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STRIKING FOR A BARGAIN BETWEEN TWO COMPLETELY INFORMED AGENTS

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ABSTRACT

This paper models the wage-contract negotiation procedure between a union and a firm as a sequential bargaining process in which the union also decides, in each period, whether or not to strike for the duration of that period. We show that there exist subgame-perfect equilibria in which the union engages in several periods of strikes prior to reaching a final agreement, although both parties are completely rational and fully informed. This has implications for other inefficient phenomena such as tariff wars, debt negotiations, and wars in general. We characterize the set of equilibria, show that strikes can occur in real time, and discuss extensions of the model such as lockouts and the possibility of multiple recontracting opportunities.

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1. Introduction:

Economic theory has trouble explaining strikes.[1] As stated by Hart (1989), "The difficulty is to understand why rational parties should resort to a wasteful mechanism as a way of distributing the gains from trade. Why could not both parties be made better off by moving to the final distribution of surplus immediately...and sharing the benefits from increased production?" A similar objection to developing a coherent theory of strikes is what Kennan (1986) calls the "Hicks paradox", namely: "The main obstacle is that if one has a theory which predicts when a strike will occur and what the outcome will be, the parties can agree to this outcome in advance, and so avoid the costs of a strike. If they do this, the theory ceases to hold...If the parties are rational, it is difficult to see why they would fail to negotiate a Pareto optimal outcome."

This paradox has been resolved by resorting to informational imperfections, in particular asymmetric information. Indeed, it is often thought that there are no other possible culprits for these inefficiencies.[2] Card (1988), for example, asserts that "It has long been recognized that any consistent theoretical model of strikes must appeal to some form of imperfect information." The basic idea underlying the asymmetric information bargaining models developed in Admati and Perry (1986), Ausubel and Deneckere (1989), Chatterjee and Samuelson (1987), Cramton (1984), Fudenberg, Levine, Tirole (1985), Grossman and Perry (1986), Hart (1989), Rubinstein (1985), and Sobel

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[1] For a review of the theories that attempt to explain strikes, see Kennan (1986).

[2] Although, of course, bounded rationality could produce inefficient behavior. See Ashenfelter and Johnson (1969) for a bargaining model in which only one side behaves optimally.

and Takahashi (1983) is that strikes, or delays in reaching agreement, are a signalling device. If a firm's profitability is unobservable by workers, then the willingness of a firm to delay agreement and therefore to forego the output associated with such a delay serves as a signal of that firm's lower profits and allows a lower wage agreement to be reached. A high profit firm would prefer to accept the higher wage agreement and obtain the revenue associated with production in those periods. Empirical work by Farber and Bazerman (1989) and by Card (1988), however, casts some doubt on the ability of this kind of theory to explain reality. Moreover, in most asymmetric information models, the Coase conjecture holds. That is, as the length of time separating bargaining periods becomes arbitrarily small, so does the real time of delay (see Gul and Sonnenschein (1988) for a rigorous discussion of this result).

Behind the assertion that imperfect information is the sole force driving strikes lies the implicit belief that, in the absence of informational asymmetries, bargaining between two parties is efficient. Both the cooperative and the non-cooperative bargaining literature can be seen as lending support to that belief. The solution concepts of cooperative bargaining theory, such as the Nash bargaining solution, assume Pareto efficient outcomes. Moreover, the best known examples of Rubinstein's (1982) non-cooperative bargaining model also produce unique and Pareto efficient equilbria.[3]

Our paper's contribution is to show that strikes, and other wasteful phenomena such as wars, can result as equilibrium behavior within a framework

[3]In the example of fixed bargaining costs of c_i per period (where i indexes the name of the player), if $c_1 = c_2$ then it is possible to have inefficient equilibria emerge.

of perfect rationality and complete information. Irrationality or informational asymmetries, while undoubtedly important factors in the explanation of many inefficient activities, are not necessary conditions for these to occur. Bargaining between two perfectly informed agents need not be efficient.

We develop a modified version of Rubinstein's (1982) bargaining model.[4] As in Rubinstein, the two agents - in our case, a union and a firm - are assumed to bargain sequentially over discrete time and a potentially infinite horizon. The union and firm alternate in making offers of wage contracts, which the other party is free to accept or reject. In our model, however, there is also an old wage contract (this is what is being renegotiated). This matters, because upon either party's rejection of a proposed wage contract, the union faces another decision: whether or not to strike that period. If the union chooses to strike, it foregoes the wage that it would have received by not striking and instead working that period. That wage is assumed to be the one stipulated by the old contract. Thus, a decision to strike is costly to both parties. The union does not get paid and the firm does not receive the revenue net of the wage bill. There is no uncertainty in this model and agents possess complete information.

We show that there exist multiple subgame-perfect equilibria, some of which are Pareto inefficient. The latter equilibria can take the following form: along the equilibrium play the union makes very high wage offers which the firm rejects. The firm, in turn, makes very low wage offers which the

[4]After completion of this paper, it has been called to our attention that Haller (1988) and Holden (1989) have developed models very similar to ours. Haller, however, concludes that there are no inefficient equilibria and therefore no strikes in equilibrium since "With complete information and rational players, bargaining is efficient". We show this conclusion to be incorrect.

union rejects. In every period in which an offer is rejected, the union strikes. This behavior continues for T periods, after which time an offer that lies somewhere between the high and low wage offers is both made and accepted. Despite the fact that reaching that same final agreement T periods earlier would be a Pareto improvement, we show that neither party will attempt to deviate from the equilibrium play behavior described above. Any attempt by one of the parties to deviate and reach an earlier agreement results in both the firm and the union thereafter playing an efficient equilibrium, but one which adversely affects the deviating party. Thus, we are able to answer the question posed in the first paragraph as to why it is that rational (and completely informed) agents may engage in inefficient behavior.

The primary purpose of this paper is not so much to propose an alternative theory of strikes as to dispel a popular misconception concerning the necessity of asymmetric information for an explanation of this phenomena. While our model has the less attractive feature that strikes occur only in some of the equilibria, it is also true that strikes in our model are not an artifact of the discrete-time bargaining framework: We show that strikes can occur in real time—they can be lengthy despite agents' ability to negotiate extremely rapidly. Furthermore, our model (or an extension of it) has as an implication that one is "more likely" to observe strikes in boom periods than in periods of recession. This agrees with the empirical finding that strikes tend to be procyclical.[5] Other testable implications of our model include the specification of a range (given by a function of the firm's revenue in the case of no strike and the union's wage in the status quo contract) in which strikes should not be observed.

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[5]See Kennan for a discussion of the empirical work.

The paper is organized as follows: In section 2 we set up the model. We discuss the efficient equilibria in section 3 and the inefficient ones in section 4. Section 4 also shows that strikes can occur in real time. In section 5 we analyze some extensions of the model: we allow the firm to engage in lockouts, and we examine the effect of multiple (predetermined) recontracting opportunities. Section 6 concludes.

2. The Model:

We consider the following situation: two parties - a union (of L identical workers hereafter normalized to equal 1) and its firm - have a contract that specifies the wage that a worker in the union is entitled to per day of work. This contract, however, has come up for renegotiation. The institutional mechanism governing contract renegotiations is assumed to be as follows: the union and firm alternate in making wage offers over discrete time periods $t \in \{1,2,\ldots\}$. In each odd period (a period is here taken for simplicity to be a day) the union proposes a wage contract x_t. The firm then responds (R_t) by either accepting the offer (Y) or rejecting it (N). If the firm accepts the offer, negotiations are over and the newly agreed upon wage contract is assumed to hold thereafter (we later relax this assumption and allow contracts to be renegotiated several, possibly infinite, number of times). If the firm rejects the wage offer, the union must then make a decision S_t: to strike (s) or not to strike (ns). If the union decides not to strike that period, workers work and receive the old wage w_0, $0 \le w_0 \le F$, specified by the pre-existing contract and the firm obtains the revenue F associated with the union's output minus the wage bill, i.e. $F-w_0$. If the union decides to strike, workers forfeit their wage that period and the firm does not earn $F-w_0$. Each party's payoff in this period is normalized to zero.

After the union executes its decision S_t, time advances a period. In every even period, the firm offers the union a wage contract y_t. The union then responds (Q_t) by accepting (Y) or rejecting (N) the firm's proposal. Once again, acceptance implies that this new contract holds thereafter. Rejection of the offer, on the other hand, means that the union must decide whether or not to strike. The same rules govern the consequences of the strike decision as described previously. The decision executed, time advances a period. Note that this bargaining process can last a potentially infinite amount of time. Figure 1 depicts the first two periods of the game.

The firm possesses a discount factor of $0 \leq \delta_f < 1$ and the union a discount factor of $0 \leq \delta_u < 1$. The union's objective is to maximize workers' utility, that is, to maximize

$$\sum_{t=1}^{\infty} \delta_u^{t-1} w_t$$

and the firm's objective is to maximize the discounted sum of profits:

$$\sum_{t=1}^{\infty} \delta_f^{t-1} (F - w_t) \quad .$$

Although the union is assumed to earn w_0 in the non-strike periods prior to signing a new contract, it is also possible to view the negotiation process as including retroactive wage increases. This would not change any of our results, since what matters to the firm and to the union is the appropriately discounted value of earnings. Thus, a new wage contract w can be viewed as consisting partly of retroactive compensation, partly of wage increase.

We will be studying the subgame-perfect equilibria of the game described above. Subgame perfection is the natural refinement of Nash equilibrium for a game with complete information such as ours. Subgame perfection eliminates those equilibria based on "incredible" threats, that is, on threats which an agent would not be willing to carry out (they would be payoff worsening for that player) if actually called upon to do so. That is, subgame-perfect strategies possess the property of inducing Nash equilibria in every subgame of the game, including those subgames that will not be reached along the equilibrium play.

It is convenient to ask what the bargaining outcome would be if the union were precommitted to striking in every period in which it had not reached an agreement with the firm. As we will show, this is tantamount to assuming that the original wage contract does not exist since w_0 is now no longer a possible cost of disagreement.

Lemma 1: If the union is precommitted to striking in every period in which there is a disagreement, then there is a unique subgame-perfect equilibrium to the bargaining game between the union and the firm. This equilibrium has agreement reached in the first period of negotiation and resulting in a wage contract of $\bar{w}$ if bargaining commences in an odd period and a contract of $\bar{z}$ if bargaining commences in an even period, where

$$\bar{w} = \frac{(1-\delta_f)F}{1-\delta_u\delta_f} \qquad \bar{z} = \frac{\delta_u(1-\delta_f)F}{1-\delta_u\delta_f} .$$

Proof: See Rubinstein (1982) or Shaked and Sutton (1984).

Note that $\bar{w}$ and $\bar{z}$ are the solutions to Rubinstein's original bargaining game. The intuition underlying this result is that by having the union committed to striking in every period of disagreement, the game is transformed into Rubinstein's original bargaining model with F being the size of the cake over which both parties are bargaining. Thus, the same solution to the bargaining problem results. $\bar{w}>\bar{z}$ shows that the player who makes the first offer has an advantage in this kind of bargaining game.

3. <u>Efficient Equilibria</u>:

In this section we completely characterize the set of Pareto efficient subgame-perfect equilibria. We first discuss three particular equilibria that are especially useful. One is the minimum wage contract that can be obtained in equilibrium, another is the maximum, and the third one has the property that the union threatens to strike in each period in which an agreement is not reached.

<u>Lemma 2</u>: There is a subgame-perfect equilibrium in which an agreement of w_0 is reached in the first period.

<u>Proof</u>: The pair of subgame-perfect equilibrium strategies given below generate a wage contract of w_0 in the first period.

The union's strategy is never to strike, i.e. $S_t = ns$ for all t, and to offer $x_t = w_0$ in every t odd and in every t even to reply to an offer y_t by:

$$Q_t = \begin{cases} Y & \text{if } y_t \geq w_0 \\ N & \text{otherwise} \end{cases} .$$

The firm's strategy is to offer $y_t = w_0$ in every t even and, when t is odd, to reply to an offer x_t by

$$R_t = \begin{cases} Y & \text{if } x_t \leq w_0 \\ N & \text{otherwise} \end{cases} .$$

It is easy to check that these strategies are subgame perfect.

Note that w_0 is the minimum wage contract that the union can receive since it always has the option of working at the preexisting wage.

Lemma 3:

If $\quad w_0 \le \dfrac{\delta_u^2(1-\delta_f)F}{1-\delta_u\delta_f} - \delta_u\bar{z},$ (C1)

there is a subgame-perfect equilibrium in which an agreement of $\bar{w}$ is reached in the first period.

Proof: Before providing a formal proof of the Lemma, an informal description of the strategies that generate the above equilibrium may be helpful: The union offers the contract $\bar{w}$ in every odd period, accepts any offer greater or equal to $\bar{z}$ in every even period, and strikes in every odd period in which its request for $\bar{w}$ is rejected and in every even period in which it is not offered at least $\bar{z}$. If, however, at some point the union deviates from this rule, then the strategies thereafter call for both players to play according to the strategies described in Lemma 2. In other words, a deviation by the union is punished by it having to accept the old wage contract of w_0.

We can now introduce the following notation. Suppose that the game has reached period t. For every period $\tau<t$ let D_τ be a function of the actions taken in that period such that:

$$D_\tau = \begin{cases} d & \text{if } \tau \text{ is odd and } x_\tau > \bar{w}, \text{ or} \\ & \text{if } \tau \text{ is even and } y_\tau \ge \bar{z} \text{ but } Q_\tau = N, \text{ or} \\ & \text{if } S_\tau = ns \\ nd & \text{otherwise .} \end{cases}$$

D_τ indicates whether or not the union has deviated in period τ. (Note that, strictly speaking, D_τ does not capture all possible deviations since it ignores those offers by the union lower than $\bar{w}$.) If a deviation has occurred in period τ then D_τ=d, if not then D_τ=nd. Similarly, suppose that the play has reached the last move of period t where the union has to decide whether or not to strike. Let D_t be a function of the actions taken previously in period t such that:

$$D_t = \begin{cases} d & \text{if } t \text{ is odd and } x_t > \bar{w}, \text{ or} \\ & \text{if } t \text{ is even and } y_t \geq \bar{z} \text{ but } Q_t = N. \\ nd & \text{otherwise .} \end{cases}$$

The strategies below generate the outcome described above and constitute a subgame-perfect equilibrium. We start with the union's strategy.

In every t odd the union offers x_t where:

$x_1 = \bar{w}$

and, for t>1,

$$x_t = \begin{cases} w_0 & \text{if } \quad D_\tau = d \text{ for some } \tau < t \\ \bar{w} & \text{otherwise .} \end{cases}$$

In every t even, the union's response to an offer y_t is

$$Q_t = \begin{cases} Y & \text{if } y_t \geq \bar{z}, \text{ or if } y_t \geq w_0 \text{ and } D_\tau = d \text{ for some } \tau < t \\ N & \text{otherwise} \end{cases}$$

and, finally, the union's decision of whether or not to strike in period t is:

$$S_t = \begin{cases} ns & \text{if } D_\tau = d \text{ for some } \tau < t, \text{ or if } D_t = d \\ s & \text{otherwise .} \end{cases}$$

The firm's strategy is as follows: In every t even the firm offers

$$y_t = \begin{cases} w_0 & \text{if } D_\tau = d \text{ for some } \tau < t \\ \bar{z} & \text{otherwise .} \end{cases}$$

In every t odd the firm's response to an offer x_t is

$$R_t = \begin{cases} N & \text{if } x_t > \bar{w}, \text{ or if } x_t > w_0 \text{ and } D_\tau = d \text{ for some } \tau < t \\ Y & \text{otherwise .} \end{cases}$$

Notice that, according to the strategies above, once a deviation by the union has occurred, the strategies call for both players to thereafter play the equilibrium strategies of Lemma 2. Thus, in order to show that the above strategies constitute a subgame-perfect equilibrium, we need only to check those subgames that do not follow a deviation by the union. Notice also that the strategies of the players are stationary (i.e., independent of time). Therefore, it is sufficient to check only the first two periods of the game under the assumption that in period t=3 (if reached) the parties will agree on the wage contract $\bar{w}$ if the union has not deviated before (i.e. D_τ=nd for τ=1,2) and that they will agree on the old wage contract w_0 otherwise. The proof proceeds by starting at the last subgame in period t=2 and moving backwards.

Suppose, therefore, that t=2 and that the union was offered a wage $y_2<\bar{z}$ which it rejected i.e., Q_2=N. The strategy then calls for the union to strike, i.e. S_2=s. It has to be shown that this is indeed its best response. Notice that if the union chooses to strike, its payoff will be zero in period 2 and $\bar{w}$ in each period thereafter. If, however, the union chooses not to strike its payoff will be w_0 per period from period 2 onwards By C1, though, $\delta_u\bar{w}>w_0$. Therefore, S_2=s is the best response. If $y_2\geq\bar{z}$ and Q_2=N, then the union should not strike since regardless of the union's decision, next period the settlement is w_0.

Suppose now that we are in the preceding subgame, i.e. t=2 and the union has to respond to an offer y_2. Suppose, first, that $y_2\geq\bar{z}$. If the union's response is "Y" its payoff over the entire game will be $y_2/(1-\delta_u)$ and if its response is "N" its payoff will be $w_0/(1-\delta_u)$. Under C1, $y_2\geq\bar{z}>w_0$ and hence "Y" is the best response. Now assume that $y_2<\bar{z}$. If Q_2=Y the union's payoff will be $y_2/(1-\delta_u)$ and if Q_2=N its payoff will be $\delta_u\bar{w}/(1-\delta_u)$. But $y_2<\bar{z}=\delta_u\bar{w}$, and hence "N" is the union's best response. Thus, in both cases, the union's strategy is indeed a best response.

Moving to the beginning of period 2, we have to show that an offer of $\bar{z}$ maximizes the firm's payoff given the continuation of the game as described by the strategies. If the firm offers $\bar{z}$, the union will immediately accept this offer and the firm's payoff will be $(F-\bar{z})/(1-\delta_f)$. Therefore, the firm should never offer more than $\bar{z}$. Can it do better by offering $y_2<\bar{z}$? In this case the offer will be rejected, the union will strike, and in the next period both parties will agree on the wage contract $\bar{w}$ yielding the firm a payoff over the game of $\delta_f(F-\bar{w})/(1-\delta_f)$. Since $F-\bar{z}>\delta_f(F-\bar{w})$, the firm cannot do better than to offer $\bar{z}$.

Suppose next that $t=1$ and that the union had offered $x_1\le\bar{w}$ but that the offer was rejected. In other words, we are in the last subgame of period 1 where the union must decide whether or not to strike given that $x_1\le\bar{w}$ and $R_1=N$. If the union strikes it will receive $\bar{z}$ from the next period onwards and if it does not strike it will receive w_0 from the current period onwards. Thus, the union is not worse off striking if and only if $w_0\le\delta_u\bar{z}$. This is exactly C1. Hence, $S_1=s$ is indeed the union's best response at this subgame. If, on the other hand, the union had offered $x_1>\bar{w}$ and this offer was rejected, the union would receive w_0 from the next period onwards. Therefore, the union should not strike in the current period.

Suppose now that we are in the preceding subgame in which the firm must respond to an offer x_1. Suppose that $x_1\le\bar{w}$. If $R_2=Y$ the firm's payoff is $(F-x_1)/(1-\delta_f)$ and if $R_2=N$ the firm's payoff is $\delta_f(F-\bar{z})/(1-\delta_f)$. Since $\delta_f(F-\bar{z})=F-\bar{w}\le F-x_1$ the firm cannot do better than to reply Y. Suppose, next, that $x_1>\bar{w}$. In such a case, if the firm replies by "N" the union will not strike and the firm's payoff will be $(F-w_0)/(1-\delta_f)$ which is better than accepting x_1 and obtaining a payoff of $(F-x_1)/(1-\delta_f)$.

It is left to be shown that at the beginning of period 1 the union cannot do better than to offer a wage contract $\bar{w}$. Notice that if it offers $\bar{w}$, its offer will be accepted and its payoff over the game will be $\bar{w}/(1-\delta_u)$. Therefore, the union should not offer any $x_1<\bar{w}$. Can it do better by offering $x_1>\bar{w}$? In such a case, and given the continuation of the game as discussed above, its offer will be rejected, it will not go on strike, and its payoff will be $w_0/(1-\delta_u)$. Since, by C1, $\bar{w}>w_0$, offering $\bar{w}$ is the union's best strategy. This completes the proof.

$\bar{w}$, however, is not the maximum wage contract that the union can obtain. This wage contract is established in the following Lemma.

Lemma 4: w' is the maximum wage contract that the union can receive in any subgame-perfect equilibrium, where

$$w' = \bar{w} + \delta_f w_0 (1-\delta_u)(1-\delta_u \delta_f)^{-1} \quad .$$

Proof: Let $w_0 \le \delta_u z'$ (z' defined below). Then, a pair of subgame-perfect strategies that support w' as an equilibrium outcome have the union offering a contract of w' in every odd period and, unlike the strategy of Lemma 3, striking only in periods in which its offer of w' is rejected (and not when it rejects the firm's offer). The union accepts offers of z' or greater, where

$$z' = \bar{z} + w_0 (1-\delta_u)(1-\delta_u \delta_f)^{-1} \quad .$$

If the union deviates from this rule, then the strategies thereafter call for both players to play according to the strategies described in Lemma 2. Barring any prior deviation by the union, the firm accepts offers of w' and less, and makes offers of z'. (A formal description of the strategies is very similar to those given in Lemma 3 with the modifications just described.)

We omit a formal proof of the statement that this is the maximum wage contract that the union can obtain, since a proof very similar to that developed in Shaked and Sutton (1984) can easily be constructed. Intuitively, the reason that this strategy of striking only on odd periods yields a greater wage contract than the policy described in Lemma 3 of striking in every period, is that the first strategy creates an asymmetry in each party's costs of rejecting the other's offer. It is now more costly for the firm to reject the union's offer than it is for the union to reject the firm's offer, since rejection of the union's offer leads to a strike (with the consequent loss of profit for the firm) whereas the rejection of the firm's offer still allows the union to earn w_0.

An alternative interpretation of w' is to note that w' can be written as

$$w' = w_0 + (1-\delta_f)(F-w_0)(1-\delta_u\delta_f)^{-1} \quad .$$

That is, by employing a strategy of striking only in odd periods, it is as though the players were bargaining over a cake of size $F-w_0$ and that the union is already guaranteed a return of w_0. Thus, w' is equal to w_0 plus the solution to the original Rubinstein game in which the cake is of size $F-w_0$.

We now characterize the entire set of subgame-perfect-equilibrium wage contracts. Moreover, we show that all these contracts can be generated by Pareto efficient subgame-perfect-equilibrium strategies.

<u>Theorem 1</u>: When w' is an equilibrium wage contract, then any other wage contract w such that $w_0 \le w \le w'$ can be generated as an equilibrium wage contract with agreement reached in the first period.

<u>Proof</u>: Let w be such that $w_0 \le w < w'$. Then the following strategies constitute an equilibrium. The union's strategy is as follows:

$$x_1 = w$$

and for t odd and greater than one:

$$x_t = \begin{cases} w_0 & \text{if } x_1 > w, \text{ or if } S_1 = ns, \text{ or if } D'_\tau = d \text{ for some } \tau,\ 1<\tau<t \\ w' & \text{otherwise .} \end{cases}$$

where D'_τ is the equivalent of D_τ with the substitution of w' for $\bar{w}$, z' for $\bar{z}$, and $S_\tau = ns$ only when τ is <u>odd</u> instead of for all $\tau<t$.

When t is even the union's response is

$$Q_t = \begin{cases} Y & \text{if } y_t \ge z', \text{ or if } y_t \ge w_0 \text{ and either } x_1 > w, \text{ or } S_1 = ns, \text{ or} \\ & \quad D'_\tau = d \text{ for some } \tau,\ 1<\tau<t \\ N & \text{otherwise .} \end{cases}$$

Finally,

$$S_t = \begin{cases} ns & \text{if } x_1>w, \text{ or if } S_1=ns, \text{ or if } D_\tau'=d \text{ for some } \tau,\ 1<\tau<t, \\ & \quad \text{or if } D_t'=d, \text{ or if } t \text{ is even} \\ s & \text{otherwise}. \end{cases}$$

where D_t' is the equivalent of D_t with the substitution of w' for $\bar{w}$ and z' for $\bar{z}$.

The firm's strategy is as follows: when t is even it offers

$$y_t = \begin{cases} w_0 & \text{if } x_1>w, \text{ or if } S_1=ns, \text{ or if } D_\tau'=d \text{ for some } \tau,\ 1<\tau<t \\ z' & \text{otherwise}. \end{cases}$$

The firm's response in period 1 is:

$$R_1 = \begin{cases} N & \text{if } x_1>w \\ Y & \text{otherwise} \end{cases}$$

and in every odd period t, t>1 it responds according to:

$$R_t = \begin{cases} N & \text{if } x_t>w', \text{ or } x_t>w_0 \text{ and either } x_1>w, \text{ or } S_1=ns, \text{ or} \\ & \quad D_\tau'=d \text{ for some } \tau,\ 1<\tau<t \\ Y & \text{otherwise}. \end{cases}$$

Note that Theorem 1 implies that if w' is an equilibrium, then any w such that $w_0 \le w \le w'$ is also obtainable as an efficient subgame-perfect equilibrium wage contract. Moreover, since w' is the maximum wage obtainable and w_0 is the minimum wage obtainable (the union would never accept a wage contract below w_0 since it can unilaterally decide to not strike and work for that wage), this range describes the complete range of wage contracts obtainable as subgame-perfect equilibria.

4. Inefficient Equilibria:

The purpose of this section is to show that despite the existence of complete information, it is possible for bargaining to generate inefficient subgame-perfect equilibria. We limit our discussion to the occurrence of strikes that last for an uninterrupted T periods, although it is also possible to have periods of "peaceful" negotiations alternate with periods of strikes.

Theorem 2 : If $\hat{w}$ is such that

$$(1-\delta_f^{1-T})F \; + \; \delta_f^{1-T}\bar{z} \;\geq \hat{w} \geq \delta_u^{-T}w_0 \tag{C2}$$

then there is a subgame-perfect equilibrium in the play of which there is a strike of T periods followed by an agreement of $\hat{w}$.[6]

Proof: See the Appendix for a formal presentation of the strategies. Below we provide an informal proof of the theorem, in which we limit ourselves to describing the strategies along the equilibrium path and to a discussion of the conditions sufficient for deviations not to occur.

In each period prior to T+1 the union makes "ridiculous" wage offers to the firm, i.e. the union offers very high wage contracts of F, which the firm rejects. In period T+1, if this period is odd, the union offers $x_{T+1}=\hat{w}$, if it is even then the union accepts an offer $y_{T+1}=\hat{w}$. The union strikes in every period up to period T+1. Prior to period T+1, the firm also makes "ridiculous" wage offers to the union, i.e. it offers the union very low wage contracts of w_0, which the union rejects. In period T+1, if this period is even, then the firm offers $y_{T+1}=\hat{w}$, if it is odd then the firm accepts an offer $x_{T+1}=\hat{w}$.

[6] It is actually possible to have a wider range for $\hat{w}$ by substituting z' for $\bar{z}$ in (C2) and using the odd-period only strikes equilibrium (described in Lemma 4).

It would obviously be a Pareto improvement if in any of the periods prior to T+1 a settlement of $\hat{w}$ were reached. In fact, there exist a whole range of wage contracts that would be Pareto improving if agreement were reached prior to T+1. These potentially Pareto improving deviations are blocked, however, by each party's response to deviations: attempts by the firm to "bribe" the union to reach a settlement earlier (by making wage offers such that the union prefers to accept the wage offered that period rather than wait until period T+1 to obtain $\hat{w}$) are met by having the strategies require both parties to thereafter play the equilibrium of Lemma 3 (which the union prefers to $\hat{w}$). That is, the union rejects the firm's offer, strikes, and in the following period offers the firm a wage contract of $\bar{w}$ which the firm then accepts. If, on the other hand, the union were to deviate and attempt to reach an earlier settlement by offering the firm a wage contract that the latter preferred over waiting to period T+1 and obtaining a wage contract of $\hat{w}$, or if the union simply decided not to strike, these deviations are met by having the strategies require both parties to thereafter play the status quo wage equilibrium w_0 given in Lemma 2 (the best equilibrium outcome for the firm). That is, the firm would reject this offer and next period it would offer the union a wage contract of w_0 which the latter would then accept. The actual $\hat{w}$ agreement in period T+1 is enforced by the subgame-perfect-equilibrium strategies described in the proof of Theorem 1. That is, assuming no deviations have occured prior to period T+1, deviations after period T+1 require both parties to play according to the strategies given in the proof of Theorem 1.

It is now easier to see how the conditions given in C2 are generated. The union can always obtain a wage contract of w_0 immediately since this wage offer will never be rejected by the firm and since the union can always choose to not strike and receive w_0 independently of any actions taken by the firm. Thus in order for the union to be willing to strike for T periods, it should prefer to receive 0 for T periods followed by a wage of $\hat{w}$ thereafter to w_0 each period commencing in period 1. That is,

$$\delta_u^T \hat{w} \geq w_0,$$

$\hat{w}$ must be sufficiently large.

If the firm were to attempt to reach an immediate settlement by offering the union $\bar{z}+\epsilon$ $\epsilon>0$, it would not be subgame perfect for the union to reject this offer, since next period it would receive $\bar{w}$ and $\bar{z}+\epsilon>\delta_u\bar{w}$. Thus, in order for this type of deviation not to be performed by the firm, it must be that it prefers to suffer the T periods of strike followed by an agreement of $\hat{w}$, to achieving an agreement of $\bar{z}$ immediately (since $\bar{z}$ is the lowest wage contract it could offer the union that could serve as a "bribe"). That is,

$$F-\bar{z} \leq \delta_f^{T-1}(F-\hat{w})$$

or, rearranging terms,

$$(1-\delta_f^{1-T})F + \delta_f^{1-T}\bar{z} \geq \hat{w},$$

$\hat{w}$ must be sufficiently small.

These are the only binding constraints on the size of $\hat{w}$ since any deviations further along the road will only be even less profitable then those just described.

We now present an example that gives strikes of two periods of duration.

<u>Example</u>: Suppose that $F=105$, $w_0=9$ and $\delta_f=\delta_u=3/4$. Then, the following negotiation process can be supported as an equilibrium outcome. In period 1 the union asks for a wage of 60, this request is rejected by the firm and the

union strikes. In period 2 the firm offers a wage of 10, the offer is rejected by the union and the union strikes again. In period 3 they settle on a wage of 20 (offered by the union and accepted by the firm).

Most models of bargaining under incomplete information have the feature that even if in equilibrium an agreement is not reached immediately, the delay in reaching an agreement becomes arbitrarily small as the (exogenously given) time interval between two successive offers becomes arbitrarily small. In other words, when periods are short allowing agents to alternate offers quickly, there is essentially no delay in reaching an agreement. This result is also known as the Coase conjecture. In Hart's (1989) model, this result is avoided by allowing the firm's profit function to decay to zero with some probability after a strike of a certain duration has occurred. We now show that we are able to obtain strikes in real time (i.e. lengthy strikes) without imposing any additional assumptions.

The first thing to note is that, in our model, shorter periods not only has agents alternate offers more rapidly, but also that a decision to strike for a period implies a shorter length of strike time. (If this were not the case, that is, if players could make offers and counteroffers quickly but the length of time of strike commitment stayed unchanged, then all our previous results would go through trivially). We will show, however, that even when the strike period becomes arbitrarily small, there exist equilibria with lengthy strikes. To do this, we introduce the notation Δ to denote the length of a period and examine the conditions for strikes of length T to be an equilibrium as Δ approaches zero.

Consider the following situation: suppose that bargaining takes place over continuous time, but that after an offer is made an amount of time Δ must elapse before another offer can be proposed. Let $F\theta$ be the firm's revenue for

the interval of time $(t, t+\theta)$ conditional on the union not striking, and let $w_0\theta$ be the union's wage pay under the old contract for that interval. Let r be the players' common (for simplicity) discount factor, so that e^{-rT} is each player's utility (assuming we are now at time 0) from receiving a dollar at time T. Suppose that time is divided into periods and that all actions are taken at the beginning of each period. That is, at the beginning of each period the player whose turn it is to make an offer proposes a wage contract and the other player responds immediately. If the response is "No", the union decides whether or not to strike for the duration of the period.
Let $\delta(\Delta)=e^{-r\Delta}$. Then the model presented in section 2 can be viewed as a formal representation of the game just described with the modification that instead of δ we now have $\delta(\Delta)$. $\bar{z}$ is now modified to $\bar{z}(\Delta)=\delta(\Delta)F\Delta/(1+\delta(\Delta))$ (as follows from allowing $\delta_u=\delta_f=\delta(\Delta)$ in Lemma 1). It is easy to see that $\delta(\Delta)$ converges to one as Δ approaches zero.

As the length of time separating the possibility of making offers becomes very short, the interesting question no longer is whether or not there is an equilibrium in which the union strikes for some positive number of periods, but rather whether there exists one in which the union strikes for some time $T>0$, irrespective of the size of Δ. For a given T, we can redefine T as T/Δ, i.e. T is the number of periods needed for a time of length T to elapse. Obviously, as Δ gets smaller, T must increase. It now follows from (C2) that the union can, in equilibrium, strike for a length of time T if:

$$(e^{-rT}-\delta(\Delta))F\Delta + \delta(\Delta)\bar{z} > w_0\Delta$$

and, cancelling the Δ on both sides of the inequality, we have

$$(e^{-rT}-\delta(\Delta))F + \delta(\Delta)^2F(1+\delta(\Delta))^{-1} > w_0.$$

Taking the limit of the above expression as Δ approaches 0, we obtain

$$(e^{-rT}-1)F + F/2 > w_0$$

or, rearranging terms,

$$e^{-rT} > F/2 + w_0 \qquad (C2')$$

(C2') gives the condition for strikes to last a length T of time. It is easy to show that there are positive values of F and w_0 such that (C2') holds.

5. Extensions:

(i). Lockouts

Thus far we have examined equilibria that emerge when solely the union is allowed to engage in actions other than offers, rejections, and acceptances. We would now like to ask how our results are affected if the firm is allowed to engage in lockouts. If we start out by examining a game in which only lockouts are feasible (unions are not allowed to strike), it is interesting to note that the equilibrium outcome that is obtained by having the firm follow the strategy of locking out the union in every even period in which an agreement is not reached (i.e. the strategy analagous to the one described for the union in Lemma 4) now yields

$$\bar{w} = \frac{(1-\delta_f)w_0}{1-\delta_u\delta_f} \qquad \bar{z} = \frac{\delta_u(1-\delta_f)w_0}{1-\delta_u\delta_f}$$

where $\bar{w}$ is the wage contract obtained if the union commences the bargaining procedure and $\bar{z}$ is obtained if the firm does.[7] This is, again, similar to the Rubinstein solution, but now the size of the cake being bargained over is

[7]The condition for this to be a subgame-perfect equilibrium is $w_0 \geq F(1-\delta_f)(1-\delta_u\delta_f)[1-\delta_u\delta_f-\delta_f(1-\delta_f)]^{-1}$

w_0. That is, this strategy allows the firm to bargain with the union over the latter's right to work and receive w_0, just as the previous odd period strike equilibrium allowed the union to bargain with the firm over the latter's right to earn $F-w_0$.

If we now allow both lockouts and strikes (one can think of these decisions as following a rejection of an offer and occurring either simultaneously or sequentially), it is possible to have equilibria in which strikes, for example, alternate with lockouts along the equilibrium play before a final agreement is reached. These inefficient equilibria are sustained by having the strategies require the parties to play the w' equilibrium if the firm deviates (i.e. the best outcome for the union) and the $\tilde{w}$ equilibrium if the union deviates (the best outcome for the firm).

(ii). Multiple Contract Renegotiations:

We now extend our model to allow for contracts that are repeatedly, potentially infinitely, renegotiated. Let us suppose that contracts are periodically renegotiated every M periods (periodicity is assumed simply for notational simplicity) after a contract has been established. All of the equilibria described in the previous sections are also equilibria in this modified setting (the strategies must now also require that after the first contract renegotiation (w^*) is concluded, the union will only accept and offer wage contracts of w^* or above and will never strike, and the firm will only accept and offer wage contracts of w^* and below.) We can now show that, unlike in the previous section, the new equilibrium contract need not necessarily offer the union a wage greater or equal to w_0 as long as the union expects there to be a future contract in which its new wage will be sufficiently high so as to compensate the union for the periods in which it worked for a lower wage. An example follows.

Example:

Consider the following equilibrium play: in the first period the union offers a wage contract of $p<w_0$ which the firm accepts. This contract comes up for renegotiation M periods later. Assuming M+1 is odd, the union then offers a wage contract of $q>w_0$, which the firm accepts. This outcome is supported by having the two parties play, as of the subgame following the deviation, the equilibrium strategies of Lemma 3 (that support $\bar{w}$) if the firm deviates, and to play the equilibrium strategies of Lemma 2 (that support w_0 if $t=1$ and support p if $t>1$) if the union deviates. In order for deviations not to be profitable, therefore, we must have the union prefer the equilibrium outcome to obtaining a wage contract of w_0 forever, i.e.

$$(q-p)\delta_u^M + p \geq w_0$$

And, if the firm rejects the union's offer of p, the union must prefer to strike and obtain a wage contract of $\bar{z}$ next period to working that period and thereafter for a wage of w_0. Hence,

$$\delta_u \bar{z} \geq w_0$$

A numerical example satisfying these conditions is: $\delta_u=\delta_f=4/5$, F=1, M=2, $w_0=2/9$, $p=1/9$, and $q=3/9$. Thus the equilibrium play has the union making an offer of 1/9 (i.e. a wage reduction) which the firm accepts, and two periods later (t=3) the wage is renegotiated and the union offers a wage contract of 3/9 which is accepted.

6. Conclusion:

This paper has shown that bargaining between two agents may be inefficient even if both parties are completely rational and fully informed. In our specific case of a union and a firm negotiating a new wage contract, we show that this process may involve periods of strikes. Hence, neither bounded rationality nor incomplete information is a necessary condition for a consistent theory of strikes. The length of time which the union can strike depends on the status quo wage—the wage specified by the preexisting contract—and on the profitability of the firm. The lower the status quo wage and the more profitable the firm, the greater the maximum length of time which the union may strike in equilibrium. The ability of the union to strike, even in those equilibria in which the union does not actually strike along the equilibrium play, can only improve the union's position at the bargaining table. Thus, the union's threat to strike may be credible despite the cost to the union of carrying out such a threat. Futhermore, even if the time separating bargaining periods becomes arbitrarily small, strikes can still occur in real time (i.e. lengthy strikes are still possible).

We showed that our model can be extended to include multiple recontracting opportunities and the possibility for the firm to also threaten the union by engaging in lockouts. Another interesting extension would be to include uncertainty in the form of possible shocks, through technology or price changes, to the firm's revenue function F. Assuming that these shocks were perfectly observable to all parties, contracts could be renegotiated in the event of a shock. The range of inefficient equilibria would be greater, i.e. it would be "more likely" to observe periods of strikes, with positive shocks than with negative ones, which agrees with the empirical finding that strikes are procyclical.

Finally, our paper's main result—that bargaining between two parties may result in inefficient outcomes—may explain the existence of Pareto inferior phenomena other than strikes. Observed inefficiencies in the international arena, e.g. the existence of tariff wars or of protracted debt negotiations interspersed with periods of debt moratoria, may also be explained by our model. In particular, our model can explain why two completely rational countries may choose to engage in war although their disagreements could be settled via the much less costly process of diplomacy.

Appendix

We provide a pair of subgame-perfect equilibrium strategies that generate strikes for T periods followed by an agreement of $\hat{w}$ in period T+1. We assume here that T is even.

For every t, $1 \leq t \leq T+1$, let AD_t be a function of the history of play up to (but not including) period t such that

$AD_1 = nd$, and for $t > 1$,

$$AD_t = \begin{cases} nd & \text{if for every } \tau,\ 1 \leq \tau < t,\ S_\tau = s, \text{ and, for every odd } \tau,\ x_\tau = F, \\ & \quad \text{and, for every even } \tau,\ y_\tau = w_0 \\ df & \text{if there exists some even } \tau' < t \text{ such that } AD_{\tau'} = nd \text{ but} \\ & \quad y_{\tau'} > w_0\ , S_{\tau'} = s \text{ and } D_\tau = nd \text{ for all } \tau,\ \tau' < \tau < t. \\ du & \text{otherwise} \end{cases}$$

The function AD_t indicates whether any of the players deviated from its equilibrium play and identifies this player. If $AD_t = nd$, no deviation has occurred, if $AD_t = df$ the firm has deviated and the union has not, and if $AD_t = du$ the union has deviated.

For every t, $1 \leq t < T+1$, let DD_t be a function from the history of play <u>at period t</u> such that:

$$DD_t = \begin{cases} d & \text{if } AD_t = nd \text{ and } t \text{ is odd and } x_t < F, \text{ or if } AD_t = df \\ & \quad \text{and either } t \text{ is odd and } x_t > \bar{w} \text{ or} \\ & \quad t \text{ is even and } y_t \geq \bar{z} \text{ but } Q_t = N, \text{ or if } AD_t = du \\ nd & \text{otherwise .} \end{cases}$$

DD_t indicates whether or not the union has deviated in or prior to period t before its decision of whether or not to strike.

For $t > T+1$ let BD_t be a function of the history of play up to (but not including) period t such that

$$BD_t = \begin{cases} df & \text{if } AD_{T+1} = df \text{ and } D_\tau = nd \text{ for all } \tau,\ T+1 \leq \tau < t, \text{ or if} \\ & \quad AD_{T+1} = nd,\ x_{T+1} \leq \hat{w},\ S_{T+1} = s \text{ and } D_\tau = nd \text{ for all } \tau,\ T+1 < \tau < t \\ du & \text{otherwise .} \end{cases}$$

The function BD_t indicates whether the union or solely the firm has deviated from the equilibrium rule.

The union's strategy is:

$x_1 = F$ and in every odd t, $1 < t < T+1$ it offers:

$$x_t = \begin{cases} F & \text{if } AD_t = nd \\ \bar{w} & \text{if } AD_t = df \\ w_0 & \text{otherwise .} \end{cases}$$

In period T+1 it offers

$$x_{T+1} = \begin{cases} \hat{w} & \text{if } AD_{T+1}=nd \\ \bar{w} & \text{if } AD_{T+1}=df \\ w_0 & \text{otherwise} \end{cases}$$

and for every t odd, t>T+1

$$x_t = \begin{cases} \bar{w} & \text{if } BD_t=df \\ w_0 & \text{otherwise} . \end{cases}$$

The union's response is:

For t<T+1

$$Q_t = \begin{cases} Y & \text{if } y_t \geq \bar{z}, \text{ or if } y_t \geq w_0 \text{ and } AD_t=du \\ N & \text{otherwise} . \end{cases}$$

For t>T+1

$$Q_t = \begin{cases} Y & \text{if } y_t \geq \bar{z}, \text{ or if } y_t \geq w_0 \text{ and } BD_t=du \\ N & \text{otherwise} . \end{cases}$$

For t<T+1 the union's striking decision is

$$S_t = \begin{cases} ns & \text{if } DD_t = d \\ s & \text{otherwise} \end{cases}$$

and in period T+1,

$$S_{T+1} = \begin{cases} ns & \text{if } AD_{T+1} = du, \text{ or if } AD_{T+1} = df \text{ but } x_{T+1} > \bar{w}, \text{ or} \\ & \text{if } AD_{T+1} = nd \text{ but } x_{T+1} > \hat{w}. \\ s & \text{otherwise .} \end{cases}$$

For every t>T+1,

$$S_t = \begin{cases} ns & \text{if } BD_t = du, \text{ or if } BD_t = df \text{ but } D_t = d \\ s & \text{otherwise .} \end{cases}$$

The firm's strategy is as follows: when t is even and t<T+1 it offers.

$$y_t = \begin{cases} \bar{z} & AD_t = df \\ w_0 & \text{otherwise,} \end{cases}$$

and when t>T+1 it offers:

$$y_t = \begin{cases} \bar{z} & \text{if } BD_t = df \\ w_0 & \text{otherwise} . \end{cases}$$

When t is odd and $t<T+1$ the firm's response is:

$$R_t = \begin{cases} Y & \text{if } x_t \leq w_0, \text{ or if } x_t \leq \bar{w} \text{ and } AD_t = df \\ N & \text{otherwise,} \end{cases}$$

and in period $T+1$ it responds

$$R_{T+1} = \begin{cases} N & \text{if } x_{T+1} > \bar{w}, \text{ or if } x_{T+1} > \hat{w} \text{ and } AD_{T+1} = nd, \text{ or} \\ & \text{if } x_{T+1} > w_0 \text{ and } AD_{T+1} = du \\ Y & \text{otherwise} . \end{cases}$$

In every odd t, $t>T+1$ the firm responds according to:

$$R_t = \begin{cases} N & \text{if } x_t > \bar{w}, \text{ or if } x_t > w_0 \text{ and } BD_t = du \\ Y & \text{otherwise} . \end{cases}$$

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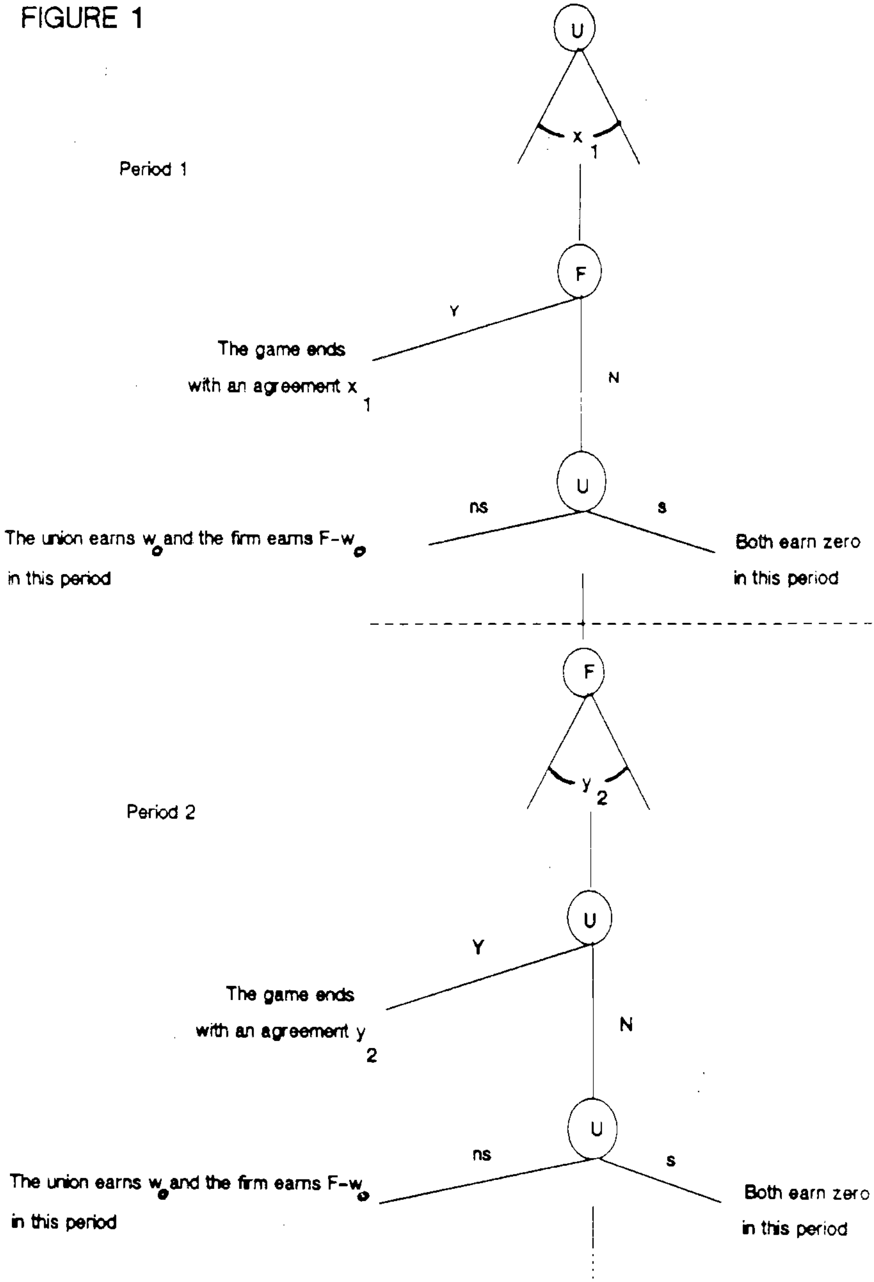
FIGURE 1


U
x 1
Period 1
F
Y
The game ends
with an agreement x 1
N
U
ns
s
The union earns w0 and the firm earns F-w0
in this period
Both earn zero
in this period
F
y 2
Period 2
U
Y
The game ends
with an agreement y 2
N
U
ns
s
The union earns w0 and the firm earns F-w0
in this period
Both earn zero
in this period