BARGAINING AND STRIKES*

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A recent literature has shown that asymmetric information about a firm's profitability does not by itself explain strikes of substantial length if the firm and workers can bargain very frequently without commitment. In this paper we show that substantial strikes are possible if (a) there is a small (but not insignificant) delay between offers; and (b) a strike-bound firm may experience a decline in profitability after a certain point. A brief discussion of the ability of the theory to explain the data on strikes is included.

I. INTRODUCTION

Strikes are generally regarded as an important economic phenomenon, and yet good theoretical explanations of them are hard to come by. 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 (or if it is uncertain to its certainty equivalent) and sharing the benefits from increased production?

The key to this puzzle would appear to be asymmetric information between firms and unions, and in the last few years a number of papers have developed dynamic models of bargaining in which firms have better information about their profitability than workers (see, e.g., Fudenberg, Levine, and Tirole [1985], Sobel and Takahashi [1983], Cramton [1987], Grossman and Perry [1986]). In such models delay to agreement is a screening device. Profitable firms lose more from a strike than unprofitable firms and hence will settle early for high wages, while unprofitable firms will be prepared to delay agreement until wages fall. The reason that the parties cannot do better by avoiding the strike and sharing the gains from increased production is that there is no way for an unprofitable firm to "prove" that it is unprofitable except by going through a costly strike.

While these asymmetric information bargaining models seem at first sight to provide a good basis for a theory of strikes, their

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adequacy has been cast into question by a result called the Coase conjecture. This result says that delay is obtained in these models only by assuming that there are significant intervals between bargaining times or that the parties can commit themselves to future bargaining strategies (for formalizations of the result, see Fudenberg, Levine, and Tirole [1985]; Sobel and Takahashi [1983]; Gul, Sonnenschein, and Wilson [1986]; Gul and Sonnenschein [1988]). In particular, if the parties can bargain frequently and there is no commitment, then once a profitable firm has settled early, it will not be in the interest of the workers and a remaining firm to drag out the bargaining—instead they will quickly reach an agreement at a lower wage. Anticipating this early reduction in wage, however, a profitable firm will prefer to wait, and the use of delay as a screening mechanism breaks down. As a consequence, equilibrium has the property that every firm settles "quickly" at a "low" wage, and there are essentially no strikes.[1]

The purpose of this paper is to modify the basic asymmetric information bargaining model so as to explain strikes of a reasonable length.[2] Our approach contains two ingredients. The first is the idea that in many union-firm negotiations it is reasonable to suppose *some* delay between offers, rather than bargaining by the second (which is what, in the limit, the Coase conjecture requires). One reason for this has to do with the transaction cost of making offers. Typically, an offer must be discussed and agreed to by several top union officials or top executives of the firm. Meetings of such individuals may be difficult to arrange, and it may therefore be quite credible that after one offer has been made, a new offer will not be forthcoming for a certain period of time, a matter of days, perhaps.

Delay may also be present for technological reasons. Suppose that production is organized in discrete units, e.g., by the day. If an offer is rejected at 9 P.M., then even if a new offer is made and agreed to quite quickly, the next day's production may be lost; e.g., because

1. The Coase conjecture was originally formulated for a durable good monopolist; analyses of this case can be found in Bulow [1982] and Stokey [1982].

2. Other approaches to overcoming the Coase conjecture should be mentioned. First, it may sometimes be reasonable to suppose that one party—perhaps through its desire to maintain a reputation—can effectively commit itself to a bargaining strategy. See Hayes [1984] for an analysis of the commitment case (our model retains the assumption of no commitment). Second, as Cramton [1987] has shown, delay can arise in models where workers have private information as well as firms—e.g., about their opportunity costs. Third, even with one-sided asymmetric information, significant delay can occur if it is not known for sure that there are gains from trade between the firm and union (see Ausubel and Deneckere [1986] and Section II); or if the firm can remove itself from the bargaining process for a time and use this length of time to signal its profitability (see Admati and Perry [1987]).

it takes time to contact workers or to prepare the plant for operation. Given this, the incentive of a party whose offer has just been rejected to come back rapidly with a better offer is much reduced; the party may as well wait until close to 9 P.M. the next day. For both these reasons—transactional and technological—it seems plausible in the union-firm context to suppose a limited delay between offers (it is difficult to come up with a number, but, at a very rough guess, one to three days does not seem unreasonable).

One may ask whether a limited delay between offers is enough by itself to explain the magnitude of strike activity observed in practice. We shall argue in Section II that the answer to this is probably no: strikes are still likely to be too short. This motivates the inclusion of a second feature in our model: the idea that the cost of a strike amounts to more than just the loss of current production. A long strike will also quite likely depress a firm's future profitability, e.g., because the firm loses ground to competitors. We formalize this by supposing that a strike-bound firm's future profitability decays (stochastically) over time. Moreover, we assume that this decay becomes more severe after a certain point; e.g., because the firm faces a "crunch" when it runs out of inventories. Under these conditions, we show that it may pay the union (who, we shall suppose, makes all the offers) to drag out the bargaining until close to the crunch in order to obtain greater leverage over the firm. As a consequence, we find that strikes of considerable duration can occur in equilibrium.

The paper is organized as follows. After presenting the basic model in Section II, we introduce decay in Section III. Sections II and III also contain a brief discussion of the ability of the theory to explain the data on strikes. Finally, Section IV contains concluding remarks.

II. A Model with Limited Delay Between Offers

We have argued that it seems reasonable to suppose at least some interval between offers in union-firm bargaining. We shall refer to this interval as a "day"—and will interpret it as such in our empirical discussion—but, as we have noted, in some circumstances the period may more realistically be interpreted as two or three days. We begin by considering what length of strikes the standard dynamic bargaining model (see Fudenberg, Levine, and Tirole [1985]; Gul, Sonnenschein, and Wilson [1986]; Sobel and Takahashi [1983]) predicts with this interval between offers.

Consider a union bargaining with a firm. Starting on day 1, the union makes one offer a day, which the firm can accept or reject. The firm is supposed not to be able to make offers.[3] The union's offers are to sell a permanent flow of labor (a fixed amount, one unit per day, say) at the daily price of w. The firm's daily profitability from using this labor, s, is a random variable, the realization of which is known to the firm but not to the union. The union is supposed to know the probability distribution of s, however. The firm's profitability in the absence of labor is zero. The union has no outside opportunities, and its objective function is taken to be the net present value of future wages.

The union and firm discount future profit and wages at the common daily discount factor, δ, $0 < \delta < 1$ (given an annual interest rate of 10 percent, $\delta \simeq 0.99974$). To simplify matters, we analyze the special case where s can take on only two values, s_H with probability π_H and s_L with probability $\pi_L (s_H > s_L > 0, \pi_H, \pi_L > 0, \pi_H + \pi_L = 1)$. We refer to a firm with $s = s_H$ as profitable and a firm with $s = s_L$ as unprofitable. The firm and union are supposed to be risk neutral.

If the union could commit itself, it is well-known that its optimal strategy would be to make a single take-it-or-leave-it offer, w^*. If (1) $\pi_H s_H > s_L$, the optimal $w^* = s_H$, which means that a profitable firm accepts the offer and an unprofitable firm rejects it, while if (2) $\pi_H s_H < s_L$, the optimal $w^* = s_L$ and both types of firms accept. Following most of the literature, however, we shall be interested in the case where commitment is impossible. This does not affect the solution in Case 2, but it does alter the Case 1 solution, since it will be in the union's interest to make a second offer to an unprofitable firm, and this will be anticipated by a profitable firm. In what follows, we analyze a perfect Bayesian equilibrium for this case (i.e., an equilibrium for which strategies are sequentially optimal given beliefs and, where possible, beliefs are derived from equilibrium strategies and observed actions using Bayes rule). The equilibrium involves the union making a declining sequence of wage offers such that a profitable firm, being indifferent about which one to accept, adopts a mixed strategy, while an unprofitable firm accepts the last one. A precise characterization is given in Proposition 1.

PROPOSITION 1. The bargaining model described above possesses a (generically) unique perfect Bayesian equilibrium. In this

3. We make this strong assumption—in line with much of the literature—in order to avoid issues of signaling by an informed party.

equilibrium bargaining ends for sure by day m, where m is the solution to

$$\rho_{m+1} < \pi_L \leq \rho_m. \tag{1}$$

Here $1 \equiv \rho_1 > \rho_2 > \dots$ is a sequence of declining numbers given (recursively) by the equation,

$$\rho_k = \delta^{k-2}\left(1 - \left(\frac{s_L}{s_H}\right)\right)\left[1\Big/\left(\frac{1}{\rho_{k-1}} - (1-\delta)\sum_{i=2}^{k-1}\frac{\delta^{i-2}}{\rho_{k-i}}\right)\right], \qquad k \geq 2. \tag{2}$$

Along the equilibrium path, the union makes offers $w_1^*, \dots, w_m^*$ satisfying

$$w_k = (1 - \delta^{m-k})s_H + \delta^{m-k}s_L, \qquad k = 1, \dots, m.$$

A profitable firm accepts the offer w_1^* with probability

$$\left[1 - \frac{\pi_L}{\pi_H}\left(\frac{1-\rho_{m-1}}{\rho_{m-1}}\right)\right],$$

the offer w_k^*, $2 \leq k \leq m-1$, with probability

$$\left\{1 - \left[\left(\frac{1-\rho_{m-k}}{\rho_{m-k}}\right)\Big/\left(\frac{1-\rho_{m-k+1}}{\rho_{m-k+1}}\right)\right]\right\}$$

conditional on the firm not having accepted a previous offer, and the offer s_L with probability zero; while an unprofitable firm waits until the day m offer of s_L and accepts this with certainty.

The proof of Proposition 1 follows directly from arguments in Fudenberg, Levine, and Tirole and Gul, Sonnenschein, and Wilson, and so we shall not present it here (see also Hart [1987]). One point is worth noting. The cutoff probabilities $\rho_2, \rho_3 \dots$ are such that, if on day k the probability that the firm is unprofitable is ρ_{m-k+1}, the union is just indifferent between continuing bargaining to day m and to day $(m-1)$ $(k = 2, \dots, m-1)$. Furthermore, in the perfect Bayesian equilibrium the posterior probability on day k that a firm which has rejected all previous offers is unprofitable is exactly ρ_{m-k+1}. It follows that if we represent the union's beliefs on day 1 by τ—where τ is the ratio of the probability that the firm is profitable to the probability that it is unprofitable—and define $V_m(\tau)$ to be the rental-equivalent expected net present value to the union of following the wage path $w_1^*, \ldots, w_m^*$; then

$$(3)\quad V_m(\tau) = \left[\pi_H - \pi_L\left[\frac{(1-\rho_{m-1})}{\rho_{m-1}}\right]\right]((1-\delta)^{m-1}s_H + \delta s_L) + \left(\frac{\pi_L}{\rho_{m-1}}\right)\delta V_{m-1}\left[\frac{1-\rho_{m-1}}{\rho_{m-1}}\right]$$

$$= \left[\frac{\tau}{1+\tau}\right]\left[1 - \left[\frac{1}{\tau}\right]\left[\frac{(1-\rho_{m-1})}{\rho_{m-1}}\right]\right]((1-\delta)^{m-1}s_H + \delta s_L) + \left[1 - \frac{\tau}{1+\tau} + \left[\frac{1}{1+\tau}\right]\left[\frac{1-\rho_{m-1}}{\rho_{m-1}}\right]\right]\delta V_{m-1}\left[\frac{1-\rho_{m-1}}{\rho_{m-1}}\right].$$

Moreover, (3) holds for all m, and so can be used to compute $V_2(\cdot)$, $V_3(\cdot)\ldots$ recursively, given that $V_1(\tau) \equiv s_L$.

Proposition 1 tells us how maximum bargaining time m is determined. The next proposition tells us how m varies with the discount factor δ. It also shows that $\rho_k \to 0$ as $k \to \infty$, which implies that there is a finite solution to (1). In order to show the dependence of ρ_k on δ in (2), we write $\rho_k = \rho_k(\delta)$ in the following.

PROPOSITION 2. $\rho_k(\delta)$ is increasing in δ for each k. In particular, $\rho_k(\delta) \le \rho_k(1) = (1 - (s_L/s_H))^k$, from which it follows that $\lim_{k\to\infty} \rho_k(\delta) = 0$.

Proof. Differentiating (2) and rearranging terms yields

$$\frac{d\rho_k}{d\delta}\,\alpha \sum_{i=2}^{k-1}(k-i)\delta^{i-2}\left[\frac{1}{\rho_{k-i+1}} - \frac{1}{\rho_{k-i}}\right],$$

which is positive since $\rho_{k-i+1} < \rho_{k-i}$. The rest of the Proposition follows directly.

Q.E.D.

Since ρ_k is increasing in δ, higher δ's lead to higher m's satisfying (1), i.e., to more bargaining. In particular, Proposition 2 implies that the greatest potential amount of bargaining, $\overline{m}$, which occurs in the limit $\delta \to 1$, is given by the solution to

$$(4)\qquad (1-(s_L/s_H))^{m+1} < \pi_L < (1-(s_L/s_H))^m,$$

and hence is finite.

Given (4), it is straightforward to obtain upper bounds on the length of bargaining for a two-point distribution. These bounds will in fact be very close to actual maximum bargaining times, given an annual interest rate of 10 percent and a corresponding $\delta \simeq 0.99974$, which is so close to 1. It is clear from the second inequality in (4) that $\overline{m}$ will be very small unless either π_L is very small or (s_H/s_L) is quite large. For example, if $s_H = 2s_L$, we require that $\pi_L < 0.031$ to get a maximum of five days of bargaining and $\pi_L < 0.001$ to get a maximum of ten days. If $s_H = 3s_L$, these conditions are relaxed to $\pi_L < 0.132$ and $\pi_L < 0.017$, respectively. On the other hand, if we fix $\pi_L = \frac{1}{2}$, then values of (s_H/s_L) equal to 5, 15, 25 yield, respectively, at most 3, 9, and 17 days of bargaining.

Of course, 3, 9, or 17 days of bargaining is actually very little. In practice, strikes can last up to a year, and, although this is rare, strikes of three or four months are not uncommon. The data on strikes suggest that the mean length of a strike conditional on there being a strike is of the order of 40 days (see Farber [1978] or Kennan [1986]; another piece of evidence worth noting is that about 15 percent of contract negotiations lead to a strike).

Clearly, to get strikes that can last three or four months with a two-point distribution would require either an extremely low value of π_L or a very large value of (s_H/s_L). Large values of (s_H/s_L) do not seem very plausible, however. It is one thing to suppose that there is an asymmetry of information between the firm and union about the firm's profitability, but it is quite another to assume that it is enormous.[4]

On the other hand, while a low value of π_L is consistent with long *maximum* times of bargaining, it does not by itself imply a substantial *expected* duration of bargaining, of the order of 40 days say. To see this, note that Proposition 1 implies that the expected duration of a strike, conditional on a strike occurring (i.e., on bargaining extending for more than one day), D, satisfies

$$D = A/B, \tag{5}$$

where

$$A = \sum_{i=1}^{m-2} (i+1)\left[\frac{\pi_L(1-\rho_{m-i})}{\rho_{m-i}} - \frac{\pi_L(1-\rho_{m-i-1})}{\rho_{m-i-1}}\right] + \pi_L m,$$

$$B = 1 - \left[\pi_H\left(\frac{\pi_L(1-\rho_{m-1})}{\rho_{m-1}}\right)\right] = \frac{\pi_L}{\rho_{m-1}},$$

4. To be more specific, if very large values of (s_H/s_L) occur under conditions of asymmetric information, one would also expect to observe them when there is symmetric information. But under symmetric information, if the union has all the bargaining power, $w = s$, and so the result should be an enormous variation in wages across different firms. (Even if the union and firm split the surplus, the percentage variation would be enormous.) We do not seem to observe this.

and m is maximum bargaining time. Using the approximation $\rho_m = [1 - (s_L/s_H)]^m$, defining $y = [s_H/(s_H - s_L)]$, and simplifying, we obtain

$$D \simeq 2 + \frac{1}{y^{m-2}} + \frac{1/y(1-(1/y)^{m-3})}{1 - 1/y} < 2 + \frac{1}{y-1} = 1 + \frac{s_H}{s_L}. \tag{6}$$

It follows that D cannot be of the order of 40, even if π_L is small, unless s_H/s_L is very large.

In interpreting these results, one should bear in mind that they have all been obtained for the case of a two-point distribution, which may not be typical. Unfortunately, analyzing more general distributions is not easy. It should be noted, however, that in their study of the uniform distribution, Grossman and Perry [1986] have obtained somewhat longer bargaining times. If s is uniformly distributed on $[s_L, s_H]$, where $s_L > 0$, they find that with $(s_H/s_L) = 25$, bargaining lasts a maximum of 22 days (in contrast to our finding of 17 days). Interestingly, they find more bargaining occurs when the firm and union make alternating offers (so that there is now one offer every half day)—in this case bargaining lasts for 33 days.

Returning to the two-point case, we should note that there is one interpretation of the model under which a high value of (s_H/s_L) does seem reasonable. Suppose that the workers have a disutility of effort R. Then the net profit in this activity is $(s - R)$, and the relevant ratio of high profitability to low profitability is $(s_H - R)/(s_L - R)$ rather than (s_H/s_L). This ratio can, of course, be very large if s_L is close to R. Hence very large values of $\overline{m}$, and large expected lengths of strike, are possible in this case.

This interpretation of the model presents some difficulties, however. First, if the firm's net profitability can be very close to zero, we would expect it in practice to be negative reasonably often, which means that we should see a significant fraction of strikes leading to closure of the firm. This appears to be a very rare phenomenon. Second, if R represents outside earning opportunities rather than the disutility of effort, it is plausible to suppose that R is only realized if the firm-union relationship terminates; e.g., the workers may have to move to other locations to earn R. But then, with the two-point distribution, either the workers would find it profitable to continue bargaining with a firm known to be unprofitable (if $s_L > R$), or they would not (if $s_L < R$). In the first case the perfect Bayesian equilibrium is unaffected by the opportunity cost (since all wage offers in the equilibrium of Proposition 1 are above R anyway), while in the second the full commitment solution involving no bargaining delay can be implemented. In both cases strike duration will be small. (Although this argument is very dependent on the two-point assumption, we suspect that the basic idea—that outside earnings close to s_L do not explain extensive delay—generalizes.)

The above remarks suggest that it may be difficult for the standard bargaining model to explain the observed data on strikes, particularly the delay to agreement. While it would clearly be premature to reject the standard model at this stage, these remarks do motivate the study of alternative models that do not suffer from the same difficulties; one such model is presented in the next section.

III. A Model with Decay

The bargaining model discussed in the last section, along with much of the bargaining literature following Rubinstein's paper [1982], supposes that a profitable opportunity which is not taken today will continue to be available tomorrow and that the only cost of delay is that the identical income stream will start one period later. This is a strong assumption. In many circumstances, it seems likely that a firm which experiences a long strike will find its profitability significantly reduced when the strike ends. There are several reasons for this. First, the firm may lose ground to competitors, and some of this loss may be permanent. For example, customers who cannot obtain supplies from this firm may switch to another firm, and to the extent that switching is costly (there may be lock-in effects), this may not easily be reversed. Second, competitors may be able to get ahead on vital investments and innovations, which may put this firm in an unfavorable position in the future. Third, the firm's machinery may depreciate more rapidly than usual during a strike due to lack of use or lack of maintenance; and also morale may fall, and key personnel may leave. Fourth, even if the firm can in principle carry out innovation or maintenance activities while the workers are on strike, it may find it harder to finance these activities given the reduction in its cash flow (some imperfection in the capital market is required for this last argument).

It also seems likely that the decay of productive opportunities is not uniform over time. A short strike may impose very little cost on a firm, while a long strike may be much more serious. This is presumably because in the short term the firm can supply customers out of inventory, and ground lost in investment and innovation activity can be made up later. After a while, however, inventories run out, and the firm may find that it has fallen irreversibly behind its competitors. In fact, it may be reasonable to suppose that the profitability of a firm facing a strike depreciates sharply after a while, with the firm facing a "crunch" at a certain point.[5]

We shall assume the existence of a crunch, starting at day T, in what follows. We shall model decay in productive opportunities by supposing that each day from T on there is some probability $(1 - \eta)$ that a strike-bound firm experiences disaster and becomes valueless before the next period, given that it has not already done so; and that with probability η the firm remains completely intact $(0 < \eta < 1)$. The probability of disaster is lower before day T—in fact, for simplicity we take it to be zero. (One can imagine that disaster occurs when a competitor takes a key long-term contract away from the firm or beats the firm in a crucial marketing decision. Note that only a strike-bound firm is assumed to be in danger of losing its value. Also the occurrence of disaster is public information, so bargaining ceases in this event.) This disaster-no disaster decay assumption is crude, but it turns out to be easier to handle analytically than the case of deterministic shrinkage in the firm's profitability. We suspect that our results are not particularly sensitive to the exact formalization used.

As in Section II, we consider a union bargaining with a firm whose profitability $s = s_H$ with probability π_H and s_L with probability π_L so long as it has not experienced disaster. We compute the perfect Bayesian equilibrium under these conditions.

Solving for the Bayesian equilibrium is complicated by the fact that the environment is no longer stationary. We shall therefore content ourselves with finding a sufficient condition for the equilib-

5. Perry, Kramer, and Schneider [1982] emphasize that a firm's ability to maintain supplies to long-standing customers during a strike has a major impact on long-run profitability. Perry, Kramer, and Schneider are concerned with firms that continue to operate during a strike, but their observations provide support for the idea that a firm which cannot continue production or obtain supplies elsewhere will find its profitability shrinking rapidly once it runs out of inventories (or is perceived to be about to run out). Support for the idea that profitability begins to decline rapidly after a certain point can also be found in statements by parties in two recent strikes. During the 1986 TWA flight attendants strike, the director of economic analysis for TWA was quoted as saying: "We will rise from losing \$3 million a day to \$5 million to \$7 million shortly. Customer loyalty is very fickle. You lose them very quickly" [*Boston Globe,* March 11, 1986]. Also, with reference to the 1988 Ford U. K. strike, the *Wall Street Journal* [February 9, 1988, p. 4] stated that "Auto analysts estimated that Ford will incur losses of \$5 million for each day the U. K. strike continues. Many analysts added that the losses would increase to about \$25 million for each day the strike continues past the first month."

rium to involve the extension of bargaining beyond day T. In what follows, it is convenient to suppose that the solution of (1), $\hat{m}$, satisfies $\hat{m} \leq T$.

It is useful to begin with the situation where bargaining extends just past the crunch to day $(T + 1)$. In this case, $w_{T+1} = s_L$, while previous wage offers $w_1, \ldots, w_T$ are such that a profitable firm is indifferent between accepting these and holding on until $(T + 1)$:

$$w_k = (1 - \delta^{T-k}\zeta)s_H + \delta^{T-k}\zeta s_L, \ k = 1, \ldots, T, \qquad \text{where } \zeta = \eta\delta.$$

This formula reflects the fact that the effective discount factor for the union-firm combination becomes $\eta\delta$ at date T, since the productive opportunity will be available at the following date only with probability η.

As in Section II, we shall find that there is a critical value for the union's prior belief that the firm is profitable such that bargaining extends beyond day T if and only if π_H exceeds this critical value. In order to calculate this critical value, we use an inductive procedure to compute at each date t the ratio σ_t of the probability that the firm is profitable to the probability that it is unprofitable such that the union is just indifferent between continuing bargaining until day $(T + 1)$ and choosing a wage path which results in the termination of bargaining before the crunch starts. Suppose that $\sigma_T, \sigma_{T-1}, \ldots, \sigma_{T-k+1}$ have been found. To find σ_{T-k}, we solve

$$\begin{aligned}(7)\quad & \left(\sigma_{T-k} - \left(\frac{\sigma_{T-k+1}}{1 - \sigma_{T-k+1}}\right)(1 - \sigma_{T-k})\right) w_{T-k} + \delta(1 - \sigma_{T-k}) \\ & \times \left(\frac{\sigma_{T-k+1}}{1 - \sigma_{T-k+1}}\right)\left(1 - \left(\frac{\sigma_{T-k+2}}{1 - \sigma_{T-k+2}}\right)\left(\frac{1 - \sigma_{T-k+1}}{\sigma_{T-k+1}}\right)\right) w_{T-k+1} \\ & + \ldots + \delta^k(1 - \sigma_{T-k})\left(\frac{\sigma_{T-1}}{1 - \sigma_{T-1}}\right)\left(1 - \left(\frac{\sigma_T}{1 - \sigma_T}\right)\left(\frac{1 - \sigma_{T-1}}{\sigma_{T-1}}\right)\right) \\ & \times w_T + \eta\delta^{k+1}(1 - \sigma_{T-k}) w_{T+1} \\ & = \max\{V_1(\sigma_{T-k}), V_2(\sigma_{T-k}), \ldots, V_{k+1}(\sigma_{T-k})\}.\end{aligned}$$

The left-hand side of (7) is the payoff from following the $(T + 1)$ day solution, while the right-hand side is the union's maximum payoff from avoiding the crunch and ending the bargaining in $1, 2, \ldots, k + 1$ days (i.e., on days $T - k, \ldots, T$). Since in the latter case we are in the model of Section II, we can plug in the payoffs, V_i (see (3)) with the appropriate initial condition $\tau = \sigma_{T-k}$. Since V_i is linear in σ_{T-k}, it is easy to show that (7) has a unique solution $\sigma_{T-k} > \sigma_{T-k+1}$. Moreover, it is the largest of the solutions obtained by setting the left-hand side of (7) equal to $V_1(\cdot)$, $V_2(\cdot) \ldots$, respectively. Finally, if $\tau > \sigma_{T-k}$, the left-hand side of (7) exceeds the right-hand side.

In fact, the right-hand side can be simplified a bit when k is large: we need only consider the first $\hat{m}$ terms in the max expression, where $\hat{m}$ is the solution to (1). This is because once we have reached day $T - k$, given that only a profitable firm will have accepted an offer with positive probability, the ratio of the probability that the firm is profitable to the probability that it is unprofitable cannot exceed $\pi_H{:}\pi_L$. But it follows from Proposition 2 that bargaining will not last more than another $\hat{m}$ periods. Hence the terms V_j, $j > \hat{m}$, can be ignored.

The above line of argument shows that if the initial probability ratio on day 1 (π_H/π_L) exceeds $(\sigma_1/1 - \sigma_1)$, i.e., $\pi_H > \sigma_1$, the union prefers to follow the $(T + 1)$ day solution rather than choose a wage path which results in the termination of bargaining on or before day T. One strategy that we have not allowed the union is to extend bargaining beyond day $(T + 1)$. While this possibility complicates the calculation of the perfect Bayesian equilibrium, it is not difficult to show that it can only cause bargaining to be even more extensive. In other words, whenever $\pi_H > \sigma_1$, the perfect Bayesian equilibrium will involve bargaining lasting until *at least* day $(T + 1)$, i.e., $\pi_H > \sigma_1$ is a *sufficient* condition (although perhaps not a necessary one) for extensive bargaining to occur.

PROPOSITION 3. A sufficient condition for every perfect Bayesian equilibrium to exhibit bargaining until at least day $(T + 1)$ is that $\pi_H > \sigma_1$.

A proof of Proposition 3 is contained in Hart [1987].

The basic tradeoff facing the union can be understood as follows. Up to day T the union is involved in a bargaining game where the effective discount factor is δ; moreover, if the union terminates bargaining before date $T + 1$, the union is involved *only* in this game. By dragging out the bargaining beyond day T, however, the union is able to participate in a second bargaining game with a lower effective discount factor $\zeta = \eta\delta$. Ceteris paribus, this new game is more attractive for the union (at least over a certain range of parameters). In particular, if δ is close to 1, the payoff from the first game will be very close to s_L (since, given that bargaining will end very quickly, each wage offer must be very close

TABLE I
SETS OF PARAMETERS THAT ILLUSTRATE THE LARGEST VALUES OF ETA CONSISTENT WITH BARGAINING UNTIL DAY $T + 1$

Parameters**									
S_h	S_1	π_h	π_1	T	eta	σ_1	w_1	Expected duration	Annual % wage change
2	1	0.85	0.15	90	0.990	0.846	1.0330	58.298	−13.0
2	1	0.75	0.25	90	0.977	0.743	1.0461	67.338	−17.9
2	1	0.75	0.25	120	0.968	0.737	1.0617	90.00	−17.7
1.5	1	0.75	0.25	90	0.845	0.743	1.0873	78.21	−32.6
1.5	1	0.75	0.25	120	0.795	0.747	1.1147	104.23	−31.3

*Recall that bargaining to day $T + 1$ occurs as long as $\sigma_1 < \pi_h$.
**Delta = 0.9997401.
Expected duration is the expected strike length conditional on agreement not being reached on day 1. A firm that dies at time $T + 1$ is treated as if it settled that day. Annual % wage change is

$$\left(\frac{w_{T+1} - w_1}{w_1}\right) \times \frac{365}{T}.$$

to s_L); while at the other extreme, if ζ is close to zero (the crunch is very severe), the union can, in the second game, approach its first-best payoff of $\pi_H s_H$ (a profitable firm that is very likely to disappear will pay close to s_H today even if it knows that the wage will fall to s_L tomorrow).

So the union must trade off the benefits of participating in this second game against the costs of waiting until $(T + 1)$ for it to start. Proposition 3 tells us that the benefits of waiting outweigh the costs as long as $\pi_H > \sigma_1$.[6]

Since very severe crunches do not seem that realistic, in assessing the practical significance of the model, we need to know whether extensive bargaining is likely even when η is fairly close to 1. Computing σ_1 analytically is difficult for large T, and so we have resorted to a computer for this. Some results are reported in Table I.

According to this table, with $T = 90$ and $s_H/s_L = 2$, the critical value of η for extensive bargaining to occur is 0.99 when $\pi_H = 0.85$

6. It should be noted that the conclusion that the union has an incentive to wait for the crunch is not an artifact of a one-sided offer model. The same effect will also be present in a two-sided offer model. We should also emphasize that we are not suggesting that the Coase conjecture fails in the present context. Even with a crunch, bargaining time tends to zero as bargaining frequency tends to infinity; the point of our analysis is simply to show that extensive bargaining can occur when bargaining is not too frequent.

(that is, extensive bargaining will occur as long as the probability of survival is below 0.99; recall that we require $\sigma_1 < \pi_H$); and it falls to 0.977 when $\pi_H = 0.75$. A decrease in (s_H/s_L) to 1.5 reduces the critical value of η further to 0.845, while an increase in T to 120 brings an additional reduction to 0.795.[7]

It is noteworthy that the crunch does not need to be very severe for the union to want to drag out the bargaining. For all the parameter values in Table I, bargaining would last at most three days if $\eta = 1$. But with $\eta < 0.968$, $\pi_H = 0.75$, and $s_H = 2s_L$, we can get bargaining of 91 or 121 days! Furthermore, the expected bargaining time conditional on a strike occurring is substantial, ranging from 58 to 104 days in Table I.[8]

While a decay rate of 0.01, say, per period may seem quite mild, it must be admitted that such a probability implies a very large attrition rate over an extended interval of time such as a year (97.5 percent probability of death of a firm if each period is a day; 71 percent probability of death if a period is three days). Note, however, that none of our results would change if the crunch were temporary rather than permanent, that is, if the survival probability of the firm reverted to 1 at some date $T + k$ (the idea might be that there is a critical period during which the firm is vulnerable but that a firm which weathers this is safe thereafter). The reason is that if $(T + 1)$ day bargaining occurs when the crunch is permanent, it will continue to occur when the crunch is temporary (the $(T + 1)$ day solution can still be implemented, while lengthier bargaining becomes less attractive). In particular, extensive bargaining will occur for all the parameter values reported in Table I (see footnote 7).[9]

7. It is worth mentioning that, for all the parameter values in Tables I and II, we have used the computer to check that the union will want to terminate bargaining on day $(T + 1)$ rather than at a later date; i.e., the $(T + 1)$ day solution really is the equilibrium in these cases. Under these conditions it is also easy to show that there is a critical value for η such that extensive bargaining occurs if and only if η is below this critical value.

8. As we have noted, the data on strikes yield a smaller conditional expected bargaining time of around 40 days. Our results can easily be made consistent with this figure, however. Simply suppose that the empirical distribution of firms is a mixture of two distributions: one of which is the "high variance" distribution we have considered; and the other of which is a "low variance" distribution. Assume further that the union observes which distribution its firm is drawn from. Then the low variance distribution will generate short strikes, which will bring the conditional expected bargaining time down. Note also that, in this way, the overall probability of a strike can be made close to the empirically observed figure of 15 percent.

9. It is also worth noting that our results would not change substantially if the increase in the decay rate from 0 to $1 - \eta$ occurred more slowly; i.e., there was a gradual buildup to the crunch. In particular, so long as the gradual buildup does not greatly increase the attrition rate of firms before date T, the tradeoff facing the union will remain very much the same.

Table I tells us that extensive bargaining is more likely to occur when T is small, π_H is large, or (s_H/s_L) is large. This is not surprising. When T is small, it is cheap for the union to wait till the crunch; while if π_H or (s_H/s_L) is large, there are substantial gains from using the crunch to separate profitable from unprofitable firms.

In Table I the values of η are such that the union is almost indifferent between extensive and short bargaining (π_H is very close to σ_1). A consequence is that the probability of a settlement on day 1 is quite small. In Table II we consider cases where π_H is substantially greater than σ_1 and where the probability of a day 1 settlement is significant. In Figure I we graph the pattern of settlements for a representative case, corresponding to row 1 of Table II. The distribution is strongly trimodal, with the vast majority of settlements by a profitable firm occurring on days 1 and 90, and settlements of an unprofitable firm (which are not graphed), occurring on day 91. The probability of a settlement on days 1, 90, or 91 is of the order of 0.88, while that of a settlement between day 1 and day 90 is about 0.12.[10]

This trimodal feature is not observed in the data on the distribution of strikes.[11] In fact, the empirical histogram suggests that the frequency of strikes is not far from being a decreasing function of time (with a few hiccups). Our model can be made consistent with this observation, however, if we drop the assumption that the crunch starts on the same day T for all firms. In particular, suppose that there is a distribution of crunch dates in the population of firms; but continue to assume that each union knows its own firm's T before it starts bargaining (imagine that the other parameters s_H, s_L, π_H, π_L, η are constant across firms). In general, the effect of such a distribution will be to smooth out the frequency histogram. For the one case that we have studied in detail—where T is uniformly distributed on [1,90]—the overall frequency of strikes can be shown now to be a decreasing function of time.

As a final observation, it is worth noting that the model can explain substantial rates of wage decline, so long as η is not too close to 1. For example, when $(s_H/s_L) = 2$, $\pi_H = 0.85$, $T = 90$, and $\eta = 0.99$, the rate of wage decline is about 13 percent a year (row 1, Table I), and this rises to about 44 percent a year when $\pi_H = 0.75$ and $\eta = 0.9$

10. It is interesting to note that experimental work by Roth, Murnighan, and Shoumaker [1988] supports the idea that parties frequently delay reaching agreement until close to a deadline.

11. See, for example, the data on part of U. S. manufacturing collected by Wayne Vroman [1981, 1982] at the Urban Institute, Washington.

TABLE II
SETS OF PARAMETERS THAT ILLUSTRATE A HIGH PROBABILITY OF SETTLEMENT AT TIME 1

Parameters										
S_h	S_1	π_h	π_1	T	eta	σ_1	w_1	Prob. of a settlement at time 1	Expected duration	Annual % wage change
2.0	1	0.750	0.250	90	0.900	0.36677	1.1208	0.385	81.047	−43.72
2.0	1	0.750	0.250	120	0.850	0.35458	1.1761	0.396	109.158	−45.55
1.5	1	0.750	0.250	90	0.750	0.64682	1.1337	0.105	81.950	−47.82
1.5	1	0.750	0.250	120	0.700	0.66515	1.1608	0.086	108.406	−42.12
2.0	1	0.750	0.250	90	0.850	0.32791	1.1697	0.423	83.481	−58.83
2.0	1	0.750	0.250	120	0.800	0.32847	1.2246	0.422	111.390	−55.78
1.5	1	0.750	0.250	90	0.650	0.60358	1.1825	0.148	83.881	−62.60
1.5	1	0.750	0.250	120	0.600	0.62236	1.2092	0.129	110.872	−52.63

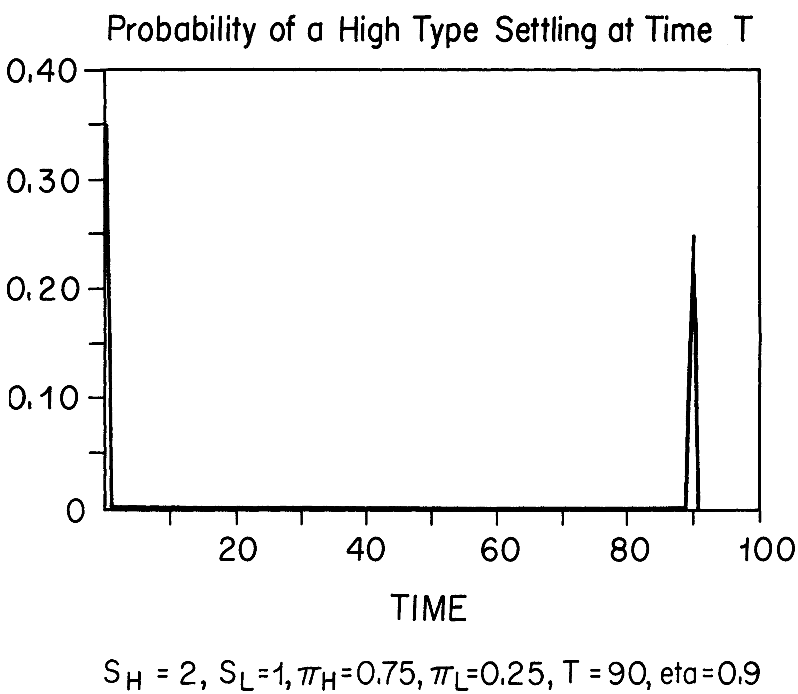

FIGURE I

(row 1, Table II). In contrast, in the standard bargaining model where bargaining duration is short, all wages will be close to minimum firm profitability and so predicted wage variation will be very small.[12]

In conclusion, let us mention two theoretical extensions that seem worth pursuing. First, the assumption that the crunch date is exogenous could be relaxed. We have noted that one reason for an increase in the firm's rate of decay after a point is that the firm runs out of inventories. Inventories are, however, a choice variable for the firm, and one might imagine that firms would try to build up their inventories before a strike starts. Introducing a strategic role for inventories seems likely to enrich the model considerably.

It may also be worthwhile to drop the assumption that rates of decay are the same for all firms. It may be argued, for example, that supernormal profit opportunities are more fragile than normal ones, i.e., they have a higher death rate, if only because even if the latter die, they are likely to be replaced by other normal opportunities. This suggests that rates of decay may be higher for a profitable firm than for an unprofitable firm. Preliminary investigation indicates that bargaining times will be even longer under this differential decay hypothesis. The reason is that delay to agreement now has extra value as a way to screen a profitable firm from an unprofitable one. In fact, it now appears that extensive bargaining can occur even if $(\pi_H s_H) < s_L$; i.e., even if the standard model would predict no strikes at all.

IV. Concluding Remarks

We have shown that in a model where profitable opportunities decay over time at a nonconstant rate extensive bargaining can occur even if the intervals between bargaining are quite short. At least two major questions have not been addressed. First, some empirical work suggests, that, when other variables are corrected for, wages rise with strike length (see footnote 12). This observation, if it is indeed correct, is not consistent with a model where only the firm has private information. It would be interesting to see whether

12. While the ability of the present model to explain substantial wage variation is an advantage, it should be noted that the data do not reveal a significant variation in wages as a function of strike length. For example, Farber [1978] and Fudenberg, Levine, and Ruud [1984] find that wages decline at, respectively, 10 and 15 percent a year; Card [1987] finds no significant relationship between wages and strike length; and some authors even find a positive correlation between the two variables (see Kennan [1986])!

the ideas presented here could be extended to explain delay when the private information lies on the union side.

Second, bargaining models like the one presented here only explain delay during initial negotiations between the union and the firm. They do not explain why strikes occur at a later date after the first contract is signed. In other words, they do not tell us why firms and unions do not sign a single contract lasting to the end of time which, among other things, rules out future strikes. Transaction costs and contractual incompleteness seem to be the keys to this, but an analysis of how strikes arise in the presence of these factors remains to be carried out.

Finally, while we have tried to indicate that the model presented here is consistent with some of the data on strikes, we have made no attempt to subject it to a formal test. In future work, it may be desirable to do this, in the same way that Fudenberg, Levine, and Ruud [1984] and Tracy [1987] have recently tried to test the standard bargaining model.[13]

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13. It is interesting to note that Kennan [1980] finds some evidence of a "reverse crunch" in situations where workers start to receive unemployment insurance after a certain period on strike (the conditional probability of a settlement is lower after the insurance starts than it is before).

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