

# Striking for a Bargain Between Two Completely Informed Agents

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*This paper models the wage-contract negotiation procedure between a union and a firm as a sequential bargaining process in which the union must decide, 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.*

Economic theory has trouble explaining strikes.<sup>1</sup> As stated by Oliver Hart (1989 p. 25), "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 John Kennan (1986 p. 1091) 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 par-

ticular, asymmetric information. Indeed, it is often thought that there are no other possible culprits for these inefficiencies.<sup>2</sup> David Card (1988 p. 1), 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 Anat Admati and Motty Perry (1987), Lawrence M. Ausubel and Raymond J. Deneckere (1989), Kalyan Chatterjee and Larry Samuelson (1987), Peter C. Cramton (1984), Drew Fudenberg et al. (1985), Sanford Grossman and Perry (1986), Hart (1989), Ariel Rubinstein (1985), and Joel Sobel and Ichiro 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 forgo 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 pro-

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<sup>1</sup>For a review of theories that attempt to explain strikes, see John Kennan (1986).

<sup>2</sup>Although, of course, bounded rationality could produce inefficient behavior. See Orley Ashenfelter and G. E. Johnson (1969) for a bargaining model in which only one side behaves optimally.

duction in those periods. Empirical work by Henry S. Farber and Max H. 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 Faruk Gul and Hugo 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 noncooperative-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) noncooperative-bargaining model also produce unique and Pareto-efficient equilibria. In the case of fixed bargaining costs of  $c_i$  per period (where  $i$  indexes the name of the player, and with no discounting), if  $c_1 = c_2$  it is possible to have inefficient equilibria emerge; for any  $c_1 \neq c_2$ , however, the subgame-perfect equilibrium is efficient.

Our paper's contribution is to show that strikes and other wasteful phenomena, such as wars, can result as equilibrium behavior within a framework 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.<sup>3</sup> As in

Rubinstein's model, 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 in that period. If the union chooses to strike, it forgoes 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 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

<sup>3</sup>After completion of this paper, it was called to our attention that Hans Haller (1988) and Steinar Holden (1989) have developed models very similar to ours. Haller (1988 p. 16) 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.

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 phenomenon. 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: strikes can occur in real time; that is, they can be lengthy despite agents' ability to negotiate extremely rapidly. Furthermore, our model (or an extension of it) has as an implication that the range of parameter values that support strikes is greater in boom periods than in periods of recession. This is suggestive of the empirical finding that strikes tend to be procyclical.<sup>4</sup> 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 by the union's wage in the status quo contract) in which strikes should not be observed.

The paper is organized as follows. In Section I, we set up the model. We discuss the efficient equilibria in Section II and the inefficient ones in Section III. In Section IV, 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. Our conclusions are presented in Section V.

### I. 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 renegotia-

tions is assumed to be as follows: the union and firm alternate in making wage offers over discrete time periods  $t \in \{1, 2, \dots\}$ . In each odd-numbered period (a period is 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 any 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  $w_0$ ,  $0 \leq w_0 \leq F$ , specified by the preexisting contract, and the firm obtains the revenue  $F$  associated with the union's output minus the wage bill, that is,  $F - w_0$ . 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 one period. In every even-numbered 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, faces the union with the strike decision. The same rules as described previously govern the consequences of the strike decision. Once the decision is executed, time advances one period. Note that this bargaining process can potentially last an infinite amount of time. Figure 1 depicts the first two periods of the game.

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

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

and the firm's objective is to maximize the

<sup>4</sup>See Kennan (1986) for a discussion of the empirical work in this area.

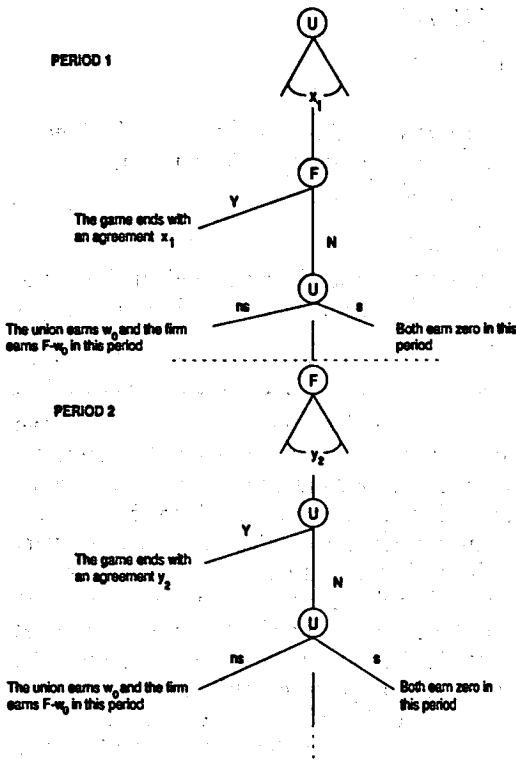


FIGURE 1. DIAGRAM OF THE FIRST TWO PERIODS OF THE GAME

ment 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 that an agent would not be willing to carry out (they would be payoff-worsening for that player). That is, subgame-perfect-equilibrium strategies induce Nash equilibria in the game and in every proper subgame, 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 committed to striking in every period in which it did not reach 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 committed 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 results in a wage contract of  $\bar{w}$  if bargaining commences in an odd-numbered period and has a contract of  $\bar{z}$  if bargaining commences in an even-numbered period, where*

discounted sum of profits,

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

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

Although the union is assumed to earn  $w_0$  in the nonstrike 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 and partly of wage increase.

We will be studying the subgame-perfect equilibria of the game described above. Subgame perfection is the natural refine-

**PROOF:**

See Rubinstein (1982) or Avner Shaked and John 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 the union’s commitment to strike in every period of disagreement transforms the game into Rubinstein’s original bargaining model with both parties bargaining over a cake of size  $F$ . The fact that  $\bar{w} > \bar{z}$  shows that the player who makes the first offer has an advantage in this kind of bargaining game.

## II. Efficient Equilibria

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 has the property that the union threatens to strike in each period in which an agreement is not reached.

**LEMMA 2:** *There is a subgame-perfect-equilibrium in which an agreement of  $w_0$  is reached in the first period.*

**PROOF:**

The pair of subgame-perfect-equilibrium strategies given below generates 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 odd-numbered  $t$  and, in every even-numbered  $t$  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 even-numbered  $t$  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 are subgame-perfect-equilibrium strategies.

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.<sup>5</sup>

<sup>5</sup>Furthermore, in a finite-horizon version of our model,  $w_0$  is the sole subgame-perfect-equilibrium outcome; no strikes can occur. For a complete-information finite-horizon Rubinstein model (but with a commitment mechanism) capable of generating delays, see Chaim Fershtman and Daniel Seidmann (1990).

**LEMMA 3:** *If*

$$(1) \quad w_0 \leq \delta_u \bar{z}$$

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

**PROOF:**

A formal proof is contained in the proof of Theorem 2 below and is therefore omitted here.<sup>6</sup>

The following is an informal description of the strategies that generate the above equilibrium. The union offers the contract  $\bar{w}$  in every odd-numbered period, accepts any offer greater or equal to  $\bar{z}$  in every even-numbered period, and strikes in every odd-numbered period in which its request for  $\bar{w}$  is rejected and in every even-numbered 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 call for both players to play thereafter according to the strategies described in Lemma 2. In other words, a deviation by the union is punished by having it accept the old wage contract of  $w_0$ .

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

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

and

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

**LEMMA 4:** *If  $w_0 \leq \delta_u z'$ , there is a subgame-perfect equilibrium in which an agreement of  $w'$  is obtained in the first period. This is also the maximum wage contract that the*

<sup>6</sup>Theorem 2 provides a pair of strategies that produce  $\bar{w}$  as an outcome in some subgames. It is not difficult to see how they can be modified to generate  $\bar{w}$  as an agreement reached in the first period.

union can receive in any subgame-perfect equilibrium.

**PROOF:**

A proof that there exists a pair of subgame-perfect-equilibrium strategies that support  $w'$  as an equilibrium outcome in the first period is given in the proof of Theorem 1. The following is an informal description of the strategies that generate the above equilibrium. In odd-numbered periods, the union offers the contract  $w'$  and strikes if this offer is rejected. In even-numbered periods, the union accepts only offers that are greater than or equal to  $z'$  but never strikes. If, however, the union deviates from this rule at some point, then the strategies call for both players to play thereafter according to the strategies described in Lemma 2. In other words, a deviation by the union is punished by having it accept the old wage contract of  $w_0$ .

We now show that  $w'$  is the maximum wage that the union can obtain in any subgame-perfect equilibrium. Suppose that it is not. Let  $w^* > w'$  be the supremum over all wage agreements obtained in any subgame of any subgame-perfect equilibrium. Consider a subgame in which an agreement of  $\hat{w} = w^* - \varepsilon$ ,  $\varepsilon < \min[(w^* - w_0)(1 - \delta_u), (w^* - w')(1 - \delta_u \delta_f)]$ , is reached. By hypothesis, at least one such subgame must exist. There are two cases to consider.

(i) Suppose this agreement occurs in a subgame in which the firm makes the offer. The following deviation is then profitable for the firm. Let the firm change its offer from  $\hat{w}$  to  $\phi + \varepsilon'$ , where  $\phi = w_0(1 - \delta_u) + \delta_u w^*$  and  $0 < \varepsilon' < (w^* - w_0)(1 - \delta_u) - \varepsilon$ . Note that the union will accept an offer of  $\phi + \varepsilon'$ , since by rejecting this offer the most that the discounted value of its earnings can be is  $w_0 + (1 - \delta_u)^{-1} \delta_u w^*$ . However, the discounted value of  $\phi + \varepsilon'$  is  $w_0 + (1 - \delta_u)^{-1} (\delta_u w^* + \varepsilon')$ . The firm gains since by construction,  $\phi + \varepsilon' < \hat{w}$ .

(ii) Suppose this agreement occurs in a subgame in which the union makes the offer. The following deviation is then profitable for the firm. Let the firm reject the union's offer and, in the following period, independently of whether the union chose

to strike in the previous period, offer the union a wage of  $\phi + \varepsilon''$  where  $0 < \varepsilon'' < [(1 - \delta_u \delta_f)(w^* - w') - \varepsilon] \delta_f^{-1}$ . As shown in (i), the union will accept such an offer. The firm gains since, as can be shown by some algebraic manipulation and recalling that  $w^* - \varepsilon > w'$ ,  $F - \hat{w} < \delta_f(F - \phi - \varepsilon'')$ .

Intuitively, the reason why this strategy of striking only in odd-numbered periods yields a greater wage contract than the strategy 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

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

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

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.

**THEOREM 1:** *If  $w_0 \leq \delta_u z'$ , then any wage contract  $w$  such that  $w_0 \leq w \leq w'$  can be generated as an equilibrium wage contract with agreement reached in the first period.*

**PROOF:**

We first introduce the following notation. Suppose that the game has reached period  $t$ . For every period  $\tau < t$  let  $D_\tau'$  be a function of the actions taken in that period such

that

$$D'_\tau = \begin{cases} d & \text{if } \tau \text{ is odd and } x_\tau > w'; \\ & \text{if } \tau \text{ is even and } y_\tau \geq z' \text{ but } Q_\tau = N; \text{ or} \\ & \text{if } S_\tau = ns \text{ and } \tau \text{ is odd} \\ nd & \text{otherwise.} \end{cases}$$

$D'_\tau$  indicates whether or not the union has deviated in period  $\tau$ . (Note that, strictly speaking,  $D'_\tau$  does not capture all possible deviations, since it ignores those offers by the union lower than  $w'$ .) If a deviation has occurred in period  $\tau$  then  $D'_\tau = d$ ; if not, then  $D'_\tau = nd$ . Similarly, suppose that the play has reached the last move of period  $t$ , at which point the union has to decide whether or not to strike. Let  $D'_t$  be a function of all actions taken in period  $t$  up to the strike decision such that

$$D'_t = \begin{cases} d & \text{if } t \text{ is odd and } x_t > w'; \text{ or} \\ & \text{if } t \text{ is even and } y_t \geq z' \text{ but } Q_t = N \\ nd & \text{otherwise.} \end{cases}$$

Let  $w$  be such that the  $w_0 \leq w \leq w'$ . 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

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

When  $t$  is even the union's response is

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

Finally,

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

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

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

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

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

Note that Theorem 1 implies that if  $w'$  is an equilibrium, then any  $w$  such that  $w_0 \leq w \leq w'$  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, this range describes the complete range of wage contracts that can be obtained as subgame-perfect equilibria.

### III. 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 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*

$$(2) \quad (1 - \delta_f^{1-T})F + \delta_f^{1-T}\bar{z} \geq \hat{w} \geq \delta_u^{-T}w_0$$

*then there is a subgame-perfect equilibrium in*

the play of which there is a strike of  $T$  periods followed by an agreement of  $\hat{w}$ .<sup>7</sup>

**PROOF:**

See the Appendix for a formal presentation of the strategies.

We now 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 a nonserious wage offer to the firm (i.e., the union offers a very high wage contract of  $F$ , which the firm rejects). In period  $T + 1$ , if this period is odd-numbered, the union offers  $x_{T+1} = \hat{w}$ ; if it is even-numbered, 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 nonserious 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-numbered, the firm offers  $y_{T+1} = \hat{w}$ ; if it is odd-numbered, the firm accepts an offer  $x_{T+1} = \hat{w}$ .

It obviously would be a Pareto improvement if a settlement of  $\hat{w}$  were reached in any of the periods prior to  $T + 1$ . In fact, there exists a whole range of wage contracts that would be Pareto-improving if agreement on them 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 thwarted by having the strategies require both parties to play thereafter 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 obtaining an agreement of  $\hat{w}$  in period  $T + 1$ , or if the union simply decided not to strike, these deviations are thwarted by having the strategies require both parties to play thereafter 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 union's failure to strike likewise would lead to an agreement of  $w_0$  in the following period. The actual  $\hat{w}$  agreement in period  $T + 1$  is supported by the subgame-perfect-equilibrium strategies described in the proof of Theorem 1. That is, assuming no deviations have occurred prior to period  $T + 1$ , deviations at or 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 (2) are generated. The union always can obtain a wage contract of  $w_0$  immediately, since the union always can choose not to 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, rather than to receive  $w_0$  each period commencing in period 1. That is,

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

(i.e.,  $\hat{w}$  must be sufficiently large).

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

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

<sup>7</sup> It is actually possible to have a wider range for  $\hat{w}$  by substituting  $z'$  for  $\bar{z}$  in (2) and using the odd-period-only strikes equilibrium (described in Lemma 4).



or, rearranging terms,

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

(i.e.,  $\hat{w}$  must be sufficiently small).

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

Many models of bargaining under incomplete information have the feature that, even if an agreement is not reached immediately in equilibrium, 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.<sup>8</sup>

An important feature of our model is that shorter periods not only imply that agents alternate offers more rapidly, but also they accordingly shorten the length of a strike, given a decision to strike for a period. (If this were not the case, that is, if players could make offers and counteroffers quickly but the duration of a strike commitment remained unchanged, then all our previous results would go through trivially). However, it is easy to show that, even when the strike period becomes arbitrarily small, there exist equilibria with lengthy strikes. The reason for this is that strikes are not a signalling device for either player in our model. The union strikes because not doing so means that it will obtain a lower wage. The maximum length of strike time depends solely on the difference in payoffs that the union can obtain by striking as compared to not striking and not on any information revealed through delay; delay is no longer a mechanism by which different types separate themselves.

<sup>8</sup>Some notable exceptions are Admati and Perry (1987), Ausubel and Deneckere (1989), Peter C. Cramton (1989), and Hart (1989).

#### IV. Extensions

##### A. Lockouts

Thus far, we have examined equilibria that emerge when only 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. In order to simplify our computations, we assume that workers earn zero if they are locked out.<sup>9</sup>

If we start by examining a game in which only lockouts are feasible (the union is not allowed to strike), it is interesting to note that the equilibrium outcome obtained when the firm follows the strategy of locking out the union in every even-numbered period in which an agreement is not reached (i.e., a strategy analogous to the one described for the union in Lemma 4) now yields

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

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

where  $\bar{w}$  is the wage contract obtained if the union commences the bargaining procedure and  $\bar{z}$  is obtained if the firm starts.<sup>10</sup> This strategy again transforms the game into Rubinstein's (1982) original game, but now  $w_0$  is the size of the cake being bargained over. Just as the odd-period-strike equilibrium allowed the union to bargain with the firm over the latter's right to earn  $F - w_0$ , the even-period-lockout strategy allows the firm to bargain with the union over the latter's right to work and receive  $w_0$ . Thus,

<sup>9</sup>In reality, workers often receive unemployment compensation. This modification would not qualitatively affect our results.

<sup>10</sup>The condition for this to be a subgame-perfect equilibrium is

$$w_0 \geq F(1 - \delta_f)(1 - \delta_u\delta_f)[1 - \delta_u\delta_f - \delta_f(1 - \delta_f)]^{-1}.$$

this agreement yields the union a wage contract smaller than the status quo contract.

If we 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  $\bar{w}$  equilibrium if the union deviates (the best outcome for the firm).

### B. Multiple Contract Renegotiations

We now extend our model to allow for contracts that are repeatedly, potentially infinitely, renegotiated. We suppose that contracts are periodically renegotiated every  $M$  periods (periodicity is assumed for notational simplicity) after a contract has been established. All of the equilibrium outcomes described in the previous sections are also equilibrium outcomes in this modified setting [the strategies must now 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]. In addition, we can now show that, unlike in the previous sections, the new equilibrium contract need not necessarily offer the union a wage greater than 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 it for the periods in which it worked for a lower wage, a wage contract lower than  $w_0$  can be accepted as part of a subgame-perfect equilibrium. 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 having them 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, that is,

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

Also, 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,

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

### V. 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 have shown 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 for 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 for 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. Furthermore, 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 have shown that our model can be extended to include multiple recontracting opportunities and the ability of the firm to engage in lockouts. Another interesting extension would be to include uncertainty in the form of shocks to the firm's revenue function through technology or price changes. If these shocks were perfectly observable to all parties, contracts could be renegotiated in the event of a shock. The range of parameter values that permit inefficient equilibria would be greater for positive shocks than for negative ones, which is suggestive of the empirical finding that strikes are procyclical.

Finally, our paper's main result—that bargaining between two parties may result in inefficient outcomes—may justify the existence of Pareto-inferior phenomena other than strikes. Observed inefficiencies in the international arena (e.g., the existence of tariff wars or protracted debt negotiations interspersed with periods of debt moratoria) may also be explained by our model. In particular, our model can offer an explanation for why two completely rational countries may 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-numbered.

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  $t > 1$ ,

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

where  $D_\tau$  is the equivalent of  $D'_\tau$  with the substitution of  $\bar{w}$  for  $w'$ ,  $\bar{z}$  for  $z'$ , and  $S_\tau = ns$  for all  $\tau < t$ .

The function  $AD_t$  indicates whether, prior to period  $t$ , any of the players deviated from 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 at period  $t$  such that

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

$DD_t$  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

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

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

The union's strategy is

$$x_1 = F$$

and in every odd-numbered  $t, 1 < t < T + 1$ , 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

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

and for every odd-numbered  $t$ ,  $t > T + 1$ ,

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

For  $t < T + 1$ , the union's response is

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

For  $t > T + 1$ , the union's response is

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

For  $t < T + 1$ , the union's strike decision is

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

and in period  $T + 1$ ,

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

For every  $t > T + 1$ ,

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

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

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

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

and when  $t > T + 1$ , it offers

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

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

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

and in period  $T + 1$ , it responds

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

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

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

## REFERENCES

- Admati, Anat R. and Perry, Motty, "Strategic Delay in Bargaining," *Review of Economic Studies*, July 1987, 54, 343-64.
- Ashenfelter, Orley and Johnson, G. E., "Bargaining Theory, Trade Unions and Industrial Strike Activity," *American Economic Review*, March 1969, 59, 35-49.
- Ausubel, Lawrence M. and Deneckere, Raymond J., "Reputation in Bargaining and Durable Good Monopoly," *Econometrica*, May 1989, 57, 511-32.
- Card, David, "Strikes and Wages: A Test of a Signalling Model," NBER Working Paper No. 2550, April 1988.
- Chatterjee, Kalyan and Samuelson, Larry, "Bargaining with Two-Sided Incomplete Information: An Infinite Horizon Model with Alternating Offers," *Review of Economic Studies*, April 1987, 54, 175-92.

- Cramton, Peter C., "Bargaining with Incomplete Information: An Infinite Horizon Model with Continuous Uncertainty," *Review of Economic Studies*, October 1984, 51, 579-93.
- \_\_\_\_\_, "Strategic Delay in Bargaining with Two-Sided Uncertainty," working paper, Yale School of Management, 1989.
- Farber, Henry S. and Bazerman, Max H., "Divergent Expectations as a Cause of Disagreement in Bargaining: Evidence from a Comparison of Arbitration Schemes," *Quarterly Journal of Economics*, November 1989, 104, 99-120.
- Fershtman, Chaim and Seidmann, Daniel J., "Deadline Effects and Inefficient Delay in Bargaining With Endogenous Commitment," working paper, Tel Aviv University, 1990.
- Fudenberg, Drew, Levine, David and Tirole, Jean, "Infinite Horizon Models of Bargaining with One-Sided Incomplete Information," in Alvin Roth, ed., *Bargaining with Incomplete Information*, Cambridge, U.K.: Cambridge University Press, 1985, 73-98.
- Grossman, Sanford J. and Perry, Motty, "Sequential Bargaining Under Asymmetric Information," *Journal of Economic Theory*, June 1986, 39, 97-119.
- Gul, Faruk and Sonnenschein, Hugo, "On Delay in Bargaining with One-Sided Uncertainty," *Econometrica*, May 1988, 56, 601-11.
- Haller, Hans, "Wage Bargaining as a Strategic Game," mimeo, Virginia Polytechnic Institute, October 1988.
- Hart, Oliver, "Bargaining and Strikes," *Quarterly Journal of Economics*, February 1989, 104, 25-44.
- Holden, Steinar, "Non-Cooperative Wage Bargaining," mimeo, London School of Economics, May 1989.
- Kennan, John, "The Economics of Strikes," in O. Ashenfelter and R. Layard, eds., *Handbook of Labor Economics*, New York: Elsevier, 1986, 1091-137.
- Rubinstein, Ariel, "Perfect Equilibrium in a Bargaining Model," *Econometrica*, January 1982, 50, 97-109.
- \_\_\_\_\_, "A Bargaining Model with Incomplete Information About Time Preferences," *Econometrica*, September 1985, 53, 1151-72.
- Shaked, Avner and Sutton, John, "Involuntary Unemployment as a Perfect Equilibrium in a Bargaining Model," *Econometrica*, September 1984, 52, 1351-64.
- Sobel, Joel and Takahashi, Ichiro, "A Multi-Stage Model of Bargaining," *Review of Economic Studies*, July 1983, 50, 411-26.