BARGAINING, REPUTATION AND STRIKES*

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WP-AD 97-09

*We wish to thank financial aid from the Valencian Institute of Economic Research (IVIE).

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Editor: **Instituto Valenciano de Investigaciones Económicas, S.A.**
Primera Edición Marzo 1997.
ISBN: 84-482-1457-9
Depósito Legal: V-726-1997
Impreso por Key, S.A.,
Cardenal Benlloch, 69, Valencia.
Impreso en España.

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A B S T R A C T

This paper analyses a finitely repeated wage bargaining game, where the union's strike decision is endogenous, but there is incomplete information about his striking strategy space. We characterize the equilibrium path and the equilibrium payoff of all Sequential Equilibria, following the techniques of Schmidt (1993). We obtain a finite bound, independent of the horizon of the repeated game, in the number of periods in which the firm tests the union and in which there are strikes. We also show that for a sufficiently long horizon, the union can credibly threaten to strike and obtain a high wage for most of the periods.

KEYWORDS: Wage Bargaining; Reputation; Screening; Strikes.

1. Introduction.

Over the last years a considerable effort has been observed in the study of wage negotiations, between unions and firms, in the context of non-cooperative game theory. An important element in this wage bargaining is the ability of the union to impose costs on the firm if there is disagreement between the parties, that is, a strike. But in fact, the union has two options if an agreement has not been reached, the union can strike or can continue working at the prevailing wage. Some authors, Haller and Holden (1990) and Fernandez and Glazer(1991) apply these ideas in an infinite-horizon alternating offers bargaining model with complete information. They obtain equilibria more favorable to the union where this one achieves a better wage using the strike threat. However, there is a drawback in these models: a severe problem of equilibria multiplicity, some of them very favorable to the firm, where the strike threat is not used. On the other hand, there is a strong contrast between the finite horizon model and the infinite horizon version. In the former, there is a unique outcome of Subgame Perfect Equilibrium (SPE), in which no strikes can occur. But, intuition strongly suggests that if we give one side of the negotiation -the union- such possibility of imposing costs, the result of the model should be the "most favorable equilibrium" for the union.

All this previous work analyses the case in which the negotiations can last several periods until an agreement is reached, but there is only a single contract negotiation. However, it is widely noticed that collective bargaining, between workers and employers, takes place periodically. Thus, if we wish to investigate the wage negotiations is better to consider these as a repeated bargaining game, rather than a single bargaining case. One would expect the threat of strike to be more effective for the union's interests in this repeated situation.

In this paper, we give a formal justification for this intuition, by means of reputation effects in a finitely repeated wage bargaining game. We assume there is some incomplete information about the union's type, but, in the sense of which "striking" strategy will follow. In particular, there is a small probability of being a "fighting" union, that is, it never accepts a wage below some high level and if it is not offered this wage, it always strikes. Then, the union may take advantage of the uncertainty of its opponent and build up a reputation of being tough, enforcing its most favorable outcome.

Our model follows the standard approach on reputation effects started by Kreps and Wilson (1982) and Milgrom and Roberts (1982) and continued with Fudenberg and Levine (1989). In particular, our analysis technically relies on the work of Schmidt (1993), who deals with the case of two long run players. We characterize the equilibrium path and the equilibrium payoff of all Sequential Equilibria (SE), instead of calculating the SE of the game. We provide, as preliminary results, an upper bound for the wages offered in equilibrium and a lower bound for the equilibrium payoff of the firm, which play an important role in obtaining the main results of the paper.

In this repeated situation, the firm has strong incentives in finding out which is the true type of union by offering low wages and observing the union's behavior. This is what we call the screening activity by the firm. Screening is an investment: the costs are the benefits lost in the strike and the possible gains are the low wages that has to pay thereafter, if the firm discovers the true type of union. We obtain a finite bound in the number of periods in which the firm tries to discriminate and test the union and in which there are strikes, independent of the horizon of the repeated bargaining game. That is, the normal union strikes in order to convince the firm that he is the "fighting" union, while the firm tries to find out the degree of commitment of the normal union to behave as if he were a fighting union. We also provide some comparative statics results. Namely, this finite bound is an increasing function of the patience of the firm and the target wage of the fighting union. And, a decreasing function of the prior beliefs about the union's strength, the fall-back position of the union and the profitability of the firm.

Finally, we characterize the equilibrium for a sufficiently long horizon. We show that the firm will not try to discriminate until the last periods of the game, because she knows that the union has strong incentives to build up his reputation, by rejecting low wages and calling a strike. Then, the union can get the highest wage in almost all periods except for the end of the game. Therefore, in our model, we obtain wage rigidity without strikes for most of the periods. In this sense, it is more accurate not to talk about "reputation building" by means of striking, but to say that the union can use the incomplete information to credibly threaten to behave as if he were a fighting union.

The rest of the paper is organized as follows. Section 2 describes the repeated wage bargaining game. Section 3 presents some preliminary results characterizing wage offers and payoffs on the equilibrium set. The core of the paper is Section 4, in which we analyze the screening activity by the firm. In section 5 we characterize the equilibrium showing wage rigidity. Finally, section 6 concludes.

2. The Wage Bargaining Model.

A union and a firm bargain over a surplus $b > 0$ each period t, in T periods. We suppose that the biggest wage that the union can obtain, is always smaller than the surplus b. We make this assumption in order to guarantee that the worst wage agreement for the firm is better than always suffering a strike. This assumption seems realistic and, from a technical point of view, avoids some uninteresting indifference cases. The stage game G is as follows: in each period t the firm proposes a wage offer w_t from the set $W = [0, b)$. The union then responds by either accepting the offer (A) or rejecting it. If the union accepts the offer, the bargaining is over, and the unions's share is w_t and the firm's share is $b - w_t$ in that period. If the union rejects the wage offer, the union must then make a decision, to strike (RS) or not to strike (RNS). If the union decides not to strike that period, workers work and receive w_o, and the firm obtains the revenue b minus the wage bill, that is, $b - w_o$. The wage w_o is considered the wage which is paid to the workers in the non-unionized sector. It reflects their participation constraint: the firm cannot enforce a lower wage because the workers would leave the firm and would go to an alternative sector. If the union decides to strike, workers lose their wage that period, and the firm does not earn $b - w_o$, each party's payoff in this period is normalized to zero, although this is not necessary.

Note that we have a stage game in which all the bargaining power is on the side of the firm. If we had complete information, the unique Subgame Perfect Equilibrium (SPE) outcome in the stage game would be $(w_o, b - w_o)$ without strikes. We have chosen such a model for two reasons. Firstly, to simplify the model. An alternating offers bargaining model would provide more realism, but it would be extremely complex as a stage game. And secondly, it is known that the results of the reputation effects are favorable to the informed party. Therefore, if in addition to this situation we add more bargaining power in the procedure to the union, we can bias the outcome. Thus, we prefer to isolate the reputation effect conceding all the bargaining power to the uninformed party, that is, the firm.

In any case, we do not feel that this is a strong assumption because if we had another stage game, for example, an alternating offers model with complete information and finite horizon, (Fernandez and Glazer (1991) and Haller and Holden (1990)), it would also yield $(w_o, b - w_o)$ with no strikes,as the unique SPE outcome.

Let G^T denote the stage game G repeated T times, $T < \infty$. Time is counted backwards, where 1 is the last period. The game G^T represents the repeated collective negotiations between a firm and a union involved in a long-run relationship. Intuition suggests that the union could use the strike, in this repeated situation, to threaten the firm in order to obtain a higher wage. Nevertheless, as it is easy to check, the unique SPE outcome of G^T has the firm offering $w_t = w_o$ in every period and the union accepting without striking.

We will assume in what follows, that there is a particular kind of incomplete information. Namely, there is a positive probability, μ^*, that there exists a type of union, which we will call the "fighting union",U^*, for which the dominant strategy in the repeated game is the following one: "Accept w only if it is greater or equal than w^*, otherwise strike", where $b > w^* > w_o$. This is the "commitment type" in the same sense of Fudenberg and Levine (1989). This type of union is "committed" to accept a wage w if and only if it is higher than a certain level w^*. The intuition behind the results we are going to obtain is that the normal type of union (U) can use the existence of a such a "fighting" type of union to credibly threaten to behave as if he were committed to this strategy as well.

Let h_t be a history of the repeated game out of the set $H_t = ([0, b) \times \{A, RNS, RS\})^{T-t}$ of all possible histories up to but not including period t, where A denotes Acceptance, RNS means Rejection without strike and RS stands for Rejection and strike. A (behavioral) strategy of the firm is a sequence of functions, $\sigma_t^F : H_t \rightarrow [0, b)$.

In an abuse of notation, a (behavioral) strategy of the normal union is a sequence of functions $\sigma_t^U : (H_t \times W) \rightarrow \sum^U$, where $\sum^U$ is the set of all probability distributions over $\{A, RNS, RS\}$.

Let $\mu_t^*(h_t)$ denote the updated probability the firm assigns to the event U* given that she observed the history h_t.

The firm (union) discounts her (his) payoff in future periods with the discount factor $\delta_f < 1$ ($\delta_u < 1$) . The expected payoffs of the firm from the beginning of period t for the rest of the game are given by:

$$V_t^F = E_t \left\{ \sum_{j=0}^{t-1} \delta_f^j \cdot [x_{t-j}(w_{t-j}) \cdot (b - w_{t-j}) + y_{t-j}(w_{t-j}) \cdot (b - w_o)] \right\},$$

where E_t is the expectation operator and $x_{t-j}(w_{t-j})$ is the probability that w_{t-j} is accepted in period $t-j$ given the history up to period $t-j$ and $y_{t-j}(w_{t-j})$ denotes the probability that w_{t-j} is not accepted but the strike is not called given the history up to period $t-j$.

We can a obtain similar expected payoff for the normal union:

$$V_t^U = E_t \left\{ \sum_{j=0}^{t-1} \delta_u^j \cdot [x_{t-j}(w_{t-j}) \cdot (w_{t-j}) + y_{t-j}(w_{t-j}) \cdot (w_o)] \right\}.$$

The appropriate solution concept for this game with incomplete information is the notion of sequential equilibrium (SE) as developed by Kreps and Wilson [1982]. We are not going to compute the SE, but instead we want to characterize the equilibrium path and the equilibrium payoffs of all SE, using the methods introduced by Fudenberg and Levine (1989) and Schmidt (1993).

3. Some preliminary results.

The bargaining game, as we commented above, is modelled in such a way that, if the firm knew the union is the normal one, she would offer no more than w_o, which would be accepted by the normal union and no strike would take place in equilibrium. The following lemma provides an upper bound for the wages offered in equilibrium and a lower bound for the equilibrium payoff of the firm in the game with incomplete information.

Lemma 1. *If $\mu_t^* > 0$, then on the equilibrium path of every SE both types of union will accept any wage offer $w_t \geq w^*$ and the firm will offer $w_t \leq w^*$. The expected equilibrium payoff for the firm from period t onwards is bounded below by:*

$$\underline{V}_t^F = \sum_{j=0}^{t-1} \delta_f^j \cdot (b - w^*).$$

If $\mu_t^* = 0$, then the firm will offer $w_t \leq w_o$ and the union will always accept any $w_t \geq w_o$.

Proof. We will prove this lemma by induction. If the firm offers w^* in the last period, both types of union will accept. With $\mu_1^* > 0$, the firm would offer $w_1 \leq w^*$, and at least would obtain $\underline{V}_1^F = (b - w^*)$ by offering w^*.

Suppose this result is true for period t. In period $t+1$ we assume $\mu_{t+1}^* > 0$, and suppose that the firm offers $w_{t+1} \geq w^*$. If the union rejects the firm's offer, then the conclusion that the firm has to take out is that she faces a normal union, because the fighting union would have accepted the offer (the normal union has revealed his type) and in the future the firm will not offer more than w_o (recall that we are assuming that the lemma holds for period t). Therefore, both types of union will always accept any $w_{t+1} \geq w^*$.

If the firm offers $w_{t+1} \geq w^*$ in equilibrium, both types of union will accept, therefore the same posterior beliefs about the union's types remain, $\mu_t^* = \mu_{t+1}^* > 0$. It can be checked that with two types of union, the continuation payoffs in any SE are unique for given posterior beliefs. Therefore, it is better for the firm to offer the smaller wage $w_{t+1} = w^*$, that is, the firm will never offer $w_{t+1} > w^*$.

Suppose the firm offers $w_{t+1} = w^*$ from period $t+1$ onwards. By the inductive hypothesis all these wage offers will be accepted and the payoff of the firm is bounded below by $\underline{V}_t^F = \sum_{j=0}^{t-1} \delta_f^j \cdot (b - w^*)$.

Note that whenever $\mu_t^* = 0$, we are back in the complete information model in which the unique SPE outcome is $w_t = w_o$ with no strikes.

■

The union will never accept a wage below w_o, that is, the wage which he can guarantee himself, and if it is offered a wage greater than w_o, it will never choose the action "Reject and not to strike". This is stated in Lemma 2.

Lemma 2. *In equilibrium the union never accepts $w_t < w_o$.*

If the firm offers $w_t > w_o$ (where $w^* > w_t$) the union will never choose the action "Reject and not to strike"

Proof. In the first case, $w_t < w_o$, the union will never accept w_t in equilibrium because he has a strategy, namely, rejecting and not striking which yields to him at least w_o. Suppose the union accepts $w_t < w_o$. Then, he reveals that is a normal union and his payoff will be w_t in that period, and w_o at most in the subsequent periods by the previous lemma. If he rejects this offer and does not strike, he gets w_o in that period and the same wage in the subsequent periods (because he also reveals his type). Therefore, the union prefers not to accept.

In the second case, if $w_t > w_o$ (and $w^* > w_t$), by similar reasons as those given above, the action "Accept" gives bigger payoffs than "Reject and not to strike". Both actions reveal that the union is the normal type, which implies subsequent payoffs of w_o, but in the current period t, if the union accepts the offer obtains w_t, which is greater than w_o. ■

Notice that the preceding lemmata imply that if the "fighting" union has positive probability, then in any equilibrium there will exist with positive probability a history in which w_t is accepted if and only if $w_t \geq w^*$.

4. Screening by the Firm and Strikes.

Our analysis in this section will focus in a history in which w_t is accepted if and only if $w_t \geq w^*$. The firm's uncertainty about the existence of the fighting union is what the normal union uses to threaten the firm to obtain a higher wage. The normal union has an incentive to imitate the fighting union in order to get a higher wage, by means of striking if he is offered a lower wage than w^*.

The firm can always concede the high wage in order to avoid the strike, but her payoff in the bargaining game will be the lowest, i.e., $b - w^*$. In case she refuses to offer the high wage w^*, she can face two possible situations. If a strike follows, she will lose her gains, but if the union accepts the lower offer, then he reveals his type of normal union and the firm would obtain her highest payoff in each period, - $(b - w_o)$-, thereafter. Hence, the firm has strong incentives to find out which is the true type of union by offering lower wages than w^*, and observing the union's behavior. This is what we call the screening activity by the firm.

The main question we want to analyze in this section, is the existence of a limit in the number of periods in which the firm will offer wages lower than w^* and suffer a strike, that is, the screening activity. The response to this question requires to answer a previous one about the existence of a critical value on the probability of strike, above which the firm is not interested in screening. The firm has to compare the potential gains with the expected losses of screening. The former are due to the possibility of discovering the true type of union, what would enable the firm to offer no more than w_o, whereas the latter are the gains lost in the strike periods. This comparison will clearly depend on the probability that the firm assigns to the occurrence of a strike. The intuition suggests that the higher is the probability of strike, the lower will be the number of periods of screening.

We shall demonstrate that there exists a critical value in the probability of strike in the case of a sequence of short-run firms, each of whom lives only for one period, or alternatively, $\delta_f = 0$. That is, above this value, any short-run firm will no longer offer lower wages.

It is clear that a lower bound for the equilibrium payoff of a short-run firm is $(b - w^*)$. Thus, if she offers $w_t < w^*$ in equilibrium it must be true that,

$x_t(w_t) \cdot (b - w_t) + y_t(w_t) \cdot (b - w_o) + z_t(w_t) \cdot 0 \geq (b - w^*)$,

where $x_t(w_t)$ is the probability of "Acceptance" of the wage offer w_t in period t, $y_t(w_t)$ is the probability of "Rejection" of w_t but without striking and $z_t(w_t)$ is the probability of "Rejection" of w_t and calling a strike.

We have to distinguish whether w_t is greater or smaller than w_o.

If $w_t \leq w_o$, we can prove that $x_t(w_t) = 0$. We know that the probability of acceptance of this wage offer for the normal union, will be zero by Lemma 2, that is, Prob(U, A) $= 0$. The probability of acceptance of $w_t \leq w_o$ for the fighting union, by definition, will also be zero, that is, Prob(U*, A) $= 0$. Therefore, $x_t(w_t) = \mu_t \cdot \text{Prob}(U^*, A) + (1 - \mu_t) \cdot \text{Prob}(U, A) = 0$.

If $x_t(w_t) = 0$, $y_t(w_t) \cdot (b - w_o) \geq (b - w^*)$, then as $x_t + y_t + z_t = 1$,

$(1 - z_t(w_t)) \cdot (b - w_o) \geq (b - w^*)$, that is,

$$\frac{w^* - w_o}{b - w_o} \geq z_t \text{ with } w_t \leq w_o$$

If the probability of rejection and strike is "smaller" than a critical value, then it is better for the firm to offer $w_t \leq w_o$. The firm has to consider the potential gains from offering a low wage, that is, $(w^* - w_o)$ versus the expected loss $(b - w_o)$ if a strike is called with probability z_t. For the firm, to offer low wages in the short run will be profitable, if the value of z_t is small. If the firm believes that z_t is big, that is, the firm thinks that the union will reject the wage offer and strike with high probability, then she will not offer a low wage because the potential gain is smaller than the expected loss.

If $w_t > w_o$ (where $w^* > w_t$), we can prove that $y_t(w_t) = 0$.

The event "Rejection without strike" is dominated by "Acceptance" if $w_t > w_o$, thus the probability of rejecting without strike of the normal union is zero by Lemma 2, that is, Prob(U, RNS) = 0. We also know that the probability of the same event by the fighting union is zero by definition, then, Prob(U*, RNS) = 0.

Therefore $y_t(w_t) = \mu_t \cdot \text{Prob}(U^*, RNS) + (1 - \mu_t) \cdot \text{Prob}(U, RNS) = 0$

If $y_t(w_t) = 0$, $x_t(w_t) \cdot (b - w_t) \geq (b - w^*)$, then $(1 - z_t) \cdot (b - w_t) \geq (b - w^*)$, that is,

$$\frac{w^* - w_t}{b - w_t} \geq z_t \text{ with } w_t > w_o.$$

Now the interpretation for the firm is again the same as the previous one, that is, if the net gain of offering $w_t > w_o$ is greater than the expected loss of a strike, the firm will offer w_t. The value of z_t plays a key role to establish the firm's offer. If z_t is higher than a critical value is better for the firm to offer w^*.

Summarizing, in the case of a sequence of short-run firms, there will be an upper bound on the probability of striking above which it is not optimal to offer $w_t < w^*$.

However, this will not typically be true in the case of a long-run firm. This one is concerned about her present and her future payoffs, so she may trade off losses today against gains tomorrow. It might be profitable for the firm to invest in collecting information in the beginning of the game, i.e., to "discover" the strength of the union with wage offers lower than w^*, even if the probability of strike is high. However, this probability can not be always arbitrarily high. Even for a long run player, the following proposition shows that for screening to be profitable there are limits in the probability of strike. In other words, the screening activity is not independent of the probability of rejection and strike of the union.

Set an integer M,

$$M \geq N = \frac{\ln(b - w^*) + \ln(1 - \delta_f) - \ln(b - w_o)}{\ln \delta_f} > 0.$$

Define a number η such that,

$$\eta = 1 - \frac{(b - w^*) \cdot (1 - \delta_f)}{b - w_o} + \delta_f^M > 0.$$

Proposition 1. *Assume $\mu^* > 0$. Take a history h_t in equilibrium in which all wage offers w_t have been accepted if and only if $w_t \geq w^*$. If there have been M*

wage offers $w_t < w^*$ along such a history, at least one of them must have had a probability of rejection and strike of at most η.

The intuition behind this proposition is easy. We know that there is a lower bound for the equilibrium payoff of the firm, that is, $\underline{V}_t^F = \sum_{j=0}^{t-1} \delta_f^j \cdot (b - w^*)$. Therefore, if the firm offers $w_t < w^*$ is because she can expect a payoff of at least $\underline{V}_t^F$. We also know that the upper bound for the equilibrium payoff of the firm is $\overline{V}_t^F = \sum_{j=0}^{t-1} \delta_f^j \cdot (b - w_o)$. Now suppose the firm "invests" in screening the type of union by making M wage offers smaller than w^*, although the firm believes that each of them will be rejected with a probability higher than η. We have constructed η and M such that if the firm makes M wage offers smaller than w^*, each of them having a probability of strike more than η, then her highest possible expected payoff is smaller than $\underline{V}_t^F$, a contradiction.

Proof. The proof is by contradiction. If $\mu^* > 0$, there exists a history h_t in which the union has accepted w_{t+j} iff $w_{t+j} \geq w^*$ $(j = 1, ...T - t)$. Consider a strategy of the firm which chooses wages lower than w^* along h_t in at least M periods with positive probability and suppose that the probability of rejection and strike for each of the first M of these offers is higher than η. We will show that this cannot be true in equilibrium, because then the firm would get less than the lower bound of her equilibrium payoff.

We call $\tau_1, \tau_2, ..., \tau_M$ the first M periods in which wage offers lower than w^* are offered with positive probability. Let $V_{\tau-1}^F(w_\tau, RS)$ be the expected equilibrium payoff from the beginning of the period $\tau - 1$ onwards for the rest of the game, given the history up to but not including period τ and given that in period τ the wage w_τ was rejected and a strike took place. In period τ_1, when the first wage $w_{\tau_1} < w^*$ (but consider that all $w_\tau > w_o$) is offered, the expected payoff for the rest of the game is given by:

$$
\begin{aligned}
V^F_{\tau_1}(w_{\tau_1} \quad < \quad & w^*) = (1 - z_{\tau_1}(w_{\tau_1})) \cdot [(b - w_{\tau_1}) + \delta_f \cdot \sum_{j=1}^{\tau_1 - 1} \delta_f^j \cdot (b - w_o)] + \\
& + z_{\tau_1}(w_{\tau_1}) \cdot [0 + \sum_{j=\tau_1 - 1}^{\tau_2} \delta_f^j \cdot (b - w^*)] \\
& + z_{\tau_1}(w_{\tau_1}) \cdot (1 - z_{\tau_2}(w_{\tau_2})) \cdot \delta_f^{\tau_1 - \tau_2} \cdot [(b - w_{\tau_2}) + \delta_f \cdot \sum_{j=1}^{\tau_2 - 1} \delta_f^j \cdot (b - w_o)] \\
& + ... + \\
& + \prod_{j=1}^{M-1} (z_{\tau j}(w_{\tau j})) \cdot \sum_{j=\tau_1 - \tau(M-1)}^{\tau_1 - \tau_M - 1} \delta_f^j \cdot (b - w^*) \\
& + \prod_{j=1}^{M-1} (z_{\tau j}(w_{\tau j})) \cdot (1 - z_{\tau_M}(w_{\tau_M})) \cdot \delta_f^{\tau_1 - M} \cdot [(b - w_{\tau_M}) + \delta_f \cdot \sum_{j=1}^{\tau_M - 1} \delta_f^j \cdot (b - w_o)] \\
& + \prod_{j=1}^{M-1} (z_{\tau j}(w_{\tau j})) \cdot [0 + \delta_f^{\tau_1 - \tau_M + 1} \cdot V^F_{\tau_M - 1}(w_{\tau_M}, RS).
\end{aligned}
$$

In the case $w_\tau < w_o$, the expression is similar, but replacing w_τ by w_o. (See Lemma 2).

Note that for all j, $j = 0, 1, ..., M$.

$$
(b - w_{\tau j}) + \delta_f \cdot \sum_{j=1}^{\tau_1 - 1} \delta_f^j \cdot (b - w_o) \leq \sum_{j=0}^{\tau j - 1} \delta_f^j \cdot (b - w_o) < \frac{b - w_o}{1 - \delta_f},
$$

and that,

$$V^F_{\tau_M-1}(w_{\tau_M}, RS) \leq \sum_{j=0}^{\tau_M-2} \delta_f^j \cdot (b - w_o) < \frac{b - w_o}{1 - \delta_f}.$$

If we suppose, that $(1 - z_{\tau j}(w_{\tau j})) < (1 - \eta)$, $j = 0, 1, .., M$.

And as we know that a probability has to be smaller than one, $z_{\tau j} \leq 1$, then,

$$\begin{aligned} V^F_{\tau_1}(w_{\tau_1} &< w^*) < (1-\eta) \cdot \frac{b - w_o}{1 - \delta_f} + \sum_{j=\tau_1-1}^{\tau_2} \delta_f^j \cdot (b - w^*) \\ &+(1-\eta) \cdot \delta_f^{\tau_1-\tau_2} \cdot \frac{b - w_o}{1 - \delta_f} + ... \\ &...... + \sum_{j=\tau_1-\tau(M-1)}^{\tau_1-\tau_M-1} \delta_f^j \cdot (b - w^*) + \\ &+(1-\eta) \cdot \delta^{\tau_1-\tau_M} \cdot \frac{b - w_o}{1 - \delta_f} + \delta^{\tau_1-\tau_M+1} \cdot \frac{b - w_o}{1 - \delta_f}. \end{aligned}$$

If we group together the first and the last term of this expression, it is easy to check that η has been chosen such that,

$$(1-\eta) \cdot \frac{b - w_o}{1 - \delta_f} + \delta^{\tau_1-\tau_M+1} \cdot \frac{b - w_o}{1 - \delta_f} \leq (b - w^*).$$

We can also check that $(1-\eta) \cdot \delta_f^{\tau_1-\tau j} \cdot ((b - w_o)/(1 - \delta_f)) < \delta_f^{\tau_1-\tau j} \cdot (b - w^*)$.

Thus, if we combine all the terms, we have:

$$V^F_{\tau_1}(w_{\tau_1} \quad < \quad w^*) < (b - w^*) + \sum_{j=\tau_1-1}^{\tau_2} \delta_f^j \cdot (b - w^*) + \delta_f^{\tau_1-\tau_2} \cdot (b - w^*) + ...$$

$$
\begin{aligned}
&\ldots.. + \sum_{j=\tau_1-\tau_{(M-1)}}^{\tau_1-\tau_M-1} \delta_f^j \cdot (b - w^*) + \delta_f^{\tau_1-\tau_M} \cdot (b - w^*) \\
= &\sum_{j=0}^{\tau_1-\tau_M} \delta_f^j \cdot (b - w^*) \leq \sum_{j=0}^{\tau_1-1} \delta_f^j \cdot (b - w^*).
\end{aligned}
$$

But this is a contradiction, because the gains of the screening activity can not be smaller than the lower bound for the equilibrium payoff of the firm, if we are in equilibrium. Therefore, if there are M wage offers lower than w^*, then at least one of them has to have a probability of rejection and strike smaller than η. ■

Now, we are ready to answer the main question with which we started this section. Whether along a history where all wage offers $w_t < w^*$ have been rejected, there is a limit on the number of times in which the firm will offer these lower wages. The answer is affirmative. The firm will offer wages lower than w^* at most K times in equilibrium, where K is a finite number depending on $\delta_f, b, w^*, w_o, \mu^*$, but independent of T. Thereafter, she will offer $w_t = w^*$ until the game ends. The intuition behind this result is the following: if the firm repeatedly offers wages smaller than w^*, she eventually expects that for some of these wages, a strike will not be called with a high probability. However, only the normal union may accept $w_t < w^*$. Hence, if $w_t < w^*$ is rejected, the updated probability that it is the fighting union increases. If the firm has expected w_t to be rejected with probability smaller than $\eta > 0$, then the updated probability that it is the fighting union after w_t has been rejected has to increase by a non negligible amount. But, this cannot be more than 1. Therefore, this can happen only in a finite number of periods. In others words, if the union has rejected wage offers lower than w^* often enough, then the updated probability that she is the fighting type of union becomes so high that the firm will not try to discriminate anymore.

Proposition 2. . *Let $\delta_f \in [0,1), \delta_u \in [0,1), b > w^* > w_o > 0, \mu^* > 0$, and let $[m]$ denote the integer part of m. Consider any equilibrium of G^T and any history consistent with this equilibrium along which the union has accepted w if and only if $w \geq w^*$. Along such a history there cannot be more than K wage offers $w < w^*$, where:*

$$K = K(\delta_f, b, w_o, w^*, \mu^*) = M \cdot \left(\left[\frac{\ln \mu^*}{\ln \left(\frac{(w^*-w_o)+\delta_f \cdot (b-w^*)}{b-w_o} + \delta_f^M \right)} \right] + 1 \right),$$

with

$$M = [N] + 1 = \left[\frac{\ln(1-\delta_f) + \ln(b-w^*) - \ln(b-w_o)}{\ln \delta_f} \right] + 1 \geq 1.$$

Proof. The proof is by contradiction. If $\mu^* > 0$, we know that there exists a history h^*, along which the union accepts w iff $w \geq w^*$, in every equilibrium of G^T. Suppose there is an equilibrium in which the firm has offered $w_t < w^*$ more often than K times. As we know, $\mu_t^* = \mu_t^*(h_t)$ stands for the updated probability that it is the fighting union given history h_t. By Lemma 1 we know that wages higher or equal than w^* will be accepted by both types of union, so the firm can not change her probability assessment if $w_t \geq w^*$ has been accepted. Wages lower than w^* will be rejected for sure by the fighting union. Firstly, we have to prove that for a history h_t^*- the history h^* truncated at period $t-$ the updated probability $\mu_t^*(h_t)$ is nondecreasing in t.

We want to show that $\mu_{t-1}^* \geq \mu_t^*$, where,

$$\mu_{t-1}^* = \Pr(U^* \mid h_{t-1}) = \Pr(U^* \mid RS, h_t).$$

Note that $\mu_{t-1}^* \geq \mu_t^*$ is equivalent to:

$$\begin{aligned} & \frac{\Pr(U^* \mid h_t) \cdot \Pr(RS \mid U^*)}{\Pr(U^* \mid h_t) \cdot \Pr(RS \mid U^*) + (1 - \Pr(U^* \mid h_t)) \cdot \Pr(RS \mid U)} \\ \geq \; & \Pr(U^* \mid h_t) = \mu_t^*. \end{aligned}$$

This inequality is equal to:

$$\frac{\Pr(RS \mid U^*)}{\Pr(U^* \mid h_t) \cdot \Pr(RS \mid U^*) + (1 - \Pr(U^* \mid h_t)) \cdot \Pr(RS \mid U)} \geq 1,$$

which is,

$$\Pr(RS \mid U^*) \cdot (1 - \Pr(U^* \mid h_t)) \geq (1 - \Pr(U^* \mid h_t)) \cdot \Pr(RS \mid U),$$

that is,

$$\Pr(RS \mid U^*) \geq \Pr(RS \mid U),$$

which is satisfied since $\Pr(RS \mid U^*) = 1$. Therefore, we have shown that $\mu_t^*(h_t)$ is not decreasing in t.

Now divide the K (or more) wage offers lower than w^* into successive blocks of M, and consider the first block of M of them. By Proposition 1 we know that at least one of them (call it w_{τ_1}) must have a probability of rejection and strike of at most η. Therefore, the updated probability of being the fighting union, after w_{τ_1} has been rejected is:

$$\begin{aligned}
\mu_{\tau_1-1}^* &= \Pr(\text{Type of union is } U^* \mid w_{\tau_1} \text{ is rejected and there is a strike in } \tau_1) \\
&= \frac{\Pr(\text{Type of union is } U^* \text{and } w_{\tau_1} \text{ is rejected and there is a strike in } \tau_1)}{\Pr(w_{\tau_1} \text{ is rejected and there is a strike in } \tau_1)} \\
&= \frac{\mu_{\tau_1}^*}{z_{\tau_1}(w_{\tau_1})} \geq \frac{\mu_{\tau_1}^*}{\eta} \geq \frac{\mu^*}{\eta}.
\end{aligned}$$

Now take the second block of M wage offers lower than w^*. Again at least one of them (w_{τ_2}) has a probability of rejection and strike smaller than η . This gives:

$$\mu_{\tau_2-1}^* \geq \frac{\mu_{\tau_2}^*}{\eta} \geq \frac{\mu_{\tau_1-1}^*}{\eta} \geq \frac{\mu^*}{\eta^2}.$$

Consider the nth block of M wage offers lower than w^* and denote by $w_{\tau n}$ one of the offers with a probability of rejection and strike lower than η. By induction the updated probability $(\mu_{\tau n-1}^*)$ after $w_{\tau n}$ has been rejected is bounded below by:

$$\mu^*_{Tn-1} \geq \frac{\mu^*}{\eta^n}.$$

However, $\mu^*_{Tn-1} \leq 1$. Therefore, there is an upper bound for n, namely,

$$n \leq \frac{\ln \mu^*}{\ln \eta}.$$

Substituting for η gives,

$$n \leq \frac{\ln \mu^*}{\ln \left(1 - \frac{(1-\delta_f)\cdot(b-w^*)}{b-w_o} + \delta_f^M\right)}.$$

Thus, an upper bound for the number of periods in which wage offers smaller than w^* are offered and rejected and a strike is called on the equilibrium path is given by:

$$K(\delta_f, b, w_o, w^*, \mu^*) = M \cdot \left(\left[\frac{\ln \mu^*}{\ln \left(\frac{(w^*-w_o)+\delta_f\cdot(b-w^*)}{b-w_o} + \delta_f^M \right)} \right] + 1 \right).$$

Note that K is increasing in M, so choosing $M = [N] + 1$ minimizes K. ■

Proposition 2 reflects the most interesting result of our paper. It establishes a clear bound in the number of periods in which the firm tries to discriminate and test the union and in which there are strikes. That is, the normal union strikes in order to convince the firm that he is the "fighting" union, while the firm tries to find out the degree of commitment of the normal union to behave as if he were a fighting union.

It is important to understand that the firm, after this K periods of strike, does not become convinced that the union is the fighting union, even if he strikes in every period whenever $w < w^*$. Rather, the firm becomes convinced that the normal union will behave as if he were the fighting one.

The above formula on K, allows us to obtain some intuitive comparative statics results on the dependence of K on the parameters $\delta_f, w_o, w^*, \mu^*$ and b.

- **K is an increasing function of δ_f, the discount factor of the firm.** If the firm is more patient, then future gains become more important and she may offer wages lower than w^* with a higher probability of rejection and strike in order to invest in gathering information. This effect increases the number of periods in which wages lower than w^* can be offered and, if it is the case, rejected. On the other hand, if $\delta_f \to 0$ it is easy to see that $N \to 0$ and,

$$K(0, b, w_o, w^*, \mu^*) = \left[\frac{\ln \mu^*}{\ln \frac{(w^* - w_o)}{b - w_o}} \right].$$

Note that this bound depends only on the initial beliefs about the union's type, and, as we can see in the denominator, on the critical probability of rejection and strike obtained previously for a sequence of short-run firms.

- **K is a decreasing function of μ^*, the prior beliefs of the firm** that she is facing a fighting union. The bigger μ^*, the less updating is needed to reach the point where μ_T^* would become higher than 1, and the smaller is K.

- **K is an increasing function of w^*, the target wage of the fighting union.** If w^* is high, then the cost of screening (and suffering strikes) is low in relative terms. The strikes provide to the firm a gain of zero, whereas if there is no strike, paying a high wage, yields to the firm $b - w^*$. On the other hand, the potential gains of discovering the union type are bigger if $w^*$is high, - $(b - w_o)$ versus $(b - w^*)$ -, therefore K increases with w^*. Notice that in the limit if $w^* \longrightarrow b$, then there is no bound in K. The intuition behind this result, is that the firm would be almost indifferent between offering $w = w^*$ and not doing so and suffering a strike.

The preceding discussion illustrates an apparent paradox. On one hand, the normal union seems interested in imitating a "very fighting" union characterized by the highest possible w^*. But, on the other hand, as w^* gets higher, increases the incentive of the firm to discriminate and resist the threat of strike. These opposite effects would imply that the "optimal" w^*, from the union's point of view, would be bounded away from b.

- **K is a decreasing function of w_o, the participation constraint or the fall-back position of the union.** The bigger w_o, the lower upper bound to the expected payoff of the firm. The potential gain of screening is lower, thus, in order to pay the screening cost and suffering a strike, the firm needs a smaller rejection and strike probability, what makes K lower.

- **K is a decreasing function of b, the profitability or added value**

of the firm. The reason is that the lower bound for the equilibrium payoff of the firm is increasing with b. Thus, if she risks offering wage proposals smaller than w^*, the possible loss is bigger and therefore the probability of rejection and strike must be smaller, what makes K smaller. But, at the same time $(b - w_o)$ increases, and the incentives to screen rise. This implies that K would be bigger. Therefore we observe two opposite effects on K, but it can be shown that the first one predominates, yielding an overall effect of reducing the value of K.

5. Wage Rigidity and Equilibrium Characterization.

This section deals with the case of a repeated bargaining game with a sufficiently long horizon. Suppose the normal union decides to build up a reputation of being "tough" imitating the fighting union. It follows from Proposition 2 that there will be at most $K(\delta_f, b, w_o, w^*, \mu^*)$ wage offers lower than w^*. If the union rejects $w_t < w^*$ and calls a strike often enough, the probability that he is the fighting union increases until it becomes so big that the firm will no longer try to wage discriminate. In this sense, the union may invest repeatedly in the reputation of being the fighting union. The costs of this investment are the lost wages in the strike. The returns are the high wages w^*, which he will get for sure after K such rejections and strikes.

The worst that can happen to him is that these K wage offers lower than w^* are offered and have to be rejected and a strike called, and that this happens in the first K periods of the game. In this case he would get 0 in the first K periods and w^* thereafter.

Hence, a lower bound for the equilibrium payoff in the game G^T of the normal union is given by:

$$\underline{V}^U = \sum_{j=0}^{K-1} \delta_u^j \cdot 0 + \sum_{j=K}^{T-1} \delta_u^j \cdot w^*$$

$$= w^* \cdot \delta_u^K \cdot \frac{1 - \delta_u^{T-K-1}}{1 - \delta_u}.$$

Notice that the union would obtain an equilibrium payoff in the complete information case of:

$$V^U = \sum_{j=0}^{T-1} \delta_u^j \cdot w_o = w_o \cdot \frac{1 - \delta_u^{T-1}}{1 - \delta_u}.$$

Observe that if the lower bound for the equilibrium payoff of the normal union, in the incomplete information model, is strictly greater than the equilibrium payoff that the union would obtain in the complete information model, then the union would be very interested in imitating the fighting union.

Thus, Proposition 2 tells us that in principle the normal union can build up this reputation. The question that arises is whether there are equilibria with the normal type of union investing in his reputation in the beginning of the game in order to get better wage offers thereafter. The answer is negative, for the paradoxical reason that the incentives to do so are too big. The normal union would want to build up this reputation as long as the end of the game is not too close. Hence, he would reject wage offers lower than w^*, but anticipating this, the firm will offer $w = w^*$ in all periods before the end of the game. Therefore, the type of the union will not be tested in the beginning of the game, the probability that he is the fighting union will remain at μ^*, and there is no reputation building in all, but perhaps, some of the last finite number of periods.

Proposition 3. . *Let* $\delta_f \in [0,1), \delta_u \in (\frac{1}{2-\frac{w_o}{w^*}}, 1], b > w^* > w_o > 0$ *and* $\mu^* > 0$. *Define* $L = L(\delta_u)$ *as the smallest integer such that* $\sum_{j=1}^{L} \delta_u^j > \frac{w^*}{w^*-w_o}$.

If $T > K(\delta_f, b, w_o, w^*, \mu^*) \cdot L(\delta_u)$, *then along the equilibrium path of every equilibrium of* G^T *a wage* w^* *is offered in at least the* $T - K \cdot L$ *first periods.*

Proof. Take any equilibrium and set a history h^* in which the union has accepted w iff $w \geq w^*$. From Proposition 2 it is known that after at most K rejections of wage offers lower than w^* the firm will offer a wage of w^* from then on. Suppose there have been $K-1$ such rejections up to period τ_1 and that there are more than L periods left ($\tau_1 > L$). If $w_{\tau_1} < w^*$ is offered and rejected with a strike, the payoff of the union from period τ_1 onwards is:

$$V_{\tau_1}^U(w_{\tau_1}, RS) = 0 + \sum_{j=1}^{\tau_1-1} \delta_u^j \cdot w^*.$$

If the union accepts w_{τ_1}, the payoff he can expect is given by:

$$\overline{V}_{\tau_1}^U(w_{\tau_1}, A) = w_{\tau_1} + \sum_{j=1}^{\tau_1-1} \delta_u^j \cdot w_o.$$

"Rejection and strike" is better than "Acceptance" if:

$$\sum_{j=1}^{\tau_1-1} \delta_u^j \cdot w^* \geq w_{\tau_1} + \sum_{j=1}^{\tau_1-1} \delta_u^j \cdot w_o,$$
$$\text{so,} \quad w_{\tau_1} \leq (w^* - w_o) \cdot \sum_{j=1}^{\tau_1-1} \delta_u^j.$$

$$\text{Then, we must show that,} \sum_{j=1}^{\tau_1-1} \delta_u^j \geq \frac{w_{\tau_1}}{w^* - w_o},$$
$$\text{but we know that} \sum_{j=1}^{\tau_1-1} \delta_u^j \geq \sum_{j=1}^{L} \delta_u^j > \frac{w^*}{w^* - w_o},$$
$$\text{thus, as } w_{\tau_1} < w^*, \text{ then, } \sum_{j=1}^{\tau_1-1} \delta_u^j \geq \frac{w_{\tau_1}}{w^* - w_o}.$$

Therefore, the normal union rejects any $w_{\tau_1} < w^*$. Of course, the fighting union always rejects $w_t < w^*$.

Nevertheless, suppose the firm would offer $w_{\tau_1} < w^*$ in equilibrium. Then, her payoff from τ_1 onwards is given by:

$$V_{\tau_1}^F(w_{\tau_1}) = 0 + \sum_{j=1}^{\tau_1-1} \delta_f^j \cdot (b - w^*).$$

A wage offer $\widetilde{w}_{\tau_1} \geq w^*$ would have been accepted with probability 1 yielding a payoff:

$$V_{\tau_1}^F(\widetilde{w}_{\tau_1}) = (b - \widetilde{w}_{\tau_1}) + \delta_f \cdot V_{\tau_1-1}^F(\widetilde{w}_{\tau_1}, A).$$

But we know that the equilibrium continuation payoff $V_{\tau_1-1}^F(\widetilde{w}_{\tau_1}, A)$ has a lower bound. Namely,

$$\underline{V}^F_{\tau_1-1} = \sum_{j=0}^{\tau_1-2} \delta_f^j \cdot (b - w^*), \text{ but, as } \delta_f \cdot V^F_{\tau_1-1} = \sum_{j=1}^{\tau_1-1} \delta_f^j \cdot (b - w^*).$$

Hence, $V^F_{\tau_1}(\widetilde{w}_{\tau_1}) > V^F_{\tau_1}(w_{\tau_1})$. Therefore, the firm will not offer $w_{\tau_1} < w^*$.

We can go on by backward induction: suppose there have been $K-2$ rejections of wage offers lower than w^* up to period τ_2. The union knows that if he rejects an offer $w_t < w^*$, then there will be already $K-1$ rejections, and the firm would not have incentives to screen until there are at least L periods left. Thus, if $\tau_2 > 2 \cdot L$, the union knows that by rejecting he will obtain a wage w^* at least in the next L periods. But the firm, anticipating that both types of union will reject these offers $w_t < w^*$, will offer a wage w^* already in this period. The proof goes on by induction until there have been $K - K = 0$ rejections of wage offers lower than w^*. ∎

Suppose that before the beginning of period T the union could publicly commit never to accept an offer smaller than w^*, otherwise he would always strike. In this commitment version of G^T the unique equilibrium, which will be called the "commitment equilibrium", prescribes that the firm always offers $w_t = w^*$, which the union will always accept. Therefore, in this model we obtain, as a result, wage rigidity without strikes. The following corollary states, in our model, a similar result.

Corollary 1. *Let δ_f,δ_u, w^*,w_o,b and μ^* satisfy $\delta_f \in [0,1)$,$\delta_u \in [\frac{1}{2-\frac{w_o}{w^*}}, 1]$, $0 < w_o < w^* < b$, $\mu^* > 0$. Consider a sequence of games G^T. If T goes to infinity the equilibrium paths of all equilibria of G^T converge to the commitment equilibrium path. That is, there are finite numbers $K = K(\delta_f, b, w_o, w^*, \mu^*)$ and $L = L(\delta_u)$ independent of T such that for all T and $t \geq T - K \cdot L$, the firm offers $w_t = w^*$. If T goes to infinity the equilibrium payoffs of the firm and the union converge to:*

$$V_\infty^F = \frac{b - w^*}{1 - \delta_f} \qquad \textit{and} \qquad V_\infty^U = \frac{w^*}{1 - \delta_u}.$$

Notice that this result holds even if the firm is much more patient than the union, as long as $\delta_f < 1$ and $\delta_u > \frac{1}{2-\frac{w_o}{w^*}}$. Intuitively one might have expected that a patient uninformed firm who deals with a relatively impatient informed union will try to screen the different type of union with wage offers lower than w^* in early periods in order to get more of the surplus thereafter. The previous corollary states that this is not the case. The reason is that as long as $\delta_u > \frac{1}{2-\frac{w_o}{w^*}}$ the normal type of union has a strong incentive to build up the reputation of being the fighting union. Therefore, every type of union will reject $w_t < w^*$ in all but the last finite number of periods. But then there is no way to screen the different types and the firm does better by offering w^*, even if she is very patient.

In summary, the union can get the highest wage in almost all periods except for the end of the game. Thus, in our model, we obtain wage rigidity without strikes for most of the periods. In this sense, it is more accurate not to talk about "reputation building" by means of striking, but to say that the union can use the incomplete information to credibly threaten to behave as if he were a fighting union and getting a high wage.

6. Conclusions.

We have presented in this paper an alternative explanation for strikes to those already existing in the previous literature (basically, strikes as a signalling and/or screening device in a single negotiation when there is some private information). We model wage bargaining as a repeated bargaining game which seems to be closer to observed real-life negotiations. In this context, strikes might be a rational activity for a union if he wishes to build up a reputation of being credibly commited to never accept low wages.

We have shown in this paper how these reputation effects work in wage negotiations between firms and unions, in order to get an equilibrium payoff more favorable to the union. Our model is a finitely repeated bargaining game, where the strike decision is endogenous and there is incomplete information on the union's type that is facing the firm. As a first result, we characterize both the equilibrium path and the equilibrium payoffs of all SE.

An important feature of this approach is that we are able to obtain a finite bound in the number of periods in which the firm tries to discriminate the union's type and in which there are strikes. This bound is independent of the horizon of the repeated bargaining game. This result allows us to provide some comparative statics results. Namely, this finite bound is an increasing function of the patience of the firm and the target wage of the fighting union. And, a decreasing function of the prior beliefs about the union's strenght, the fall-back position of the union and the profitability of the firm. It is also shown that for a sufficiently long horizon, the union can use the incomplete information to credibly threaten with strikes and get a high wage for most of the periods. Therefore, in this case, we obtain wage rigidity.

In this paper we have considered only two types of union. Obviously it seems more realistic to think of many different possible commitment types to which the firm assigns positive probability. It can be checked that this will not affect the qualitative results (whenever we restrict the analysis to the set of SE satisfying the Weak Markov Property, see Schmidt (1993)). We have worked only with two types for simplicity. A much more interesting and future development of our model would be to extend the analysis allowing for two-sided incomplete information, that is, both the union and the firm have uncertainty about the type of player that they are facing.

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