STRIKE ACTIVITY AND WAGE SETTLEMENTS*

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1. INTRODUCTION

Strikes are recognized as an inevitable product of the conflict of interests between management and union. Paradoxically, strikes occur despite the obvious improvement in welfare for all that could be gained by peaceful settlement. It has frequently been argued that the inefficiency of strikes implies that some degree of irrationality on the part of either unions or firms must be present. However, this need not be the case--strikes can arise from ignorance rather than stupidity. In this paper we derive a simple model of strike activity and wage settlements in which we assume that both the firm and the union are rational, but that the union is uncertain about the profitability of the firm. Strikes occur when the union believes that the firm is highly profitable and holds out for a large settlement, when in fact the firm is relatively unprofitable, and cannot afford such a settlement. The outbreak of a strike acts as a signal to the union indicating that the firm is indeed as unprofitable as it says it is. The firm's continued resistance lowers the union's expectations until eventually an agreement is reached. Our goal is to analyze the forces leading to strikes and to empirically estimate their importance.

Our empirical analysis builds on the work of Ashenfelter and Johnson (1967) and Farber (1978). The purpose of their research was, in part, to test bargaining theories of industrial disputes. A central issue in such theories, as we note above, has been whether strikes are symptoms of rational behavior (see Ashenfelter-Johnson, pp.35-36 or Farber, footnote 2). Ashenfelter-Johnson and Farber used models in which management maximizes the net present value of profits, while the union behaves "politically." The union's behavior is summarized plausibly by a concession schedule: as the length of a strike increases, the proportional wage increase demanded falls. Because the union's behavior is directly specified these models cannot be used to test the rationality of strikes.

The concession schedule approach, as previously implemented, suffers two specific weaknesses, both attributable to its heuristic nature. First, because the concession schedule is specified as a model of political behavior, estimates of its parameters have no standard for comparison. Lacking such a standard, the reasonableness of the estimates (and of the model) cannot be assessed. Second, the concession schedule is expressed in terms of <u>proportionate</u> wage increases. While wage negotiations are often conducted in these terms, the absolute size of the wage increase is presumably the variable of interest for both parties.

While we use much of the same wage chronology data as Ashenfelter-Johnson and Farber, we explicitly model wage negotiations as a non-cooperative game. We <u>derive</u> a concession schedule quite similar to those employed previously. Our schedule is parameterized by the discount factors of management and the union, the alternative wages available to union members, the firm's profitability and the extent to which the union can commit itself to particular wage offers. While rationality is, of course, a joint hypothesis and cannot be unambiguously rejected, we can evaluate its restrictiveness by examining the economic reasonableness of the estimated economic parameters.

Our model is similar to those of Fudenberg-Tirole (1983) and Sobel-Takahashi (1983) except we take the horizon to be unbounded. Each period, the union makes a wage offer that the firm can accept or reject. The union strikes until an offer is accepted. While this negotiation process is special, it is the institutional arrangement reported, for example, by Rees (1977).

Strikes can occur in equilibrium because the information structure is incomplete: the union does not know the value of the settlement to the firm. Following Ashenfelter-Johnson and Farber, we assume output and employment are fixed, so that the total rent earned on the firm's fixed factors is independent of the wage. The value of the settlement to the firm is then this rent minus the wage bill. We employ a special functional form for the uncertainty about the rent which allows a closed form solution sufficiently simple to estimate. This specification was previously used by Sobel-Takahashi (1983) who solved the finite horizon case.

The next section states our assumptions and solves for the equilibrium. We find that the negotiated settlements decrease exponentially, yielding a concession schedule quite similar to those employed previously. Section 3 discusses the data in general terms. Section 4 analyzes the length and frequency of strikes. Section 5 analyzes wage settlements.

2. THE THEORETICAL MODEL

We develop a testable game-theoretic model of wage determination and strike activity. Both unions and firms are assumed to be rational utility maximizers. We assume that the union's objective is to maximize the total wage bill, or equivalently, the wage of a "representative worker." Thus, the union does not perceive a trade off between wages and employment, nor does it seek to tie wage negotiations to non-wage issues such a work rules. While this assumption is clearly inappropriate in some industries, it is a reasonable approximation for those in our sample (see Mitchell (1972) for a discussion of the "Ross-Dunlop Debate" on the union's objective).

A single union negotiates with a single firm. The representative worker receives the constant reservation wage μ if he does not work for the firm, for example, during a strike. (More realistically μ might be expected to decline over time as unemployment benefits and union funds decline.) All the firm's employees belong to the same union. Bargaining takes place in successive periods. At time t=0 the union proposes an increment w_o above the reservation wage. The firm may accept or reject this offer. If it rejects the offer the union goes on strike. It takes the union Δ years (presumably Δ is a small number) to prepare a second offer w_Δ, which again may be accepted or rejected by the firm. In general the union's offer after a strike of length t is w_t. If the offer is accepted the actual wage received is $\mu + w_t$.

It should be clear that the lag in introducing new offers Δ plays an important role in the analysis. It represents the ability of the union to commit itself: once it has made an offer it must stick to it for at least Δ years. If $\Delta = \infty$ then the union makes a take-it-or-leave-it offer. Although in our analysis we treat Δ as a fixed constant in a more general model Δ would be endogenous reflecting the ability of the union to bind itself to an offer for a period of time.

We assume that both sides view the negotiations as fixing real wages once and for all. This assumption overstates the net present value of the surplus to be divided. More importantly, we ignore any incentives the parties may have to alter their behavior in this round of negotiations in order to improve their position when the contract comes up for renewal. Consideration of these long-run incentives would lead to a "supergame"-like model with a multiplicity of equilibria.

The union's objective is to maximize the expected present value of wage payments to the representative worker. As the contract lasts forever, this expected value is

$$(2.1) \qquad \mu/\rho_u + \exp(-\rho_u t)\, w_t/\rho_u$$

where ρ_u is the interest rate at which the worker can borrow and lend. The firm produces a fixed amount, independent of the negotiated wage. Thus, the surplus to be divided between the union and the firm is the rent the firm receives on its fixed factors. Denoting this rent by r the firm's profit per unit of time if it agrees to a wage increment w_t is just $r - w_t$. (Note that we have normalized the size of the labor force to equal one.) The interest rate at which the firm can borrow and lend is ρ_f so the firm's objective is to maximize

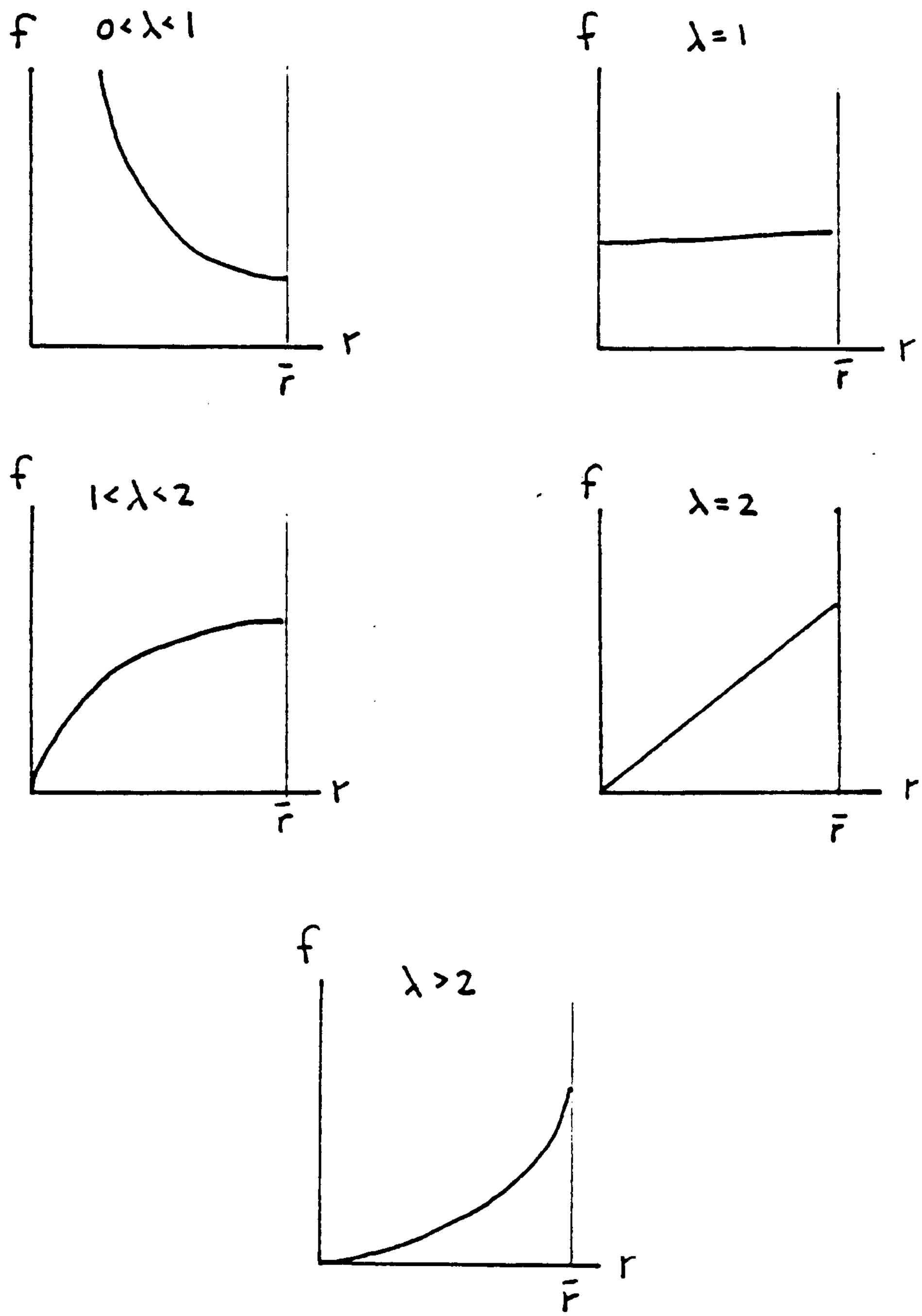
$$(2.2) \qquad \exp(-\rho_f t)(r-w_t)/\rho_f$$

The reservation wage μ is common knowledge, but the union is uncertain about r the total rents earned on the firm's fixed factors. Using all available information the union has a prior cdf on r given by

$$(2.3) \qquad F(r) = \begin{cases} 0 & r < 0 \\ (r/R)^{\lambda} & 0 \leq r \leq R \\ 1 & r > R \end{cases}$$

where λ and R are two positive parameters. Note that R is simply a scale parameter proportional to the expected rents earned by the firm. Figure 1 plots the shape of the density function corresponding to different values of λ The distribution (2.3) is chosen for analytic convenience, but represents a fairly flexible functional form. The convenience of this distribution was first noted by Sobel-Takahashi (1983).

Figure 1 - The Union's Prior pdf



As Harsanyi (1967) has shown, this game of incomplete information may be viewed as a game of imperfect information in which one player's valuation function is drawn at random at the start of the game according to the cdf (2.3) which is assumed to be common knowledge. A strategy for the union specifies for each period p the wage offer $w_{p\Delta}$ as a function of the previous offers w_o, $w_\Delta, \ldots, w_{(p-1)\Delta}$. A strategy for the firm determines for each value of r and each period p which offers will be accepted, again as a function of the previous offers.

A Bayesian equilibrium requires that for each value of r, the firm's chosen strategy is the best response to the strategy of the union, and that the union's strategy be optimal given the firm's strategy and the union's beliefs about r. In addition, as the strike progresses the union must update its prior beliefs (2.3) in accordance with Bayes law. We further require that the equilibrium be subgame perfect: that players believe their opponents will optimize in the future regardless of what has happened in the past. This rules out empty threats. For example, the union might try to set a take-it-or-leave-it offer at the outset of negotiations. However, the firm should not believe this threat, because after the firm rejects the offer it is not optimal for the union to stop negotiating. A strategy selection which satisfies both of the above conditions is a "perfect Bayesian equilibrium." A discussion of this concept of equilibrium can be found in Fudenberg-Tirole (1983). It is related to, but weaker than, Kreps-Wilson's (1982) notion of a sequential equilibrium.

We now solve to find the unique "stationary reservation price" equilibrium. By a reservation price equilibrium we mean that the firm chooses a function $w^*(r)$ and accepts the first offer $w_t \le w^*(r)$. We have shown in Fudenberg-Levine-Tirole (1984) that w^* is necessarily a strictly increasing function--more profitable firms will accept higher wages since they have more to lose during a strike. Consequently, if a settlement has not yet been reached and the lowest wage previously offered by the union is w_{min}, the union now knows that $r \le w^{*-1}(w_{min})$. Applying Bayes rule we find that the union's posterior belief about r if w_{min} has been refused, $F(r|w_{min})$, satisfies

$$(2.4) \qquad F(r|w_{min}) = \begin{cases} 0 & r < 0 \\ (r/w^{*-1}(w_{min}))^{\lambda} & 0 \le r \le w^{*-1}(w_{min}) \\ 1 & r > w^{*-1}(w_{min}). \end{cases}$$

The updating rule in (2.4) is equivalent to measuring r in new units $r^* \equiv [w^{*-1}(w_{min})/R]r$, as only the <u>scale</u> of the posterior is changed. This is why the distribution in (2.3) is so useful: past play influences current beliefs only through a reduction in the upper bound of the support of r, and with (2.3) changing the upper bound does not change the shape of the distribution. This invariance makes it possible to look for a "stationary" equilibrium in which the union's offer at any time is a fixed proportion of the maximum possible rents; that is, if the union found it optimal to offer w_o when its beliefs were described by the prior distribution with upper bound R, then when the union's previous lower offer is w_{min} it should choose to offer

$$(2.5) \qquad [w^{*-1}(w_{min})/R]w_o.$$

In particular it follows from (2.5) that along the equilibrium path, offers decrease geometrically,

$$(2.6) \qquad w_{t+\Delta} = \gamma w_t,$$

for some $1 > \gamma > 0$. Hereafter, we shall restrict attention to equilibria satisfying (2.5) (and thus (2.6)), which we call <u>stationary equilibria.</u>

Assuming (2.6) let us now examine the reservation price function w^*. If the firm accepts w_t it gets $r - w_t$ now. If it waits one period it receives instead $\exp(-\rho_f\Delta)[r - \gamma w_t]$ The reservation price $w^*(r)$ is the value of w_t that makes the firm indifferent between these values

$$(2.7) \qquad w^*(r) = \eta r$$

$$\eta \equiv \frac{1-\exp(-\rho_f\Delta)}{1-\gamma\exp(-\rho_f\Delta)} .$$

This characterizes the optimal strategy of the firm. Observe that the more rapidly the union concedes (the smaller γ) the smaller is η, which is to say that the firm plays tougher, demanding a larger share of the surplus. This is reasonable: if the union is conceding rapidly there is no reason for the firm to yield. All it has to do is take a short strike and it can get a much better offer. It is also easy to show that as ρ_f or Δ grows, and the cost of waiting increases, η grows and the firm yields more rapidly.

To find the optimal strategy of the union let η be given and suppose the firm rejected an offer of $w_{t-\Delta}$ last period. If the union charges $\gamma w_{t-\Delta}$ now the probability that this offer is rejected is just $F(\gamma\mu_{t-\Delta})/F(w_{t-\Delta}) = \gamma^{\lambda}$. Let J_t be the expected present value to the union of charging w_t in period t. With probability $1 - \gamma^{\lambda}$ the offer w_t is accepted and the union gets $w_t = \gamma w_{t-\Delta}$. With probability γ^{λ}, w_t is refused, and w_{min} is rescaled to γw_{min}. From the updating rule (2.4) and our assumption of a stationary equilibrium, all future offers are scaled down by γ, while the acceptance probabilities are constant. Since the expected present value J_t is linear in the negotiated wage, the union's value at the start of the next period is w_t if refused is $J_{t+1} = \gamma J_t$. Thus

(2.8) $$J_t = (1-\gamma^{\lambda})\gamma w_{t-\Delta} + \gamma^{\lambda}\exp(-\rho_u\Delta)\gamma J_t \quad \text{or}$$

$$J_t = (1-\gamma^{\lambda+1}\exp(-\rho_u\Delta))^{-1}(1-\gamma^{\lambda})\gamma w_{t-\Delta}.$$

Differentiating (2.8) with respect to γ, we find that the first order condition for a maximum of J_t is

(2.9) $\exp(-\rho_u \Delta)\lambda\gamma + \gamma^{-\lambda} = \lambda + 1,$

which is independent of t. This equation has a unique solution, which is strictly between zero and one and which satisfies the second order condition for a maximum, so it implicitly defines the optimal γ. Differentiating (2.9) shows that as ρ_u or Δ is increased (and the cost of striking increases) γ declines and the union concedes more rapidly. As λ increases γ increases and the concession rate is lower. To see why this is so refer to Figure 1: as λ gets larger the weight in F becomes more concentrated near R. Since even a minor concession will cause most firms to accept the offer there is no reason to concede rapidly.

When the union's last offer was $w_{t-\Delta}$ it knows $\eta r \leq w_{t-\Delta}$ and sets $w_t = \gamma w_{t-\Delta}$ Since it initially knows $r \leq R$ by stationarity it should set $w_o = \gamma\eta R$, and

(2.10) $w_t = \gamma\eta R\gamma^{t/\Delta}$

We have now derived an equilibrium concession schedule in which wage settlements decline exponentially with strike length. There are however two key differences between our schedule and that of Ashenfelter-Johnson-Farber. First our schedule gives the rate of decrease of the union's demands, while theirs gives the rate of decrease of the offers the union is willing to accept. Second, our schedule is for absolute wage increments, while theirs is for percentage increments above a base wage.

We have solved for the unique stationary reservation price equilibrium. That it is also a perfect Bayesian equilibrium follows from the fact that it is the limit of the finite horizon perfect Bayesian equilibria derived by Sobel-Takahashi (1983) and from the limit theorem of Fudenberg-Levine (1983). s_1

This completes our characterization of the equilibrium and our discussion of the theoretical model.

3. THE DATA

Using the data set from Hank Farber's 1978 study plus data from Moody's we compiled 159 observations on contracts reached by 15 firms (see Figure 3) during the period 1955-79. The variables used in the study, together with their means and standard errors are shown in Figure 2. The key endogenous variables are W the contracted real based wage rate (for janitors), S the real per worker (measured on a janitor equivalent basis) sales and T the length of the strike. These are broken out separately by firm in Figure 3, and a correlation matrix is given in Figure 4.

Firm Specific Variables		Mean	Standard Error
W	- contracted real base wage (for janitors)	2.4	0.56
S	- real per worker equivalent sales	10.3	8.4
T	- length of strike (years)	.023	.066
s_L	- labor's share of total cost	-	-
Y_v	- proxy for share of variable cost, $Y_v \equiv (1-s_L)/s_L$	3.1	2.5
D_{ns}	- no-strike dummy	.82	.39
X_w	- real minimum wage times employment rate for prime males	1.2	0.14
X_u	- extent of unionization	.67	.15
X_r	- net return on assets	.12	.059
Economy Wide Variables			
CPI	- consumer price index	1.1	.31
WLEV	- industrial wage level	2.5	1.2
UR	- unemployment rate	5.4	1.3
URM	- unemployment rate for prime males	.036	.012

Figure 2 - Variables Used in Study

		T	W	S
1.	American Cyanamid	.186	1.99	4.87
2.	Armour	0	2.77	17.5
3.	Atlantic Richfield	.0113	2.83	26.7
4.	Boeing	.00522	2.68	5.33
5.	Firestone	.0680	2.88	7.41
6.	FMC	0	2.20	5.17
7.	General Electric	.0828	1.72	2.59
8.	General Motors	.0170	3.03	7.68
9.	International Paper	.004	2.34	6.51
10.	International Shoe	.00549	1.71	3.40
11.	PPG Industries	.0370	2.63	5.09
12.	Rockwell	0	2.46	3.35
13.	Simmons	.0235	1.92	4.20
14.	U.S. Steel	.0517	2.62	3.58
15.	Weyhauser	.0366	2.58	6.52

Figure 3 - Means of Endogenous Variables by Firm

	W	S	T
W	1.00	0.54	-0.01
S	0.54	1.00	-0.16
T	-0.01	-0.16	1.00

Figure 4 - Correlation Matrix of Endogenous Variables

Our theory predicts that longer strikes are associated with smaller wage settlements (see (2.10)). The data is consistent with this in the sense that the base wage and strike length are negatively correlated, although this correlation is apparently weak. Less profitable firms than expected by the union (lower r values) have a lower reservation wage by (2.7) and consequently, by (2.10), suffer longer strikes. Indeed this must be a feature of any theory of rational bargaining: if among firms which are equally profitable from the union point of view less profitable firms have shorter strikes, the more profitable firms will surely pretend that they are less profitable and thus avoid a costly strike. This suggests that firm sales should be negatively correlated with strike length since firms which a re more profitable than the union expects should in general have more sales _ex post._ However this is a bit problematic since firms surely have lower sales in strike years--they are shut down by the strike for part of the year. However, even if we assume the firm has no sales during the strike (surely an unreasonably extreme assumption) and inflate sales correspondingly, revenues and the strike length are _still_ negatively correlated, although the correlation drops from -0.16 in Figure 4 to -0.09. The extent of the negative correlation between inflated sales and strikes is reinforced if we compare the mean revenue in years without strikes--equal to 10.9--to the mean revenue of inflated sales in years with strikes--equal to 7.5. Thus firms tended to have unusually low sales in strike years even after inflating for the effect of the strike. This tends to support the viewpoint that bargaining is indeed rational.

4. STRIKE ACTIVITY

We begin our empirical analysis by applying our model's predicted distribution of strike length to our data on strikes. This will let us estimate the probability an offer is refused, γ^{λ}, and the commitment length Δ. The next section completes the analysis by examining the conditional distribution of sales and wages given strike length. We present the comparatively simple strike-length estimates first to familiarize the reader both with the model and with the data, and to check the consistency of the former with the latter.

A strike occurs if and only if the reservation value of the firm ηr is less than the first offer made by the union, $\gamma\eta R$. From equation (2.8) this implies that the probability of a strike is

$$\text{pr}(T=0) = 1 - \gamma^{\lambda} \tag{4.1}$$

which in the sample was 81.8% of the time. We can therefore estimate γ^{λ} to be .182 (see Figure 6). Recall that this is the probability perceived by the union. We should emphasize that the firm knows exactly how long the strike will last. This follows from the assumption that the firm has complete information about its own rents and the union's reservation wage.

Also using (2.3), (2.7), and (2.10) we can compute that when a strike does occur the strike length density is the exponential

$$\text{(4.2)} \qquad pr(T=t) = (1-\gamma^{\lambda})\gamma^{\lambda t/\Delta}$$

From this we can compute that the expected length of a strike (conditional on a strike occurring) is $\Delta/(1-\gamma^{\lambda})$, equal in the sample is 0.126 years. Since γ^{λ} was already estimated equal to .182 we estimate Δ to be 0.10 or about 5.2 weeks.

Rounding Error	Percent of Observations
0.0 - 0.1	21%
0.1 - 0.2	21%
0.2 - 0.3	14%
0.3 - 0.4	17%
0.4 - 0.5	28%

(The rounding error is computed by dividing strike length by 0.10 and taking the absolute distance to the nearest integer.)

	Percent of Observations	
Length of Strike	Empirical	Theoretical
0.0 - 0.1	55.2%	54.8%
0.1 - 0.2	13.8%	20.4%
0.2 - 0.3	17.2%	11.2%
0.3 - 0.4	10.3%	5.1%
0.4 - 0.5	0.0%	1.9%
0.5 - 0.6	3.4%	1.0%
0.6 +	0.0%	0.9%

($X^2(6) = .19$)

Figure 5 - Histogram of 29 Strike Periods

The estimate $\Delta = 0.10$ poses a problem in interpreting the data: it implies that observed strike lengths should be integer multiples of this amount. As the histogram of rounding errors in Figure 5 shows actual strike lengths are by no means integer multiples of 0.10. Several conclusions are possible. We may conclude that the stationarity assumption underlying the model is wrong -- that the probability of a strike persisting another period is not independent of the length of the strike. However, stationarity seems a reasonable approximation, and is necessary for a closed form solution to the model. Second, we could conclude that Δ is not a fixed constant but is a random variable which is different in different negotiations. However, it seems unlikely that Δ varies substantially, and in any case estimation of the model is computationally impractical unless Δ is held fixed.

A third alternative is to replace the assumption of discrete time periods with a continuous time model. In continuous time, the union's ability to commit itself to an offer does not stem from an inability to change offers for a given length of time because the union can make a new offer each instant. Instead, the union's ability to commit itself must stem from a cost of changing offers (as in Anderson's (1983) work on price competition oligopoly--see also Crawford (1981)).

For the purposes of this paper we simply extrapolate the union's concession schedule (2-11) to continuous time. While, as we have just observed, this approximation may be questioned, it does not seriously violate the spirit of our model. Given this approximation for $t > 0$ we have $w_t = \eta r$: the settlement reached if the strike occurs is at the firm's reservation value. The induced density of strike lengths for $t > 0$ is the continuous exponential

$$(4.3) \qquad f_T(t) = -\gamma^{\lambda}[\log(\gamma^{\lambda/\Delta})]\gamma^{\lambda t/\Delta}$$

in place of (4.2) ((4.1) remains unchanged). Our revised estimate of Δ is now the maximum likelihood estimate using (4.3), equal to 0.214 or 11.2 weeks. This is larger than the previous estimate since with fixed Δ and the firm making proposals in intermediate periods strikes tend to be shorter. Figure 5 gives a histogram for strike lengths; the goodness of fit test shows that the exponential in (4.3) fits the data quite well. Recently, Tracy (1985) fitted a flexible functional form to strike length data which did not reject the exponential distribution.

Variable	Estimates	Standard Error
γ^{λ}	0.182	(0.0306)
Δ (discrete time	0.100	
Δ (continuous time)	0.214	(0.0519)

	Union Discount Rate (ρ_u)			
	1%	5%	10%	20%
$\lambda = 13/\rho_u$	1300	260	130	65
$\gamma = (.182)^{1/\lambda}$	.9987	.9935	.9870	.9741
$h = \gamma^{1/\Delta}$	99.39%	97.00%	94.06%	88.46%

Figure 6 - Estimates Using Strike Length Data

Given the union's interest rate we can use (2.9) to estimate the concession factor γ and the distribution parameter λ. Figure 6 gives estimates corresponding to different choices of the union's (real) interest rate based on a (good) linear approximation. The distribution parameter λ tends to be quite large suggesting that the union prior tends to be concentrated near the upper bound R (see Figure 1). This means that the union concedes quite slowly. Incidentally the equilibrium we have described is insensitive to changes in the union prior pdf in the range above the reservation value corresponding to the first offer made (γR). Since 82% of the reservation values lie to the right of this cutoff our model requires only that the lower 18% tail of the union prior have the shape of the pdf in Figure 1.

Firm Discount Rate (ρ_f)	Union Discount Rate (ρ_u)			
	1%	5%	10%	20%
0.5%	45%	14%	8%	4%
1%	62%	24%	14%	8%
5%	89%	61%	45%	28%
10%	94%	76%	62%	46%

Figure 7 - Value of η (Union's Share)

Using the estimates of Δ and γ and the firm discount rate, η can be estimated from (2.7) (see Figure 7). Either the firm or the union does worse when it has a higher discount rate, because greater impatience makes players more willing to settle for a poor bargain. If we accept that both negotiators have a discount rate equal to 5% we see that the union gets 61% of the amount being bargained over.

5. WAGES AND SALES

The overall likelihood function for the three endogenous variables W, S and T can be written as $f(W,S|T)f(T)$. The previous section explored the implications of the marginal density for strike length $f(T)$. In this section we consider the specification and estimation of the wage and sales equations $f(W,S|T)$ conditional on strike length T.

The relationship between the observed variables W and S is

$$W = w_T + \mu$$

$$S - \mu = r + v$$

where v is variable costs. The wage equation follows from the definitions of μ and w_T; the sales equation is an accounting identity that sets opportunity costs plus economic rents equal to revenues. Conditional on strike length T, the wage settlement w_T is given by (2.10). We parameterize w_T as $\eta\theta h^T$ where $\theta \equiv \gamma R$ and $h \equiv \gamma^{1/\Delta}$. . The expectation of rents r is more complicated. When there is a strike, $T > 0$, the firm's reservation price equals the wage settlement so that $r = W_T/\eta$. But when no strike occurs, rents are greater than or equal to $w_0/\eta = \gamma R$ so the expectation of r jumps discontinuously above γR :

$$E(r|T) = \begin{cases} \alpha\gamma R, \ \alpha > 1 & \text{if } T = 0 \\ \gamma R \gamma^{T/\Delta} & \text{if } T > 0 \end{cases}$$

We parameterize this expectation by

$$E(r|T) = \theta[h^T + \alpha 1(T=0)],$$

where $1(*)$ is the indicator function that gives a dummy variable for the case of no strike. The parameters should satisfy the restrictions $\theta, \alpha > 0$ and $0 < h < 1$. Several other nonlinear constraints must hold in order to recover the discount rates implicit in this specification.

The system of equations that we estimate is

$$W = \eta\theta h^T + \beta_{w0} + \beta_{w1}X_w + \beta_{w2}X_u + \varepsilon_w$$

$$S - W = \beta_{s0} + \theta[(1-\eta)(h^T + \alpha 1(T=0)) + \beta_{s1}Y_v + \beta_{s2}Y_v 1(T=0) + \beta_{s3}X_r] + \varepsilon_s$$

where specifications for the reservation wage μ and costs v have been added. The reservation wage is assumed to be a linear function of a measure of the real minimum wage and the extent of unionization in the industry. The variable costs are assumed to be a linear function of the net return on assets X_r and a proxy for per worker variable costs Y_v (which equals $[1-s_L]/s_L$, where s_L is the labor share of costs). The variable-costs proxy variable is also interacted with the no-strike dummy to reflect the fact that variable costs actually incurred will be smaller when there is a strike. All three variables are obviously correlated with actual costs. But our specification for variable costs clearly ommits some components and thereby introduces specification error into our empirical model because the included variables are correlated with the missing components. Using an instrumental variables estimator, we will take advantage of these correlations without introducing inconsistency to our estimators.

To complete the specification, we allow the parameter θ to be different for each firm. Since the size of the workforce is normalized to one, each θ is a measure of the size of the firm relative to its workforce. We also recognize that the specification of variable costs is vitiated by observation error and specify several variables as instruments for Y_v: the economy-wide variables, the explanatory variables for the reservation wage, strike length, the no-strike dummy, and firm specific dummies.

The two equation system was estimated by nonlinear three stage least squares (NL3SLS), without imposing any a priori constraints on the parameters. Heteroskedasticity appeared to be present in the sales equation and we corrected for this with a two-step weighted estimator. This correction made unappreciable differences in the estimates. The estimates that we are about to discuss are the weighted ones and they are listed in Figure 8. Following this discussion, we describe the heteroskedasticity problem.

WAGE EQUATION (R^2=0.102)	ESTIMATE	STANDARD ERROR
β_{w0}	1.441	0.170
β_{w1}	0.672	0.163
η	0.218	1.119

SALES EQUATION (R^2=0.891)	ESTIMATES	STANDARD ERROR
β_{s1}	1.618	1.717
β_{s2}	0.332	1.146
β_{s3}	22.166	128.64
α	-1.102	5.061
h	0.848	2.224

Figure 8 - Estimates of Model Parameters

Let us first review the parameters of secondary interest, those in the reservation wage and variable costs specifications. These parameters generally accord with one's expectations, but because they are "reduced form" parameters these parameters do not provide much information on the performance of our model. The reservation wage depends positively on the minimum wage. We would expect variable costs to contribute positively to S-W because large variable costs for fixed sales implies that there are fewer rents for the union to hope to capture. We find that variable costs contribute positively to S-W (1.168) and are a bigger contributor when there is no strike (an additional 0.332). The net return on assets also contributes positively, but neither this estimate nor the others in the sales equation are precisely estimated.

The key structural parameters are η, $h \equiv \gamma^{1/\Delta}$., and α, none of which are precisely estimated. Our estimates of η and h both satisfy the constraints implied by our economic model that they lie in the unit interval (0,1). The union garners 21.8% of the rents which is a substantial departure from the outcome of a perfectly competitive labor market. The rate of union concession is 15.2% per year, which is quite different from the rate of 86.5% per year implied by Farber's earlier study. The estimates do not appear to be significantly different given the standard error of our estimate. But the slower concession rate is quite consistent with the data summary statistics which show a weak correlation between strike length and wages. One should also note that Farber's data did not include strike length, but only strike occurrence, which suggests that the concession rate would be difficult to identify in his study.

The estimated addition to the expectation of rents for no-strike observations α is <u>negative</u> but poorly estimated. This contradicts a prediction of the model and is a departure that we cannot explain.

The original structural parameters ρ_f, ρ_u, λ, and γ can be recovered by combining the estimates of Δ and γ^{λ}. from the strike length data with these estimates of η and $\gamma^{1/\Delta}$. Since η and $\gamma^{1/\Delta}$. were estimated conditionally on strike length and Δ and γ^{λ} were estimated marginally on strike length, these pairs of estimates have no covariance. Therefore, we use the standard Wald linearization (some drawbacks of which are discussed in Gregory and Veall (1983)) to obtain estimates of asymptotic errors for ρ_f, ρ_u, λ, and γ.

The estimates of these parameters and their standard errors are given in Figure 9. Note that values of ρ_f and ρ_u are not defined for all values of the econometric model parameters. Thus the point estimates of 4.5% and 29.0% derived from unconstrained reduced form estimates are not only reasonable values but also satisfy further predictions of our model. Nevertheless, the union is estimated to be quite impatient, while the firm is relatively patient. Neither parameter is estimated precisely, but a confidence interval of two standard deviations for the ratio of the firm to union discount rates is 0.07 to 0.24, confirming the relative patience of the firm. This relative patience is consistent with the estimate that the union obtains only 13.5% of the rents.

PARAMETER	ESTIMATE	STANDARD ERROR
Δ	0.214	0.0521
γ	0.965	0.542
λ	48.284	273.4
ρ_u	0.290	0.061
ρ_f	0.045	0.553
ρ_f/ρ_u	0.154	0.042

Figure 9 - Estimates of Economic Parameters

We suspect that our estimate of the firm's relative patience is an over-statement. The firm may have more ability to precommit itself than the model predicts, and such ability is confounded with patience in our simple formulation.

The estimates of θ for each firm are listed in Figure 10. Each estimate is positive but note are significantly different from zero. We combined these estimates with our estimate of η and the average wage of each firm to compute the wage premium earned by each union above the competitive level. This premium is also listed in Figure 10. There is a modest range, from 3% (Rockwell) to 15% (International Shoe) with a median of 9.2% (FMC). Overall, unionization has a large estimated effect on wages, but unfortunately this estimate has a large standard error. Our estimates of the wage premimum are in broad agreement with those

Farber obtained with a subset of our data. The average premium of 8.6 percent is modest compared with the estimated ranges of 10 to 15 percent obtained by Lewis (1963) and 21 to 32 percent found by Freeman and Medoff (1984). The estimates are not fully comparable, however, because the base wage implicit in each differs. Our base wage is the best alternative wage expected by union members during a strike, whereas the base wage in the other studies represents a long run competitive wage for an industry.

Firm	θ	Std. Error	Wage Premium $\eta\theta/(w-\eta\theta)$	Farber
1. American Cyanamid	0.885	(5.186)	11.0%	5.0%
2. Armour	1.149	(6.557)	10.5%	n.a.
3. Atlantic Richfield	1.317	(7.531)	11.6%	n.a.
4. Boeing	0.601	(3.681)	5.4%	n.a.
5. Firestone	0.697	(4.167)	5.7%	5.0%
6. FMC	0.832	(4.904)	9.2%	n.a.
7. General Electric	0.811	(4.795)	11.7%	9.6%
8. General Motors	0.571	(3.485)	4.4%	4.3%
9. International Paper	0.847	(4.962)	8.8%	4.2%
10. International Shoe	1.019	(5.890)	15.0%	n.a.
11. PPG	0.750	(4.475)	6.7%	5.6%
12. Rockwell	0.315	(2.126)	3.0%	n.a.
13. Simmons	1.075	(6.122)	14.3%	6.5%
14. U.S. Steel	0.583	(3.639)	5.2%	11.7%
15. Weyhauser	0.765	(4.535)	7.1%	6.2%
AVERAGE			8.6%	7.3%

Figure 10 - Firm Size Coefficients

Our estimation focussed on the first moments of the data, but the model also implies that a particular form of heteroskedasticity is present in the sales equation. As noted above, the expectation of rents, conditional on strike length, is discontinuous at zero. This is also true of the variance. Due to the uncertainty about rents for no-strike observations, the variance in the sales equation should increase for those observations. In addition, the variance of rents is proportional to R^{-2} and hence θ^2 and this implies heteroskedasticity across firms.

Using the estimated θ's from Figure 9, we estimated models of heteroskedasticity of the form

$$\text{Var}(\varepsilon) = b_0 + (b_1\theta + b_2\theta^2)\, 1(T=0)$$

for both the sales and wage equations, using squared fitted residuals as dependent variables in OLS regressions. These estimates were also consistent with our expectations. The wage equation version yielded

$$\text{Var}(\varepsilon_w) = \underset{(0.074)}{0.338} - (\underset{(0.245)}{0.2411\,\theta} + \underset{(0.196)}{0.190\,\theta^2})\, 1(T=0)$$

and the sales equation version was

$$\text{Var}(\varepsilon_s) = \underset{(2.700)}{7.186} - (\underset{(8.981)}{32.725\,\theta} + \underset{(7.184)}{35.329\,\theta^2})\, 1(T=0)$$

which is increasing in θ for our sample (standard errors of the OLS estimates are given in parentheses below the point estimates). These estimates suggest conformity with our predictions.

6. CONCLUSION

We developed and estimated a model of strikes due to union uncertainty about firm profitability. Except for the fact that periods without strikes seemed to have lower sales (and thus lower profits) than expected, our estimates are quite consistent with the model's predictions. We get plausible real interest rates of 12% for the union and 1.1% for the firm. We also estimate that the union is able to appropriate about 13.5% of the firm's profits--a substantial departure from pure competition resulting in a median 55% wage premium above the competitive level.

Our estimates are of course dependent on the particular bargaining game (union makes all the offers) and functional forms we employed. Our estimates of the interest rates are not intended to be of strong independent interest; rather, they serve as a test of the plausibility of the model. Our main point is that strikes and wage negotiations <u>can</u> be modelled and empirically analyzed using the theory of games of incomplete information. We hope that this theory will be used to develop more complex and thus more descriptive models of strikes with rational negotiations.

FOOTNOTES

s_1 Recently, Gul-Sonnenschein-Wilson (1985) have shown that there are also nonstationary equilibria. The multiplicity of equilibria comes from our assumption that the support of the distribution over the firm's rents has a lower bound of zero. If the lower bound is strictly greater than zero, then the results of Fudenberg-Levine-Tirole imply that the equilibrium unique. However, this case is less tractable.

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