5)$$

The union has N members, all alike. L of them are employed and achieve a level of utility w. If not employed by the firm a worker achieves a level of utility $\bar{u}$ which can be thought of as the utility from receiving an unemployment compensation benefit. The union wishes to maximize $wL+(N-L)\bar{u}$, which can be written as $[w-\bar{u}]L+N\bar{u}$. Since N and $\bar{u}$ are treated as data for the purpose of union wage setting the problem can be summarized by saying that the union wishes to maximize the membership's aggregate gain from employment, over and above the utility $\bar{u}$ that every member starts with:

$$u^u = \sum_{t=0}^{T} \delta_u^t \, [(w_t-\bar{u})1/w_t^2 + N\bar{u}], \qquad\qquad 0<\delta_u<1 \qquad (6)$$

The conflict between private sector and government is generated by the hypothesis that the current level of output, because of the negotiation process which makes wages depending on the relative

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bargaining powers of the parties, is below the level desired by the government. Hence, it has an incentive to inflate, so as to lower the real wage and increase output. But if the parties realize this, they will agree on a higher nominal wage during the negotiation process.

The strategic interaction between government's behavior and the equilibrium result of the bargaining is analyzed throughout the paper under different hypothesis about the information available to the players.

3. Wage Bargaining

The bargaining situation I model is the following. At the beginning of each period the firm and the union have to reach an agreement on the nominal wage that is going to prevail until the end of that period. Once the wage is set, the firm chooses the volume of employment unilaterally.

The payoff of the firm for the agreement is its profit $y(L)-wL$, while that of the union is the total utility $(w-\bar{u})L+N\bar{u}$ received by its N members. I restrict agreements to be nominal wages W in which the profit of the firm is nonnegative $(W/p\leq\infty)^2$, and which are at least equal to the wage which makes union's members indifferent between being employed and unemployed $(W/p\geq\bar{u})$. Thus each pair of utilities that can result from agreement takes the form $(p/W, [W/p-\bar{u}](p/W)^2+N\bar{u})$, where $W/p\geq\bar{u}$ and $0\leq L\leq N$. If the two parties fail to agree, then they disrupt production temporarily, until an agreement is reached. During a disruption of production the firm obtains a payoff of zero, since $y(0)=0$, and the union receives $N\bar{u}$, so that the disagreement utility pair is $d=(d^f,d^u)=(0,N\bar{u})$. Then the set of utility pairs that can be attained in an agreement is

$$U = \{(u^f,u^u)\in R^2: (u^f,u^u)=(p/W, [W/p-\bar{u}](p/W)^2+N\bar{u}), u^f\geq 0, u^u\geq N\bar{u}\}.$$

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2 The upper unboundedness of the negotiable nominal wage depends essentially on the absence of fixed costs. It would not be hard to eliminate it, by introducing sunk costs which the firm sustains only when agreement, and consequently production, takes place. Under this specification, the maximum wage that the firm is willing to agree upon would be finite and the corresponding payoff would coincide with the disagreement payoff of zero.

U is a compact convex set, which contains the disagreement point $d=(0,N\bar{u})$ in its interior. Thus the pair (U,d) defines the bargaining problem[3]. The equilibrium concept I focus on is the Nash asymmetric bargaining solution which is uniquely given by

$$\underset{(d^f,d^u)\leq(u^f,u^u)\in U}{\text{argmax}} \quad (u^f-d^f)^\gamma(u^u-d^u)^{1-\gamma}, \qquad \gamma\in(0,1).$$

Wage bargaining takes place at the beginning of each period, when the government inflationary policy is not observable by the parties. They therefore have to form expectations about the real wage and the employment level that the negotiated nominal wage will actually yield in that contract period, once inflation has been chosen by the government. The predicted nominal wage for my problem is then

$$W = \underset{E(W/p)\geq\bar{u}}{\text{argmax}} \quad \{E[u^f]\}^\gamma\{E[u^u-N\bar{u}]\}^{1-\gamma}=$$

$$\underset{E(W/p)\geq\bar{u}}{\text{argmax}} \quad \{E(p/W)\}^\gamma\{E[(W/p-\bar{u})(p/W)^2]\},^{1-\gamma} \qquad (7)$$

where the parameter γ can be interpreted as the bargaining power of the firm, and $1-\gamma$ as the bargaining power of the union.

Let the parties have common beliefs that $\Pi=0$ occurs with probability q and $\Pi=\bar{\Pi}\neq 0$ with probability $(1-q)$. Then the expected utilities from agreement of the firm and the union are respectively:

$$E[u^f] = k^f/W,$$

and

$$E[u^u] = k_1^u/W - \bar{u}k_2^u/W^2,$$

where $k^f=[1+(1-q)\bar{\Pi}]$, $k_1^u=[q+(1-q)(1+\bar{\Pi})]$, $k_2^u=[q+(1-q)(1+\bar{\Pi})^2]$, and prices at the beginning of the period have been normalized to one. The asymmetric Nash equilibrium of this bargaining game gives the nominal wage

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[3] Formally, a bargaining problem is a pair (S,d), where $S\subset R^2$ is compact and convex, $d\in S$, and there exists $s\in S$ such that $s_i>d_i$ for all i, where i denotes the player.

$$\hat{W} = (k_2^u / k_1^u) \, \bar{u} \, (2-\gamma). \qquad \qquad (8)$$

$\hat{W}$ is increasing in the utility of the union's member from being unemployed and decreasing in the firm's bargaining power. If q=1 (i.e. inflation is expected to be zero with probability one), then k_2^u / k_1^u =1; when q=0, k_2^u / k_1^u =1+$\bar{\Pi}$. Therefore, the equilibrium real wage under perfect information is simply $\bar{u}(2-\gamma)$. γ=1 gives the competitive outcome for this model: if there were no union and $\bar{u}$ were the level of utility attainable elsewhere in the economy[4], then $\bar{u}$ would be the given supply price of labor to the employer, who would maximize profits at L=1/$\bar{u}^2$. The case of a monopoly union which can set the wage unilaterally, corresponds to the case where γ=0. The best wage for the union to set is determined mathematically by finding the maximum of (w-$\bar{u}$)L with respect to w and L, subject to the constraint y'(L)-w=0. Given the functional forms that I assumed, it yields in fact w=2$\bar{u}$.

4. Monetary Policy

Monetary policy is characterized as a repeated game between the government and the private sector. The private sector is represented by the wage formation process described above.

I assume that the equilibrium wage of the bargaining process yields a level of output which is below what is optimal for the government[5]. As a consequence, it has incentive to reduce the real wage by creating unexpected inflation. The private sector realizes this and takes into account the expected behavior of the government during the wage negotiation process, each party according to its own preferences over the discrepancy between actual and expected inflation. The outcome of the bargaining is thus affected by the government's strategy and does in turn affect the government's payoff by determining, via wage rates,

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[4] That would be the case, for instance, if there were no unemployment compensation, but a large supply of jobs at wage $\bar{u}$.

[5] Government may consider optimal, for instance, the level of output implied by the real wage determined in a competitive labor market (γ=1). The presence of the union can be thought of as the source of the distortion, and consequently of the time inconsistency of the monetary policy, in this model.

the level of employment and output in each period.

The game is repeated T times, that is the number of periods that the government survives in power. For simplicity of exposition, I will restrict my analysis to the case in which T=2; the results can then be easily generalized to any arbitrary finite T.

The game consists of the government choosing Π_t and the public choosing W_t, with payoffs given by equations (3), (5) and (6), respectively for the government, the firm and the union.

4.1 Precommitment regime

This section computes the equilibrium in which the government can precommit to a monetary policy rule before nominal wages are set by the bargaining process. This equilibrium serves as a benchmark against which to evaluate the outcomes that arise with discretionary monetary policy.

The game proceeds as follows. At the beginning of each period, the government sets the money supply, taking into account the private sector's response. Then, the union and the firm bargain over the nominal wage, after having observed the government action. Output, inflation and real wages are then determined according to equations (1), (2) and (4).

From the bargaining process it follows immediately that the equilibrium nominal wage is (time subscripts are omitted when superfluous)

$$W = \bar{u}(2-\gamma)(1+\Pi),$$ (9)

where $(1+\Pi)=p$ is the beginning of period price level plus the current inflation, which is observed by the parties. Substituting this value into (4), and then (4) into (2), we get that in each period output is unaffected by monetary policy:

$$y = 2/[\bar{u}(2-\gamma)]$$ (10)

Finally, substituting (10) into the government utility function, equation (3), we obtain that the optimal monetary policy rule is always to set inflation at zero. We thus obtain that, in equilibrium with monetary policy precommitments,

$$\Pi^P = 0, \quad W^P = \bar{u}(2-\gamma), \quad y^P = 2/[\bar{u}(2-\gamma)], \tag{11}$$

where the P superscripts stand for "precommitment".

The intuition behind this result is exactly as in the standard literature: with binding commitments, the government takes into account that nominal wages respond one for one to any change in prices. Hence, monetary policy is neutral. The best thing that government can do is to set inflation to zero and let output be determined by the private sector.

4.2 Discretionary regime

A setup in which the monetary authority is not allowed to enter into binding commitments can be described by a noncooperative repeated game with government and private sector moving simultaneously. The subgame perfect equilibrium of such a game can be derived by working backwards from the last period. Since there is no dynamic state variable, the unique Nash equilibrium of the "one-shot" game is the subgame perfect equilibrium of the repeated game.

The "one-shot" Nash equilibrium can be computed as follows. The government maximizes its one-period utility function, subject to (2) and (4). Since it moves at the same time as the bargaining occurs, it has to take nominal wages as given. Hence, its first-order condition yields:

$$\Pi = 2\tau/W \tag{12}$$

The union and the firm negotiate over the nominal wage, taking the government's decision as given; therefore, the equilibrium outcome is again expressed by equation (9), where Π now is not observed but taken as given by the parties during the bargaining[6]. Then the discretionary

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[6] Here, I am assuming that the private sector is perfectly informed about the preferences of the government (in particular, I assume that the constant τ in the utility function of the government is known to the parties). Therefore, the parameter q (i.e. the probability that the parties assign to the event of observing zero inflation), which appears in equation (8), has to be taken equal to zero. Under the assumption of incomplete information and when the game is repeated, q becomes a function of the reputation of the government.

equilibrium is obtained by combining (2) and (4) with the solution to the system of equations (9) and (12):

$$\pi^D = [1/4 + 2\tau/\bar{u}(2-\gamma)]^{1/2} - 1/2, \qquad w^D = [\bar{u}(2-\gamma)](1+\pi^D),$$
$$y^D = 2/[\bar{u}(2-\gamma)], \qquad\qquad\qquad\qquad (13)$$

where the D superscripts stand for "discretion".

Comparing (13) with (11), the only difference between the discretionary equilibrium and the equilibrium with policy precommitments concerns the rate of inflation, which is positive under discretion but zero with precommitments. Real output and real wages are identical in the two equilibria. Hence, the government is better off with precommitments, whereas the union and the firm are indifferent between the two regimes since they only care about real magnitudes. This is the well-known result that rules are better than discretion, obtained by Kydland and Prescott (1977) and Barro and Gordon (1983) with the standard representative agent model. The intuition here is similar to those models. Once nominal wages have been set, the government might be tempted to reduce the real wage by means of unexpected inflation, so as to increase output. The union realizes this, and asks, during the bargaining process, higher nominal wages. In equilibrium real wages are at the level prescribed by the negotiation outcome, which is entirely determined by the bargaining powers of the parties and independent of the monetary policy, and inflation is positive.

4.3 Reputational equilibrium

The discretionary equilibrium is the unique subgame perfect equilibrium under the assumption of complete information and finite horizon. Hence, no announcement will ever be believed unless it coincides with the solution to the government first-order condition given by equation (13) above. If either of the two assumptions is dropped, however, announcements may become an effective policy instrument.

Here the game is solved for a finite horizon and under the hypothesis that the public has incomplete information about the parameter τ in the government objective function. For simplicity, it is assumed that τ can take one of two values: it may be $\tau=0$, that is the government behaves as it is committed irrevocably to pursuing a zero-inflation policy (a "tough" government); or $\tau=\bar{\tau}>0$, that is the government behaves

as if it is rationally attempting to maximize the utility function (3) (a "weak" government). If the government is actually tough, its optimal strategy is simply to set M_t so as to have $\Pi_t=0$ in any period. If the government is weak, its optimal behavior is more sophisticated. As we saw in section 3, the equilibrium nominal wage of the bargaining process depends on the private sector beliefs about the government preferences. Consequently, even a weak government may choose not to inflate. By resisting inflation it develops a reputation for being tough which it hopes will discourage expectation of inflation in the future. In this section I examine such a reputational equilibrium. The setting is as in Kreps and Wilson (1982b), Backus and Driffill (1985) and Barro (1986). The solution concept is Kreps and Wilson's (1982a) sequential equilibrium, which enable to find the solution recursively, starting with the final period. The game proceeds as follow: when the game is started the players, government and private sector, choose their actions simultaneously, given the strategy of the other player; besides, the government takes into account the impact of its current behavior on its next period's reputation. Then the government choice becomes observable and the parties revise their beliefs according to Bayes rule. This new probability will be taken into account by the parties during the wage negotiation in the following contract period.

The central feature of the model is the government's ability to manipulate its reputation. Let $x_t=$ prob$(\tau=0)$ be the public's beliefs at time t; let $q_t=$ prob$(\Pi_t=0)$ and $x_t^*=$ prob$(\Pi_t=0|\tau=\bar{\tau})$. Therefore, q_t is the unconditional probability that there will be no inflation at time t, and x_t^* is the conditional probability of zero inflation, given that the government is weak. I will characterize the strategy of the weak government as a probability of playing tough in both pure and mixed strategies. Thus x_t^* represents the government's choice variable and q_t is the value considered by the parties during the bargaining process. From these definitions it follows that

$$q_t = x_t + (1-x_t)x_t^* \qquad (14)$$

The hypothesis that x_t is revised according to Bayes rule implies that

$$x_{t+1} = 0 \qquad\qquad\qquad \text{if } \Pi_t \neq 0,$$
$$x_{t+1} = x_t/[x_t+(1-x_t)x_t^*] = x_t/q_t \qquad \text{if } \Pi_t=0 \qquad (15)$$

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Consider now the solution of the game. In the final period, T, a weak government will always inflate, since destroying its reputation can have no future consequences. Its optimal inflationary strategy is given by the solution to the system of equations (8) and (12). Now the private sector is not perfectly informed about the government's type. Consequently, the Nash equilibrium of the one-shot game depends on the reputation of the government. Let $\bar{W}(q_t)$ and $\bar{\Pi}(q_t)$ denote the Nash equilibrium values of the "one-shot" game, given that the reputation of the government in period t, x_t, is such that the private sector expects $\Pi_t = 0$ with probability q_t and $\Pi_t \neq 0$ with probability $1-q_t$. After some straightforward substitutions, using (2), (3) and (4), the expected utility of a weak government in period T can be written as

$$u^g_T \Big|_{\Pi_{T-1}=0} = 2\tau\left[\tau/\bar{W}^2(q_T) + 1/\bar{W}(q_T)\right]$$

if in period T-1 it has pursued a noninflationary strategy. If instead in period T-1 the government has inflated, we have

$$u^g_T \Big|_{\Pi_{T-1}\neq 0} = 2\tau\left[\tau/(W^D)^2 + 1/W^D\right]$$

where inflation and output are expressed in terms of the equilibrium real wage of the bargaining game under discretion since, by playing weak at T-1, the government has revealed its type to the parties.

In period T-1, the government must consider the impact of its behavior on its reputation in the final period. With probability x°_{T-1} the government sets $\Pi_{T-1} = 0$; if $\Pi_{T-1} = 0$ is realized, its utility in period T-1 is

$$u^g_{T-1} \Big|_{\Pi_{T-1}=0} = 2\tau/\bar{W}^2(q_{T-1})$$

With probability $(1-x^{\circ}_{T-1})$ the government plays the optimal inflationary strategy, $\Pi_{T-1} = \bar{\Pi}(q_{T-1})$; in this case, its utility is given by

$$u^g_{T-1} \Big|_{\Pi_{T-1}\neq 0} = 2\tau\left[\tau/\bar{W}^2(q_{T-1}) + 1/\bar{W}(q_{T-1})\right]$$

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Denoting by $V_{T-1}(x_{T-1})$ the government expected utility from period T-1 up to the end of the game we then have

$$V_{T-1}(x_{T-1}) = x^*_{T-1}\left\{2\tau/\bar{W}^2(q_{T-1}) + \delta_g 2\tau\left[\tau/\bar{W}^2(q_T) + 1/\bar{W}(q_T)\right]\right\} +$$

$$(1-x^*_{T-1})\left\{2\tau\left[\tau/\bar{W}^2(q_{T-1}) + 1/\bar{W}(q_{T-1})\right] +\right.$$

$$\left.\delta_g 2\tau\left[\tau/(W^D)^2 + 1/W^D\right]\right\} \qquad (16)$$

The last term in (16) reflects the fact that if the government inflates in period T-1, which it does with probability $(1-x^*_{T-1})$, then its reputation is blown and the public will expect inflation in the final period. The first term expresses the probability of playing zero actual inflation in T-1, and then collecting a payoff in T associated with a reputation x_T, where x_T is given by equation (15). For a given nominal wage in period T-1, $V_{T-1}(x_{T-1})$ is linear in x^*_{T-1}. But W_{T-1} has to be taken as given, since the public does not observe the government's action when it chooses the wage rate in period T-1. Moreover, $0 \le x^*_{T-1} \le 1$. Hence, there are three cases to consider:

(i) $\partial V_{T-1}(x_{T-1})/\partial x^*_{T-1} > 0$, which implies $x^*_{T-1} = 1$. That is, the optimal government strategy in period T-1 is the pure strategy of no inflation. Hereafter, an equilibrium in which the government plays such a strategy will be called *pooling*.

(ii) $\partial V_{T-1}(x_{T-1})/\partial x^*_{T-1} < 0$, implying $x^*_{T-1} = 0$. Here the optimal strategy is the pure inflationary strategy: $\Pi_{T-1} = \bar{\Pi}$. In this case, the equilibrium will be called *separating*.

(iii) $\partial V_{T-1}(x_{T-1})/\partial x^*_{T-1} = 0$, in which case the government chooses a mixed strategy (it plays $\Pi_{T-1} = 0$ with probability $x^*_{T-1} > 0$, and $\Pi_{T-1} = \bar{\Pi}$ with probability $(1-x^*_{T-1}) > 0$).

Differentiating the right-hand side of (16) with respect to x^*_{T-1} and simplifying, we obtain that $\partial V_{T-1}(x_{T-1})/\partial x^*_{T-1} \gtreqless 0$ as:

$$\bar{\tau}/\bar{W}^2(q_{T-1}) \lesseqgtr \delta_g\left[\bar{\tau}/\bar{W}^2(q_T) + 1/\bar{W}(q_T) - \bar{\tau}/(W^D)^2 - 1/W^D\right] \qquad (17)$$

The left-hand side of (17) is the net gain for the government from creating unexpected inflation today, i.e., it is the "temptation to cheat". The right-hand side of (17) is the net cost for the government from creating unexpected inflation today rather than tomorrow or, in

other words, it is the gain from maintaining a reputation. When the two sides of (17) are equal, the government chooses a mixed strategy (i.e., $0 \leq x^o_{T-1} \leq 1$), since it is indifferent between creating unexpected inflation today rather than tomorrow. If (17) holds with a > sign, then the net gain of inflating today exceeds the corresponding net cost, and the government chooses a pure inflationary strategy right away (i.e., $x^o_{T-1}=0$). Conversely, if (17) holds with a < sign, the net gain from creating unexpected inflation is smaller than the cost of losing its reputation, and the government resists the temptation to inflate (i.e., $x^o_{T-1}=1$).

If in period T-1 the weak government plays $\Pi_{T-1}=0$ with certainty ($x^o_{T-1}=1$), then, according to (15), its reputation at the beginning of the last period is the same as in period T-1: $x_T=x_{T-1}$, since the parties do not learn by observing the government's action. Hence, bargaining in the last period will yield $W_T=\bar{W}(x_{T-1})$, i.e. the equilibrium nominal wage which occurs when the parties expect $\Pi_T=0$ with probability $q_T=x_{T-1}$ and $\Pi_T=\bar{\Pi}(x_{T-1})$ with probability $1-q_T$. Condition (17) then implies that the weak government will indeed find it optimal not to inflate in period T-1 if

$$W_{T-1} \geq \bar{\tau}/\delta_g \left[\bar{\tau}/\bar{W}^2(x_{T-1}) + 1/\bar{W}(x_{T-1}) - \bar{\tau}/(W^D)^2 - 1/W^D \right]^{-1/2} \equiv W^p \qquad (18)$$

Thus W^p denotes the minimum wage rate compatible with a pooling equilibrium in period T-1. If the wage rate in period T-1 is set above such value, the government will not inflate, since the value of its reputation exceeds the temptation to cheat.

Conversely, if in period T-1 the weak government inflates with certainty ($x^o_{T-1}=0$), and if in that period zero inflation is observed by the private sector, then according to (15) $x_T=1$ (i.e., the private sector infers from that the government is tough). In the subsequent period the parties will then set the nominal wage conditional to the belief $q_T=x_T=1$: $W_T=\bar{u}(2-\gamma)$. Condition (17) then implies that, given this future behavior on the part of the private sector, the weak government does indeed find it optimal to play the inflationary strategy in period T-1, $x^o_{T-1}=0$, if

$$W_{T-1} \leq \bar{\tau}/\delta_g \left[\bar{\tau}/\bar{u}^2(2-\gamma)^2 + 1/\bar{u}(2-\gamma) - \bar{\tau}/(W^D)^2 - 1/W^D \right]^{-1/2} \equiv W^s \qquad (19)$$

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Thus W^s is the maximum wage rate compatible with a separating equilibrium in period T-1. If in period T-1 the nominal wage rate is set below W^s, then the weak government inflates that period, since at that period the temptation to cheat exceeds the cost of loosing its reputation.

By definition, $W^s < W^P$. Furthermore, $\bar{W}(x_{T-1}) > \bar{u}(2-\gamma)$. Three possible situations may thus occur.

Proposition 1: If $W^P \leq \bar{u}(2-\gamma)$, the unique perfect equilibrium of the game with simultaneous moves is pooling, with the public playing

$$W_{T-1} = \bar{u}(2-\gamma), \qquad W_T = \bar{W}(q_T),$$

and the weak government playing

$$\Pi_{T-1} = 0, \qquad \Pi_T = \bar{\Pi}(q_T), \qquad (q_T = x_{T-1}).$$

Proof: If the public sets $\bar{u}(2-\gamma)$ during the bargaining process and $W^P \leq \bar{u}(2-\gamma)$ holds, then condition (18) is satisfied and the government finds it optimal to play $\Pi = 0$. Given this behavior of the government, the optimal response of the parties is to agree on $\bar{u}(2-\gamma)$. In order to show that this equilibrium is unique, suppose that the parties agree upon a wage $W < W^P$. Then, the optimal strategy of the weak government is to play $\Pi = 0$ with a probability x^*_{T-1} less than one. More precisely $x^*_{T-1} = 0$ if $W \leq W^s$ and $x^*_{T-1} \in (0,1)$ if $W > W^s$, and the probability of observing zero inflation will be equal to $q_{T-1} = x_{T-1} + (1-x_{T-1})x^*_{T-1}$. But, given this probability, the parties would rather set $\bar{W}(q_{T-1}) > \bar{u}(2-\gamma) \geq W^P$. A contradiction.

Proposition 2: If $W^s \geq \bar{W}(x_{T-1})$, the unique perfect equilibrium of the game with simultaneous moves is separating, with the public playing

$$W_{T-1} = \bar{W}(x_{T-1}), \qquad W_T = W^D, \qquad \text{if } \Pi_{T-1} \neq 0$$
$$\text{and} \quad W_T = \bar{u}(2-\gamma) \quad \text{if } \Pi_{T-1} = 0$$

and the weak government playing

$$\Pi_{T-1} = \bar{\Pi}(x_{T-1}), \qquad \Pi_T = \Pi^D.$$

Proof: If the public sets $\bar{W}(x_{T-1})$ during the bargaining process and $W^s \geq \bar{W}(x_{T-1})$ holds, then condition (19) is satisfied and the government

finds it optimal to play $\Pi=\bar{\Pi}(x_{T-1})$. Given this behavior of the government, the optimal response of the parties is to agree on $\bar{W}(x_{T-1})$. To show the uniqueness, let the parties choose a wage $W>W^s$. The government's best response to this action is to set $\overset{o}{x}_{T-1}$ greater than zero (either $\overset{o}{x}_{T-1}\in(0,1)$, if $W<W^p$, or $\overset{o}{x}_{T-1}=1$, if $W\geq W^p$). Then, the probability of observing zero inflation at time T-1 is no longer $q_{T-1}=x_{T-1}$, but $q_{T-1}=x_{T-1}+(1-x_{T-1})\overset{o}{x}_{T-1}>x_{T-1}$, and the equilibrium wage from the bargaining process will be $\bar{W}(q_{T-1})<\bar{W}(x_{T-1})\leq W^s$. A contradiction.

Proposition 3: If $W^p > \bar{u}(2-\gamma)$ and $W^s < \bar{W}(x_{T-1})$, the unique perfect equilibrium of the game with simultaneous moves is in mixed strategies, with the public playing

$$W_{T-1}= \bar{W}(\overset{o}{q}_{T-1}), \qquad W_T= \bar{W}(\overset{o}{q}_T)$$

and the weak government playing

$$\Pi_{T-1}= 0 \text{ with probability } \overset{o}{x}_{T-1},$$
$$\Pi_{T-1}= \bar{\Pi}(\overset{o}{q}_{T-1}) \text{ with probability } 1-\overset{o}{x}_{T-1}$$

and $\qquad \Pi_T= \bar{\Pi}(q_T);$

where $\overset{o}{x}_{T-1}$ is the probability which makes the government just indifferent between inflating and not inflating in period T-1 and $\overset{o}{q}_{T-1}$ and $\overset{o}{q}_T$ the corresponding probabilities of observing zero inflation.

Proof: If the public sets $\bar{W}(\overset{o}{q}_{T-1})$ during the bargaining process, then the government finds it optimal to play $\Pi=0$ with probability $\overset{o}{x}_{T-1}$, since $\overset{o}{x}_{T-1}$ is just the value which maximizes (16), given that $W_{T-1}=W^i(\overset{o}{q}_{T-1})$ and $W_T=W^i(\overset{o}{q}_T)$. Given this behavior of the government, the optimal response of the parties is to agree upon a wage rate equal to $\bar{W}(\overset{o}{q}_{T-1})$. The same reasoning employed in the proofs of proposition 1 and 2 can be repeated here to show that, whenever $W^p > \bar{u}(2-\gamma)$ and $W^s < \bar{W}(x_{T-1})$, the equilibrium of the game can be in mixed strategies only. Moreover, some easy algebra proves that, under this circumstance, the optimal probability for the weak government to play zero inflation, $\overset{o}{x}_{T-1}$, which simultaneously solves the government first-order condition and the public reaction functions

(respectively, equation (16), $W_{T-1} = \bar{W}(q_{T-1})$ and $W_T = \bar{W}(q_T^{\cdot})$), is unique[7].

Figures 1, 2 and 3 illustrate the reaction functions of the two players. On the vertical axis is the probability with which the weak government plays zero inflation in period T-1; nominal wages at T-1 are on the horizontal axis. The upward-sloping curve represents the government's reaction function; the downward-sloping curve is the optimal response of the private sector to the government's action. The equilibrium is given by the intersection of the two curves. Figures 1 and 2 illustrate the pooling and the separating equilibrium. The equilibrium in mixed strategies is described in Figure 3.
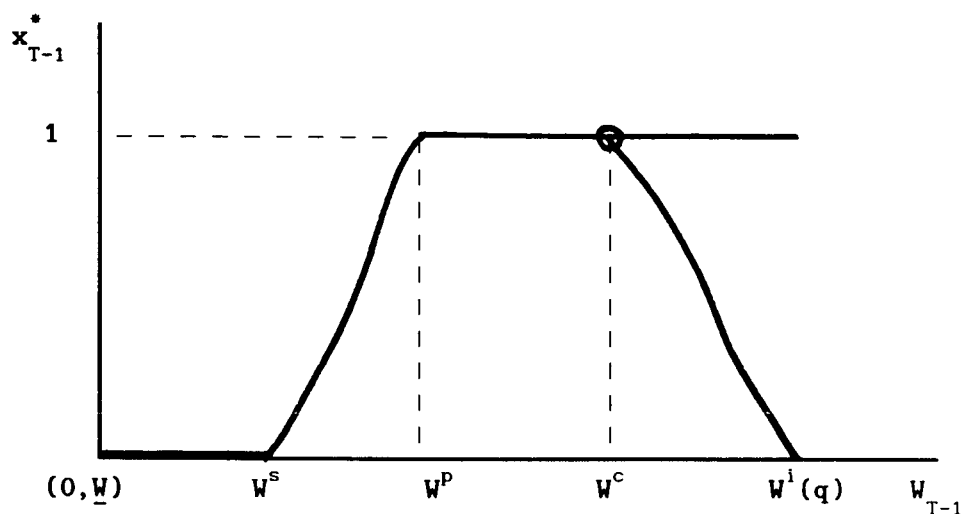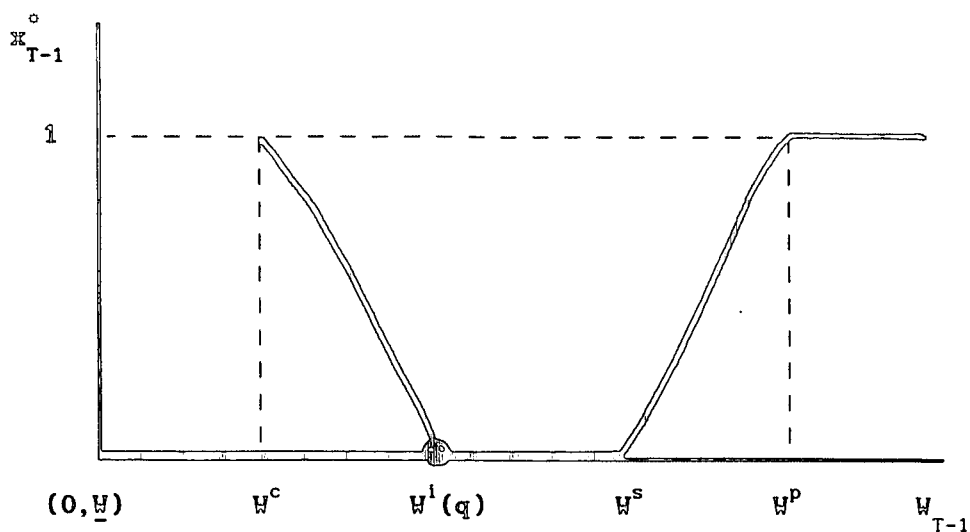

Fig.1

Fig.2

Fig.3

5. Equilibrium with wage precommitment

Under the institutional setting currently prevailing in all industrial countries, the monetary authority cannot enter into binding commitments and enjoys a large degree of flexibility. Nominal wages, on the other hand, are generally either partially or completely predetermined by binding labor contracts lasting some specific interval of time. This setup is best captured by a noncooperative repeated game in which the private sector has the first move in each period. Under

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this setting the behavior of the private sector is more sophisticated, since it is provided with an active strategic role; this turns out to affect the qualitative feature of the solution.

The subgame perfect equilibrium of such a game will be derived, like in the simultaneous moves case, by working backwards from the last period. The solution to the "one-shot" game is now given by the Stackelberg equilibrium of the one-period problem. It can be computed as follows. The government maximizes (3), subject to (2), (4), after having observed the outcome of the wage negotiation. His optimal behavior is still described by its first-order condition, equation (12). While bargaining over the nominal wage, the parties maximize (5) and (6), subject to the reaction function of the government, equation (12). The equilibrium nominal wage will then be given by

$$W = \underset{E(W/p) \geq \bar{u}}{\operatorname{argmax}} \quad \{(1+\Pi)/W\}^{\gamma}\{(1+\Pi)/W - \bar{u}[(1+\Pi)/W]^{2}\}^{1-\gamma}$$

$$\text{s.t.} \quad \Pi = 0, \quad \text{with probability } q,$$

$$\Pi = 2\bar{\tau}/W, \quad \text{with probability } 1-q. \quad (20)$$

The "one-shot" Stackelberg equilibrium is obtained by combining (12) and (20) with (4) and (2). Let $\bar{W}^{S}(q_t)$ and $\bar{\Pi}^{S}(q_t)=2\bar{\tau}/\bar{W}^{S}(q_t)$ be the Stackelberg equilibrium values of nominal wage and inflation, when the private sector expects $\Pi_t=0$ with probability q_t and $\Pi_t=2\bar{\tau}/W_t$ with probability $1-q_t$. $q_t=1$ gives the precommitment outcome. Under this regime we still have the equilibrium nominal wage $\bar{u}(2-\gamma)$ and zero optimal inflation. When $q_t=0$ we have the discretionary solution[8]. Let W^{SD} and Π^{SD} denote the equilibrium wage-inflation pair under discretion. Then the weak government in period T-1 will choose the pure strategy of no

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[8] Solving (20), with q=0, we get the private sector first-order condition under discretion

$$W^3 + [4\bar{\tau}-(2-\gamma)\bar{u}]W^2 - [6(2-\gamma)\bar{\tau}\bar{u}]W - 8(2-\gamma)\bar{\tau}^2\bar{u} = 0.$$

For my parameter values, it yields only one admissible value for W.

inflation (pooling strategy) or the pure inflationary strategy (separating strategy) as

$$\bar{\tau}/[\bar{W}^S(q_{T-1})]^2 \lesseqgtr \delta_g\left[\bar{\tau}/[\bar{W}^S(q_T)]^2 + 1/\bar{W}^S(q_T) - \bar{\tau}/(W^{SD})^2 - 1/W^{SD}\right] \quad (17')$$[9]

(in the remainder of the analysis I will neglect the possibility of a mixed strategy equilibrium). Analogously to the game with simultaneous moves, I define W^{SP} and W^{Ss} the minimum and the maximum wages compatible respectively with the pooling and the separating equilibrium, in the game with the private sector having the first move in each period. They are given by

$$W^{SP} \equiv \bar{\tau}/\delta_g\left[\bar{\tau}/[\bar{W}^S(x_{T-1})]^2 + 1/\bar{W}^S(x_{T-1}) - \bar{\tau}/(W^{SD})^2 - 1/W^{SD}\right]^{-1/2} \quad (18')$$

and

$$W^{Ss} \equiv \bar{\tau}/\delta_g\left[\bar{\tau}/\bar{u}^2(2-\gamma)^2 + 1/\bar{u}(2-\gamma) - \bar{\tau}/(W^{SD})^2 - 1/W^{SD}\right]^{-1/2}. \quad (19')$$

If in period T-1 the parties set the nominal wage above W^{SP} the government will optimally choose not to inflate. Conversely, if $W_{T-1} \leq W^{Ss}$ realizes, then the government will inflate with probability one.

In order to complete the characterization of the equilibrium, I now need to analyze how the private sector, in view of this reaction by the government, sets nominal wages. Even though a mixed strategy equilibrium is subgame perfect and could be preferred by the parties for some parameter values, I will restrict the analysis to the private sector choice between the pooling and the separating equilibrium. Therefore, while setting the nominal wage the parties face an intertemporal trade-off: in a separating equilibrium they face some uncertainty in the current period, but the government action reveals its type, so that the uncertainty will be resolved as of next period. On the other hand, in a pooling equilibrium the parties face no uncertainty in the current period, but they do not learn by observing the government action. Furthermore, the equilibrium of the bargaining process is such that the

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[9] The derivation of condition (17') is exactly the same as the derivation of condition (17).

expected real wage under uncertainty ($q \in (0,1)$) is always less than the real wage under certainty ($q=1$). The utility of the union is increasing in the real wage and concave; the firm, on the other hand, has preferences which are decreasing and convex in the real wage. Given that both parties discount the future, then we necessarily have that the union prefers the pooling to the separating equilibrium while the firm is better off under the separating outcome. This reasoning provides the intuition for the following two propositions.

Proposition 4: If $W^P \leq \bar{u}(2-\gamma)$ the unique perfect equilibrium of the game with the public having the first move in each period is pooling. In this equilibrium the public plays

$$W_{T-1} = \bar{u}(2-\gamma), \qquad W_T = \bar{W}^S(q_T),$$

and the weak government plays

$$\Pi_{T-1} = 0, \qquad \Pi_T = \bar{\Pi}^S(q_T), \qquad (q_T = x_{T-1}).$$

Proof: Suppose that the public sets $\bar{u}(2-\gamma)$ during the bargaining process and $W^P \leq \bar{u}(2-\gamma)$ holds; then condition (18') is satisfied and the government finds it optimal to play $\Pi=0$ with probability one. Given this behavior of the government, the optimal response of the parties is to agree upon a wage rate equal to $\bar{u}(2-\gamma)$. In order to show that the parties cannot be made better off by the government playing the separating strategy consider first the preferences of the firm. The firm would rather offer a wage lower than W^s, since by doing so it would sustain a separating outcome which is strictly preferred by the firm to the pooling equilibrium for a given nominal wage at T-1 and therefore, *a fortiori*, for a lower wage. To verify that the firm is playing optimally, hence, I need to prove that the union would never be willing to agree on a wage less than $\bar{u}(2-\gamma)$. By virtue of the fact that the utility of the union is increasing and concave in W, any wage below $\bar{u}(2-\gamma)$ gives the union a lower expected payoff. Therefore, any wage offer below $\bar{u}(2-\gamma)$ must be rejected by the union for its action to be optimal. Given this behavior of the union the best the firm can do is to agree on $\bar{u}(2-\gamma)$.

Proposition 5: If $W^s \geq \bar{W}^S(x_{T-1})$ the unique perfect equilibrium of the game with the public having the first move in each period is

separating. In this equilibrium the public plays

$$W_{T-1} = \bar{W}^S(x_{T-1}), \qquad W_T = W^{SD}, \qquad \text{if } \Pi_{T-1} \neq 0$$
$$\text{and} \quad W_T = \bar{u}(2-\gamma) \qquad \text{if } \Pi_{T-1} = 0$$

and the weak government playing

$$\Pi_{T-1} = \bar{\Pi}^S(x_{T-1}), \qquad \Pi_T = \Pi^{SD}.$$

Proof: Suppose that the public sets $\bar{W}^S(x_{T-1})$ during the bargaining process and $W^s \geq \bar{W}^S(x_{T-1})$ holds; then condition (19') is satisfied and the government finds it optimal to play $\Pi=\bar{\Pi}^S(x_{T-1})$ with probability one. Given this behavior of the government, the optimal response of the parties is to agree upon a wage rate equal to $\bar{W}^S(x_{T-1})$. In order to show that the parties cannot be made better off by the government playing the pooling strategy consider first the preferences of the union. The union would rather offer a wage higher than W^P since by doing so it would sustain the pooling outcome which is strictly preferred by the union to the separating equilibrium for a given nominal wage at T-1 and therefore, a *fortiori*, for a higher wage. To verify that the union is playing optimally, hence, I need to prove that the firm would never be willing to agree on a wage higher than W^P. By virtue of the fact that the utility of the firm is decreasing and convex in W, any wage above W^P gives the firm a lower expected payoff. Therefore, any wage offer above W^P must be rejected by the firm for its action to be optimal. Given this behavior of the firm the best the union can do is to agree on $\bar{W}^S(x_{T-1})$.

Propositions 4 and 5 say that the solution to the game with the players moving simultaneously coincides with the equilibrium when the public has the first move in each period. In fact, also in this case, the pooling equilibrium is attainable if and only if, for a given set of parameter values, the condition $W^P \leq \bar{u}(2-\gamma)$ happens to be satisfied. Analogously, the separating equilibrium occurs if and only if $W^s \geq \bar{W}^S(x_{T-1})$ holds[10]. More interestingly, providing the private sector with

[10] Even though the choice for mixed strategy equilibria were allowed, the condition for a pooling equilibrium to occur would still be given by

an active strategic role by allowing it to precommit·its action, does not alter the set of parameter values for which a reputational equilibrium with zero inflation may occur. The intuition behind this result is that wages are determined by a bargaining·process between the firm and the union. The preferences of the parties are such that if the union is better off under the pooling equilibrium, the firm prefers uncertainty and hence acts strategically in order to sustain the separating outcome. The result is that the potential active strategic role of the private sector, as a whole, is strongly weakened. Like in the simultaneous moves game, the parties cannot do better than set the wage prescribed by their relative bargaining powers.

As it should result clear from the previous discussion, qualitatively different outcomes would be attained if the union were allowed to set wages unilaterally. In the following section I will let γ, the bargaining power of the firm, be zero so as to consider the case where the union is the only agent representing the private sector. I will show that the exclusive presence of the union in the wage setting process makes the reputational equilibrium with zero inflation more likely to occur.

·5.1 The case of a monopoly union

Throughout this section I assume $\gamma=0$. The bargaining problem reduces then to the maximization of the union's utility function, equation (6). The characterization of the equilibrium is analogous to the one derived in the previous· section. The "one-shot" Stackelberg equilibrium is still described by the government moving according to its first-order condition, equation (12), and the union maximizing (6),

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$W^P \leq \bar{u}(2-\gamma)$ (since the union would never be willing to swap the pooling equilibrium for a lower wage). Conversely, if equilibria in mixed strategies were an option, $W^S \geq \bar{W}^S(x_{T-1})$ would be neither a necessary nor a sufficient condition for a separating equilibrium to occur. Depending on the relative propensity of the parties toward risk and on how much they discount the future, a mixed strategy equilibrium might occur even with $W^S \geq \bar{W}^S(x_{T-1})$ (if both parties prefer higher wages in exchange of higher uncertainty). On the other hand, $\bar{W}^S(x_{T-1}) \geq W^S$ might sustain the separating outcome (if both parties are willing to trade less uncertainty for lower wages).

subject to the government's reaction. Hence,

$$W = \operatorname*{argmax}_{E(W/p)\geq \bar{u}} \quad \{(1+\Pi)/W - \bar{u}[(1+\Pi)/W]^2\}$$

$$\text{s.t.} \quad \Pi = 0, \quad \text{with probability } q,$$

$$\Pi = 2\bar{\tau}/W, \quad \text{with probability } 1-q. \quad (21)$$

Let $\bar{W}^u(q_t)$ be the solution to (21) when the union expects the government to play zero-inflation with probability q_t and $\Pi_t = 2\bar{\tau}/W_t$ with probability $1-q_t$ [11]; let $\bar{\Pi}^u(q_t)$ be the corresponding equilibrium inflation. Let, further, $\bar{W}^{uD}$ be the solution to (21) when $q=0$, the discretionary outcome; thus $\bar{\Pi}^{uD} = 2\bar{\tau}/\bar{W}^{uD}$. By imposing $q=1$, we get the equilibrium wage under precommitment: $2\bar{u}$. By virtue of the same argument employed in sections 4.3 and 5, I am able to define

$$W^{uP} \equiv \bar{\tau}/\delta_g \left[\bar{\tau}/[\bar{W}^u(x_{T-1})]^2 + 1/\bar{W}^u(x_{T-1}) - \bar{\tau}/(W^{uD})^2 - 1/W^{uD}\right]^{-1/2} \quad (22)$$

and

$$W^{us} \equiv \bar{\tau}/\delta_g \left[\bar{\tau}/4\bar{u}^2 + 1/2\bar{u} - \bar{\tau}/(W^{uD})^2 - 1/W^{uD}\right]^{1/2}, \quad (23)$$

respectively, the minimum (maximum) wage compatible with the pooling (separating) equilibrium. Since by hypothesis the union is concerned only about real magnitudes, in setting the nominal wage in period T-1, it might seek to make the government behavior more predictable. Given that the government best response is described by equations (22) and (23), it could turn out to be optimal for the union to set the wage just above W^{uP}, even though the wage rate that would prevail with precommitments is not so high [12]. The union might indeed end up gaining from this action,

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[11] Straightforward computations show that $\bar{W}^u(q)$ is given by the solution to
$$W^3 + [4(1-q)\bar{\tau} - 2\bar{u}]W^2 - 12(1-q)\bar{\tau}\bar{u}W - 16(1-q)\bar{\tau}^2\bar{u} = 0.$$

For my parameter values, it gives only one admissible value for W.

[12] Observe that the utility of the union is not always increasing in W. Under precommitments ($q=1$), it reaches a maximum for $W=2\bar{u}$. Values of W higher than $2\bar{u}$ thus give a lower payoff to the union.

since by doing so it would sustain the pooling equilibrium and delay by one period the uncertainty about the inflation rate. This intuition is stated more rigorously in the following two propositions.

Proposition 6: If $W^P \leq 2\bar{u}$ the unique perfect equilibrium of the game with the union having the first move in each period is pooling. In this equilibrium the union plays

$$W_{T-1} = 2\bar{u}, \qquad W_T = \bar{W}^u(q_T),$$

and the weak government plays

$$\Pi_{T-1} = 0, \qquad \Pi_T = \bar{\Pi}^u(q_T), \qquad (q_T = x_{T-1}).$$

Proof: The same reasoning employed in the proofs of propositions 1 and 4 can be replicated here to show that the strategies of the union and the government are indeed mutually best responses. It is straightforward to see that the union cannot be made better off by the government playing any other strategy. As a matter of fact, by playing $W_{T-1} = 2\bar{u}$, the union achieves its maximum utility with probability one in the current period, and its maximum expected utility (given $q_T = x_{T-1}$) in period T. In contrast, in order to induce the government to play the separating strategy the union must suffer a loss in period T-1, since it must set nominal wages at a level which is below $\bar{W}^u(x_{T-1})$, its optimal response to the government inflationary strategy (since $W^P \leq 2\bar{u}$ implies $\bar{W}^u(x_{T-1}) \geq W^{us}$). Further, it will end up delaying of one period the certain optimal outcome associated to the real wage $2\bar{u}$. The risk aversion of the union and the fact that it discounts the future assure that the union, by setting $W_{T-1} = 2\bar{u}$, is acting optimally.

Proposition 7: Let $u^u_{T-1}[W]$ be the expected utility of the union from period T-1 up to the end of the game, from setting $W_{T-1} = W$. Then, if $W^{us} \geq \bar{W}^u(x_{T-1})$ the unique perfect equilibrium of the game with the union having the first move in each period is pooling if $u^u_{T-1}[W^P] > u^u_{T-1}[\bar{W}^u(x_{T-1})]$ [13]; it is separating otherwise. If the equilibrium

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[13] More precisely,

is pooling, in period T-1 the union plays $W_{T-1} = W^p$ and the weak government does not inflate; in period T the union plays $W_T = \bar{W}^u(x_{T-1})$ and the weak government plays $\Pi_T = \bar{\Pi}^u(x_{T-1})$. If the equilibrium is separating, then the union sets $\bar{W}^u(x_{T-1})$ in the first period and the weak government inflates. From then on the equilibrium is as in the game with complete information.

Proof: If $W^{us} \geq \bar{W}^u(x_{T-1})$ and in period T-1 the union plays its optimal response to the weak government inflationary strategy, $\bar{W}^u(x_{T-1})$, the weak government indeed finds it optimal to separate and play such a strategy. In this case, the union expected utility from period T-1 up to the end of the game is $u^u_{T-1}[\bar{W}^u(x_{T-1})]$. If instead in period T-1 the union plays the minimum wage consistent with the pooling equilibrium, $W_{T-1} = W^p$, its expected utility from T-1 up to the end of the game is $u^u_{T-1}[W^p]$. Hence, if $u^u_{T-1}[W^p] > u^u_{T-1}[\bar{W}^u(x_{T-1})]$ holds, then the union prefers the pooling equilibrium at T-1; otherwise it prefers the separating equilibrium.

Finally, if $W^{us} < \bar{W}^u(x_{T-1})$ the union cannot play $\bar{W}^u(x_{T-1})$ and

$$u^u_{T-1}[W^p] = [1/W^p - \bar{u}/(W^p)^2] + \delta_u \left\{ x_{T-1} \left[1/\bar{W}^u(x_{T-1}) - \bar{u}/[\bar{W}^u(x_{T-1})]^2 \right] + \right.$$
$$\left. (1-x_{T-1}) \left[[1+\bar{\Pi}(x_{T-1})]/\bar{W}^u(x_{T-1}) - \bar{u}[(1+\bar{\Pi}(x_{T-1}))/\bar{W}^u(x_{T-1})]^2 \right] \right\},$$

$$u^u_{T-1}[\bar{W}^u(x_{T-1})] = \left\{ x_{T-1} \left[1/\bar{W}^u(x_{T-1}) - \bar{u}/[\bar{W}^u(x_{T-1})]^2 \right] + \right.$$
$$\left. (1-x_{T-1}) \left[[1+\bar{\Pi}(x_{T-1})]/\bar{W}^u(x_{T-1}) - \bar{u}[(1+\bar{\Pi}(x_{T-1}))/\bar{W}^u(x_{T-1})]^2 \right] \right\} +$$
$$\delta_u [1/(2\bar{u}) - \bar{u}/(2\bar{u})^2].$$

The condition $u^u_{T-1}[W^p] > u^u_{T-1}[\bar{W}^u(x_{T-1})]$ can thus be written as

$$[1/W^p - \bar{u}/(W^p)^2] > (1-\delta_u) \left\{ x_{T-1} \left[1/\bar{W}^u(x_{T-1}) - \bar{u}/[\bar{W}^u(x_{T-1})]^2 \right] + \right.$$
$$\left. (1-x_{T-1}) \left[[\bar{W}^u(x_{T-1}) + 2\tau]/[\bar{W}^u(x_{T-1})]^2 - \bar{u}\{ [\bar{W}^u(x_{T-1}) + 2\tau]/[\bar{W}^u(x_{T-1})]^2 \}^2 \right] \right\} +$$
$$\delta_u/(4\bar{u}).$$

The first term in bracket in the right-hand side is the expected utility of the union under uncertainty about the government inflationary policy; the second term is the utility from the discretionary outcome. Since the first term is greater than the second, the right-hand side is increasing in the union discount factor. Hence, as the intuition suggests, the pooling equilibrium is less likely to occur the more the union cares about the future.

still sustain the separating outcome. In this case the condition for the existence of a pooling equilibrium is weaker, since in choosing between the pooling and the separating equilibrium, the separating equilibrium is now relatively more costly for the union.

Proposition 7 underscores the importance of having nominal wages set unilaterally by a single union rather than by a bargaining process where both firm and union take part. In this case I showed that the equilibrium of the game is entirely dependent on the bargaining power of the parties: for given inflationary expectations, they cannot do better than agree on the equilibrium nominal wage prescribed by their relative strength. In contrast, whenever the union is allowed to set wages unilaterally, nominal wages do not just reflect inflationary expectations. Instead, they are determined strategically by the union so as to influence monetary policy. The set of parameter values for which a pooling equilibrium occurs results to be enlarged, since the union may be willing to tolerate some reduction in its current utility so as to provide the government with adequate incentives to pursue a noninflationary strategy.

6. Some evidence

The purpose of this section is to test the prediction of the model concerning a determinant of the level of inflation which involves policy-makers' incentives to inflate.

In the previous sections, I showed that the equilibrium of the game between the government and the private sector relies on the relative weight assigned to each party, firm and union, involved in the wage negotiation process. Maybe surprisingly, the prediction of the theory is that the reputational equilibrium with low inflation is achievable when labor unions are stronger, or business associations are weaker. In the limit case where the firm has absolutely no power, the set of parameter values for which the pooling equilibrium occurs is enlarged even further. The intuition behind this result can be summarized as follows. First, the incentive of the government to create unexpected inflation is decreasing in the cost of labor: the gain in output from surprising the public is inversely related to the current level of real wages. This property comes from the optimizing behavior of the firm when choosing the level of employment, and it is true for a broad class of production function. Secondly, real wages depend on of the bargaining power of the

parties involved in the wage negotiation process. Wages are higher when labor unions are stronger. Thus, the prediction of the theory is that inflation will be higher in economies characterized by lower levels of real wages. My empirical analysis is devoted to assess whether there exists in the data any indicative evidence of negative correlation between wage levels and inflation.

My basic sample consists of all of the non-centrally planned economies for whom data on wages and inflation are available. This sample consists of 102 countries. I also investigate the relationship between wages and inflation for a variety of narrower samples. The period under consideration goes from 1973 to 1989.

National accounts data are from the International Financial Statistics of the International Monetary Fund and the World Tables of the World Bank. Inflation is measured as the change in the log GDP deflator. Real wages are measured as the earnings of employees as percentage of value added. This variable, which shows labor's share in income generated in the manufacturing sector, is immediately suitable for cross-country comparisons. Moreover, it fits the present analysis better than a straight measure of real wages; as a matter of fact, this last variable would be meaningless in explaining the firm's profitability from expanding production if not compared to some indicator of labor productivity. For both variables, inflation and earnings, I consider the average over the years beginning in 1973. Finally, data on real income per capita, which is used as a control variable in some specifications, are from Summers and Heston (1988); I use the figure for 1980, since this is approximately the mid-point of the post-1973 period and since 1980 is a benchmark year for Summers and Heston.

A few countries in the sample have extremely high average inflation rates. Thus the parameter estimates from a linear regression would be determined almost entirely by a handful of observations. A simple change that reduces the importance of the countries with extreme inflation rates is to consider the log rather than the level of average inflation. Thus my basic specification is a regression of the log of average inflation on a constant and the average labor's share.

The other specification differs from the basic one by controlling for another factor. In particular, I consider real income per capita, which can serve as a general measure of development, and thus may capture a variety of factors that influence average inflation.

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The results for the broad sample of countries are presented in Figure 4 and Table 1.

Figure 4 is a scatterplot of the mean rate of inflation since 1973 (measured on a logarithmic scale) against the average labor's share. The corresponding regression is reported in the first column of Table 1. The t-statistic on labor's share is -3.2: there is a significant negative relationship between wages and inflation, just as the theory predicts. Moreover, the estimated impact of wages on inflation is quantitatively large. The point estimates in Column 1, for example, imply an average rate of inflation of 17% for an economy with a labor's share of 20%, 12% for an economy with a labor's share of 40%, and 8% for an economy with a labor's share of 60%. Finally, the fraction of the variation in inflation explained by the regression is non-trivial: labor's share alone accounts for approximately ten percent of the cross-country variation in average inflation rates.

The second column of Table 1 investigates the robustness of this result to a change in the specification which adds log real income per capita to the regression. The idea is to verify whether the negative relation between real wages and inflation is attributable to the fact that poorer countries, which may have suffered higher rates of inflation, are also characterized by lower labor's shares. The regression suggests that higher real income is associated with a modest decline in average inflation. The estimated impact of labor's share on inflation is little changed. The t-statistic on labor's share is -2.8, which indicates that the negative relationship between wages and inflation is still significant.

Table 2 investigates the results for some sub-samples. For each sample I report the results for both the basic specification and the specification that includes the log of real income per capita.

Columns 1 and 2 exclude countries with average inflation rates greater than 60% from the sample. The estimated coefficient for labor's share is slightly smaller than before in both specifications, but the t-statistics remains in excess of 3 in the basic specification, and in excess of 2 when the control variable is added to it. Thus the result does not depend on a few countries with extreme high inflation rates.

Columns 3 and 4 restrict the sample to the most highly developed countries. This group consists of the 16 wealthiest countries

in the sample other than the main oil producers[14]. Among these countries there is virtually no link between labor's share and inflation. Average inflation rate in these countries is low (8.8%). Outside this small group of highly developed countries, in contrast, inflation rates are high and still negatively related to labor's shares (columns 5 and 6). The average inflation rate for the set of 83 countries that excludes the highly developed 16 is 17.7%. In this sample, the t-statistic on labor's share is -2.2 in the basic specification and -2.7, when controlling for per-capita income. The point estimates in the basic regression imply that average inflation falls from 18% to 10% as labor's share rises from 20% to 60%. Finally, labor's share accounts for a non trivial fraction of the variation in inflation among these countries: a simple regression of the log of average inflation on a constant and labor's share has an R^2 of approximately 6%.

An alternative explanation of the inverse relationship between real wages and inflation could be that inflation erodes wages, fixed in nominal terms, and that the private sector is not able to anticipate and prevent this effect. Nevertheless, this phenomenon requires much less than perfect indexation and widespread money illusion on the part of labor, which, if persuaded on a priori grounds by the neoclassical position, appears implausible.

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[14] The countries are Austria, Australia, Belgium, Canada, Finland, France, Germany, Island, Japan, Luxembourg, the Netherlands, Norway, Sweden, the United Kingdom and the United States. They represents all countries in the sample with real income per capita greater than $7,500, excluding the major oil producers (Kuwait, Saudi Arabia and the United Arab Emirates).
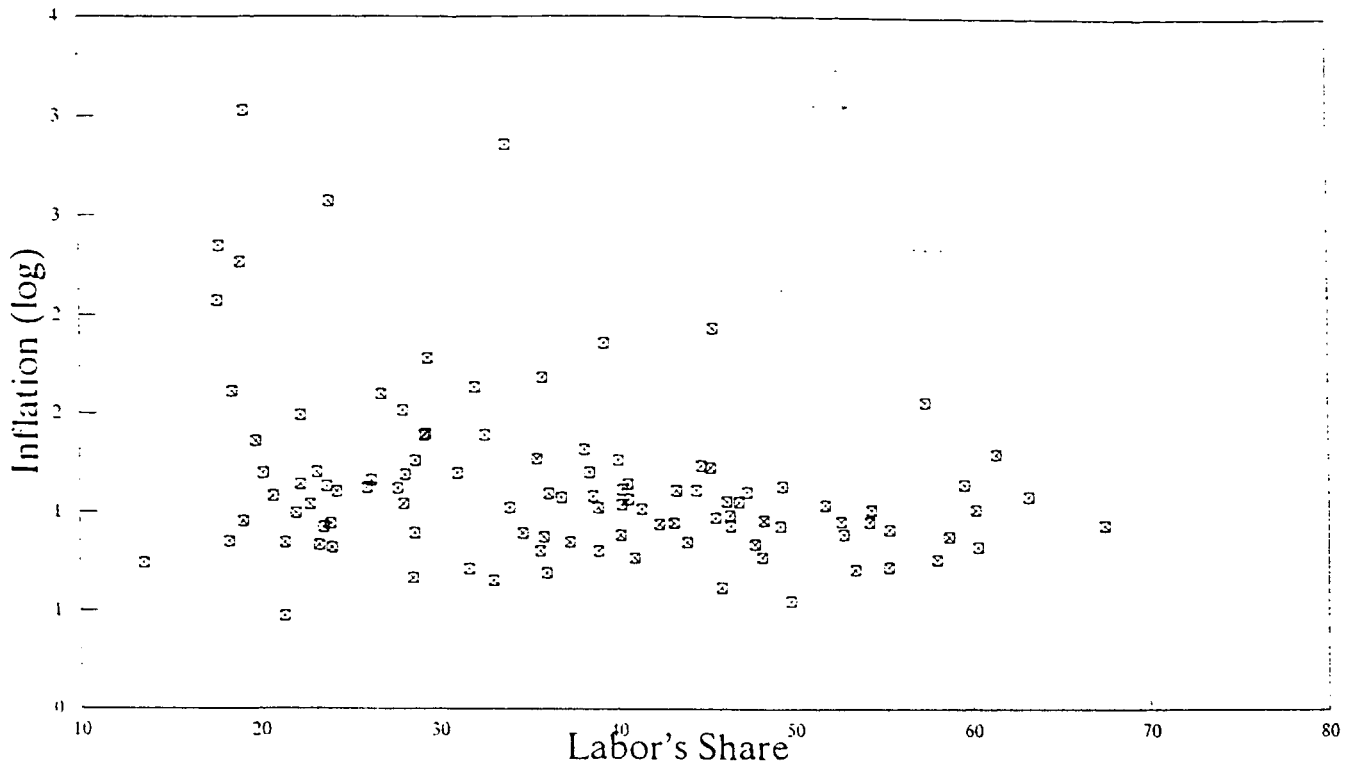
Fig. 4

Table 1

	(1)	(2)
Constant	3.213	3.263
	(0.215)	(0.465)
Labor's share	-0.018	-0.017
	(0.005)	(0.006)
Log Real Income per Capita		-0.008
		(0.678)
R^2	0.095	0.095
t-Statistic for Labor's share	-3.241	-2.790

The sample consists of 102 countries. The dependent variable is the log of the average inflation rate from 1973 to 1989. Wages are measured by earnings of employees as a percentage of value added (average from 1973 to 1989). Real Income per Capita data are for 1980. Standard error in parentheses.

Table 2

	(1)	(2)	(3)	(4)	(5)	(6)
	High Inflation Countries Excluded		16 Highly Developed Countries		16 Highly Developed Countries Excluded	
Constant	3.015	3.379	0.899	8.567	3.188	2.268
	(0.178)	(0.375)	(0.849)	(10.87)	(0.245)	(0.594)
Labor's share	-0.015	-0.012	0.022	0.022	-0.015	-0.019
	(0.004)	(0.005)	(0.016)	(0.017)	(0.007)	(0.007)
Log Real Income		-0.061		-0.84		0.145
per Capita		(0.055)		(1.188)		(0.086)
R^2	0.099	0.111	0.112	0.145	0.059	0.092
t-Statistic for						
Labor's share	-3.257	-2.307	1.328	1.33	-2.259	-2.736
Sample size	98	98	16	16	83	83

The dependent variable is the log of the average inflation rate from 1973 to 1989. Wages are measured by earnings of employees as a percentage of value added (average from 1973 to 1989). Real Income per Capita data are for 1980. High inflation countries are ones with average inflation rates greater than 60%. Highly developed countries are the 16 wealthiest countries in the sample other than the major oil producers. Standard errors in parentheses.

7. Final remarks

This paper has investigated the issue of reputation in a model of monetary policy with imperfect information. Unlike in the existing literature on this topic, here the private sector is described by a wage formation process which incorporates the actions of two parties: a trade union and a firm. They set wages by solving a bargaining problem, taking into account the effect of their actions on government incentives.

The game has been solved under the hypothesis that the players move simultaneously, a framework which properly describes decentralized labor markets, as well as for the case where the private sector acts as a Stackelberg leader, which is suitable for economies where the wage setting process is centralized. Both specifications of the game admit always a unique equilibrium. Unlike in the standard result, the equilibrium is such that as the distortion of the economy becomes bigger, namely as the weight assigned to the union, in terms of its bargaining power, gets higher, the reputational equilibrium with low inflation is more likely to occur. In the limit case where the firm has absolutely no power, the qualitative feature of the solution changes and the set of parameter values for which the reputational equilibrium occurs results to be enlarged even further.

This paper has also demonstrated that average rates of inflation are lower in economies characterized by higher labor's shares. This relationship is statistically significant, quantitatively large, and robust. The model offers an explanation of this relationship. Because a higher cost of labor per unit of output reduce the gain in terms of employment from creating unexpected inflation, the benefit of surprise expansion is decreasing in the labor's share. Thus, if the monetary authorities' temptation to expand is an important determinant of inflation, that is if the absence of binding precommitment is important to monetary policy, the result will be inefficiently high levels of inflation in economies with low labor's shares.

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