STRIKES AND HOLDOUTS IN WAGE BARGAINING: THEORY AND DATA

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Abstract

We develop a private-information model of union contract negotiations in which disputes signal a firm's willingness to pay. Previous models have assumed that all labor disputes take the form of a strike. Yet a prominent feature of U.S. collective bargaining is the holdout: negotiations often continue without a strike after the contract has expired. Production continues with workers paid according to the expired contract. We analyze the union's decision to strike or hold out and highlight its importance to strike activity. Strikes are more likely to occur after a drop in the real wage or a decline in unemployment.

Strikes and other costly disputes are commonplace. Yet a theory of why they happen has been slow to develop. John R. Hicks (1932) concluded that most strikes result from faulty negotiation. Arthur M. Ross (1948) moved toward an alternative explanation of strikes by recognizing that union leaders are motivated by personal advancement and the growth of the union. Orley Ashenfelter and George E. Johnson (1969) developed Ross's political model of unions into a theory of strikes.

In the Ashenfelter and Johnson (1969) model, strikes occur when the wage expectations of the rank and file are out of line with what the firm is willing to pay. If the union leaders present a low-wage contract for ratification when the rank and file's wage expectations are high, the rank and file may accuse the leaders of selling out to management. The union leaders may prefer to strike, rather than risk dissension within the union. A strike serves to convince the rank and file that a high wage is not possible: "the basic function of the strike is as an equilibrating mechanism to square up the union membership's wage

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expectations with what the firm may be prepared to pay" (Ashenfelter and Johnson, 1969, p. 39). An implication of this theory is that the union's wage demands should fall during a strike. A weakness of the theory is that these wage demands are based on conjecture, rather than derived from a bargaining process.

Recent developments in noncooperative bargaining theory make it possible to derive the union's demands by specifying the bargaining setting in detail.[1] Strikes are explained by private information about some aspect critical to reaching agreement, such as the firm's willingness to pay.[2] Bargainers are uncertain about each other's preferences and have incentives to misrepresent private information. Disputes arise as a credible means of communicating this private information. A firm with a high willingness to pay prefers to settle at a high wage without a strike; a firm with a low willingness to pay prefers to endure a strike and settle at a low wage. Hence, a firm with private information about its willingness to pay can signal this information through its willingness to endure a strike.

This private-information theory of strikes applies in either the bilateral-monopoly setting, in which a union and firm are bargaining with asymmetric information, or the agency model of Ashenfelter and Johnson (1969), in which the informational problem is between the rank and file and the union leaders.[3] What is essential in both formulations is that private information cannot be verified at a low cost. While we agree with Ross (1948) that there are important differences between the rank and file and the union leaders, throughout this paper we analyze the bilateral-monopoly model, because it is more tractable.

Our approach differs from other private-information models of wage bargaining in that we recognize an important feature of U.S. labor negotiations: workers can continue to work under the terms of the old contract after the contract has expired. Hence, as of the contract expiration date, the union has two alternatives to settlement: the union can strike, or it can hold out by continuing to work under the expired contract. Prior research has ignored the holdout option, focusing solely on strikes (see e.g., Drew Fudenberg et al., 1985; Oliver Hart, 1989; Kennan and Wilson, 1989). We argue that the analysis of labor negotiations is significantly affected by including the holdout option.

In this paper, we develop a bargaining model that includes the union's threat decision. We then use the model to interpret data on union contract negotiations. An implication of the model is that the attractiveness of the strike threat varies with changes in economic variables, such as the real wage and the un-

[1] See John Kennan and Robert Wilson (1989, 1992), Martin J. Osborne and Ariel Rubinstein (1990), and Ken Binmore et al. (1992) for recent surveys.

[2] Other motivations for inefficiencies have been presented, such as uncertain commitments (Vincent P. Crawford, 1982) and multiple equilibria in the bargaining game (Hans Haller and Steinar Holden, 1990; Raquel Fernandez and Jacob Glazer, 1991). Henry S. Farber and Max H. Bazerman (1987, 1989) discuss other reasons for bargaining inefficiencies.

[3] See Brian P. McCall (1990) for an analysis of an agency model in which disputes take the form of arbitration.

employment rate. In equilibrium, strikes only occur when the real wage is low. Only then can the union expect wage gains from a strike that are enough to offset the higher bargaining costs associated with a strike. This is consistent with a prominent feature of the strike data: the incidence of strikes increases when unemployment declines and when the real wage falls.

We begin by presenting new evidence on the extent of strikes and holdouts in U.S. contract negotiations in Section 1. The evidence suggests a need to expand existing bargaining models to include the holdout threat. We then present a private-information model that illustrates the role of strikes and holdouts in bargaining in Section 2. We argue that including the union's decision to strike or hold out will sharpen empirical tests of private-information bargaining models.

1 Strikes and Holdouts: The Data

The empirical features we focus on are bargaining disputes, both strikes and holdouts. A holdout is defined as the time between the expiration of the previous contract and either the beginning of a strike or the settlement of a new contract, whichever comes first. According to the National Labor Relations Act, as amended, the terms and conditions of employment during the holdout are governed by the previous contract. The employer may not unilaterally change these terms until a bargaining impasse is reached. In addition, either party can elect to increase the bargaining costs by initiating a lockout or a strike.[4]

Holdouts have received virtually no attention in the empirical literature on strikes.[5] This does not reflect a paucity of holdouts in the data. Table 1 summarizes information on holdouts and strikes for the sample of data we focus on in this paper.[6] In our sample of 5,002 contract negotiations involving large bargaining units (1,000 or more workers) during the period 1970-1989, the incidence of bargaining disputes is 57 percent. Dispute incidence is measured as the percentage of contract negotiations that involve either strike, lockout, or holdout. Strike incidence is 10 percent, lockout incidence is 0.4 percent, and holdout

[4] An exception to this process is the transportation industry, where some of the bargaining units are covered by the Railway Labor Act (the railroad and airline bargaining units are covered by the Railway Labor Act, while the maritime, longshore, and trucking bargaining units are covered by the National Labor Relations Act). Under the Railway Labor Act, a holdout typically occurs until a series of mediation steps is completed. After this mediation process is over, a major dispute is often resolved through legislative action rather than through collective bargaining. Because of this substantial difference in the bargaining process, we have excluded from our sample all contracts negotiated under the Railway Labor Act. See Herbert R. Northrup (1971) for a detailed discussion of the Railway Labor Act.

[5] The exception is Tracy (1988), in which the stockmarket response to settlements, strikes, and holdouts is analyzed. The definition of holdout used in that paper was more restricted in that holdouts followed by a strike were treated simply as a strike.

[6] Our data come from the Bureau of Labor Statistics (*Current Wage Developments*, *Current Work Stopages*, and *Industrial Relations Facts*) and the Bureau of National Affairs (*Collective Bargaining Negotiations and Contracts*). See Sheena McConnell (1989) and Tracy (1986) for a detailed description.

Table 1: Dispute Incidence And Duration By Industry

		Incidence (percentage)			Median [mean] duration (days)			
Industry	Contracts	Holdout	Strike	Dispute	Holdout	Strike[a]	Strike[b]	Dispute
Overall	5002	47	10	57	32	27	53	37
					[63]	[43]	[76]	[65]
Manufacturing,	1408	47	7	54	30	27	64	34
durable					[62]	[48]	[88]	[65]
Manufacturing,	1431	33	18	51	18	30	48	28
nondurable					[57]	[46]	[72]	[62]
Transportation	175	59	14	73	60	13	72	60
					[86]	[20]	[109]	[90]
Communication	226	50	8	58	39	47	64	41
					[56]	[47]	[88]	[61]
Utilities	532	37	6	43	48	42	70	60
					[77]	[62]	[82]	[90]
Retail Trade	809	66	7	73	40	17	50	40
					[59]	[26]	[56]	[59]
Services	421	65	8	72	32	20	46	34
					[68]	[26]	[67]	[68]

Notes: Holdout means the contract was signed without a strike more than one day after the contract expiration. Strike means a strike occured before the contract was signed. Dispute means either a holdout or a strike occured before the contract was signed.
[a] Days from the beginning of the strike to the end of the strike
[b] Days from the contract expiration to the end of the strike

incidence is 47 percent. The incidence of disputes ranges across industries from a high of 73 percent in transportation to a low of 43 percent in utilities.

A useful measure of how rapidly disputes are settled over time is the settlement rate from dispute, defined as the conditional probability (frequency) of moving from a state of dispute to a state of settlement, given that the dispute has lasted a particular duration. Figure 1 shows the empirical settlement rate from dispute plotted against the number of days relative to the previous contract's expiration date. A clear "deadline effect" exists in the data.[7] Ignoring contracts that are renegotiated and made effective before contract expiration, only 12 percent settle before the contract expiration. The daily settlement rate on the expiration date and the following day are 15 percent and 24 percent, respectively. Over the next six days, the daily settlement rate falls from around 4 percent to about 2 percent. Figure 2 shows the weekly settlement rates from a dispute and from a strike over the first 100 days following contract expiration. After the first week, the weekly settlement rate from dispute is roughly constant at 11 percent.

Strikes account for only 18 percent of all disputed settlements (Table 1). A majority of strikes begin almost immediately following the contract expiration. Of the disputes that involve a strike, 50 percent begin within two days after the contract expiration, and 61 percent begin within a week after the contract expiration. By two months following the expiration date, 89 percent of the

[7] See Alvin E. Roth et al. (1988) for a discussion of the deadline effect in experimental work.

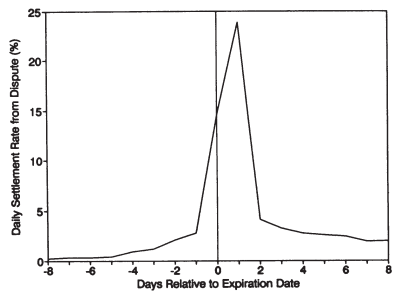

Figure 1: Daily Settlement Rate Around Expiration.

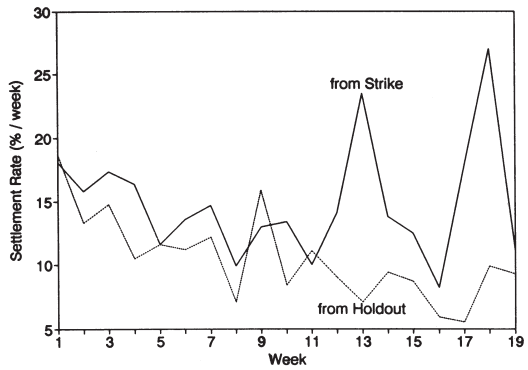

Figure 2: Weekly Settlement Rates.

overall sample of strikes have started. Strike incidence, though, remains high as the length of holdout increases. The conditional strike incidence is roughly constant at 8 percent.

The median and mean dispute durations are also given in Table 1. For contracts that have not settled by the day following the expiration date, the median (mean) dispute duration is 37 (65) days. The median (mean) holdout duration is 32 (63) days. The median (mean) strike duration is 27 (43) days. Including the holdout before the beginning of the strike brings the median (mean) dispute duration for strikes to 53 (76) days. Interestingly, the median holdout duration is roughly the same as the median strike duration.

Table 2 illustrates the incidence and duration of disputes across different years in our sample. An important feature of this table is that the dispute incidence has a much smaller variance across years than the strike incidence. The primary determinant of the variation in the strike incidence across years in our sample is not variation in the overall dispute incidence; rather, it is variation in the composition of disputes between holdouts and strikes.

Table 2: Dispute Incidence And Duration By Year

		Incidence (percentage)			Median [mean] duration (days)			
Year	Contracts	Holdout	Strike	Dispute	Holdout	Strike[a]	Strike[b]	Dispute
1970	19	32	21	53	103	37	103	103
1971	152	36	13	49	95	33	129	104
1972	115	46	9	55	94	12	81	92
1973	238	37	12	49	48	20	62	51
1974	324	42	14	56	26	24	37	29
1975	244	41	9	49	23	47	52	28
1976	279	42	16	57	21	29	60	32
1977	362	37	11	49	38	35	50	41
1978	211	39	16	55	22	29	49	30
1979	278	36	13	49	42	33	51	44
1980	349	35	8	43	19	26	68	29
1981	223	45	8	53	23	19	39	26
1982	279	46	7	53	30	26	39	31
1983	362	52	8	60	35	42	65	39
1984	266	52	10	62	28	16	46	31
1985	258	56	11	67	36	24	46	38
1986	317	58	13	71	27	27	43	30
1987	221	67	8	75	41	15	40	41
1988	238	65	9	74	24	31	84	31
1989	249	65	4	69	36	38	52	37
1970-1979	2222	39	13	52	37	29	57	42
1980-1989	2780	53	9	62	30	26	50	33
1970-1989	5002	47	10	57	32	27	53	37

Notes: Holdout means the contract was signed without a strike more than one day after the contract expiration. Strike means a strike occurred before the contract was signed. Dispute means either a holdout or a strike occurred before the contract was signed.

[a] Days from the beginning of the strike to the end of the strike

[b] Days from the contract expiration to the end of the strike

2 A Model of Wage Bargaining

A union and a firm are bargaining over the wage to be paid during a contract of duration T. For simplicity, we assume that only a single new contract is negotiated.[8] The union's reservation wage is common knowledge. The reservation wage is what the worker receives during a strike. If the worker is able to secure temporary employment during the strike, then the reservation wage is the nonunion wage; otherwise, the reservation wage is determined by the worker's access to unemployment insurance (UI), welfare, or other strike benefits. Let v be the firm's value of the current labor force working under a contract of duration T. It is common knowledge that v is drawn from the distribution F with positive density f on an interval support $[l, h]$. However, the realized value of v is known only to the firm.

The game begins with the union selecting a threat $\theta \in \{H, S\}$, either holdout or strike, which applies until a settlement is reached.[9] In the threat θ, the payoff to the union is x_θ, and the payoff to the firm is $y_\theta(v)$. Only the firm's threat payoff may depend on the value v.[10] We consider a linear threat model:

[8]This assumption is problematic for the following reason. We show that the wage from the old contract plays an important role in the current contract negotiation; but this implies that the wage negotiated for this contract will be important in the next contract negotiation. By looking at a single contract negotiation, our analysis is incomplete in that we are ignoring the effect today's wage bargain has on future negotiations. Although extending the analysis to allow for a sequence of contracts is important, it is beyond the scope of this paper. Cramton and Tracy (1991a) provides a brief analysis of the game with a sequence of contracts. That study identifies particular settings in which the analysis with a sequence of contracts is the same as the single-contract analysis presented here. Holden (1990a) also has made progress along these lines in a model with full information. He shows that wage bargaining can lead to inflation, as workers can obtain nominal wage increases by threatening to hold out.

[9]The model presented here does not allow the firm to lock out the union. This restriction would be problematic if lockouts were frequently observed in the U.S. contract data, but they are not (only 3 percent of work stoppages are lockouts). One explanation for the absence of lockouts is that they may be very costly for the firm. For example, a lockout can expose the firm to a substantial liability if there is a ruling by the National Labor Relations Board that the firm committed an unfair labor practice. Also, in 21 states, workers collect UI benefits in the event of a lockout (Robert Hutchens et al., 1989). To the extent that UI programs are experience-rated, lockouts in the these states result in workers getting paid by the firm (at least partially), but production does not occur. Another explanation, which is outside our model, is that a lockout by the firm might reduce subsequent productivity by damaging firm-worker relations. This explanation rests on an asymmetry in the employment relationship: the workers rely on the firm for their pay, which is easy to contract on, but the firm relies on the workers' cooperation in production, which is difficult to contract on. In this case, there may be long-term costs associated with a lockout, which reduce its desirability for the firm (Holden, 1990b).

[10]Firms sometimes backdate wage settlements to the contract expiration if a strike is not called. Since x_θ does not depend on v it may appear that we do not allow backdating. However, we can interpret backdating as a lump-sum payment to the workers, which can be amortized over the remaining life of the contract to form a correspondingly higher settlement wage. With this interpretation, incidence and duration are not biased by backdating, but the observed wages would be too low as a result of backdating. Backdating may be an important issue in a model with a sequence of contracts to the extent it can be used by the firm to lower the settlement wage from what it would be without backdating

$y_\theta(v) = a_\theta v - b_\theta$, where $a_\theta \in [0,1)$ and $b_\theta \geq 0$. The term $1-a_\theta$, which we call the *dispute cost*, measures how far the parties are from the Pareto frontier during the threat θ. We define $c_\theta = (b_\theta - x_\theta)/(1-a_\theta)$ to be the *relative payment difference* during the threat θ: what the firm pays less what the union gets divided by the dispute cost. Since the total payoff in agreement is v and the total payoff in the threat is $a_\theta v - b_\theta + x_\theta$, the pie that the parties are bargaining over is $(1-a_\theta)v + b_\theta - x_\theta = (1-a_\theta)(v + c_\theta)$. We assume that this pie is positive for all $v \in [l,h]$, which implies $c_\theta > -l$.

For now, we will not be more specific about the strike threat $(x_s, a_s v - b_s)$. The advantage of analyzing general strike threats is that we can say how the bargaining outcome changes as the strike threat varies due to changes in economic or policy variables.

The holdout threat, however, can be further specified. Let w^0 be the current wage, that is, the wage under the expired contract. By law the workers are paid the current wage w^0 during a holdout, so $b_H = x_H = w^0$ and $c_H = 0$. Presumably, the firm could unilaterally raise the holdout wage, but later we provide an explanation for why it would not want to do so. We assume that there is some inefficiency associated with a holdout: $a_H < 1$. There are three motivations for this inefficiency. First, during a holdout the workers have an incentive to slow down or "work to rule"; that is, to work exactly according to the rules of the expired contract and no more. When the firm must rely on the cooperation of the work force for efficient production, this may be an important source of inefficiency in the holdout threat. Second, one issue in the negotiation may be changes in the work rules that will increase productivity. This is consistent with our model if we assume that the changes will increase the value added by the work force by a fixed factor (from $a_H v$ to v). Third, because of the disruption that a potential strike might cause, some of the firm's customers and suppliers may be reluctant to deal with the firm during a holdout. The precise value of a_H is not important for many of our empirical findings. In particular, we will show that dispute incidence and dispute duration do not depend on a_H, so long as $a_H < 1$.

An outcome of the game, denoted $\langle t, w, \theta \rangle$, specifies the time of agreement, $t \in [0,T]$, the contract wage w at the time of agreement, and the threat $\theta \in \{H, S\}$ before agreement. The players' payoffs are calculated as a combination of the threat payoff and the agreement payoff, weighted by the fraction of time spent in dispute, as shown in Figure 3. We are assuming, then, that the players are risk-neutral and that the payoff flows, both during the threat and after agreement, are constant over time.[11] Define

$$D(t) = \frac{1 - e^{-rt}}{1 - e^{-rT}}$$

to be the discounted fraction of time spent in dispute if agreement occurs at time t, where $r > 0$ is the discount rate. Then, given the outcome $\langle t, w, \theta \rangle$, the union's payoff is

[11] Cramton and Tracy (1991b) extends the model to nonstationary threat payoffs.

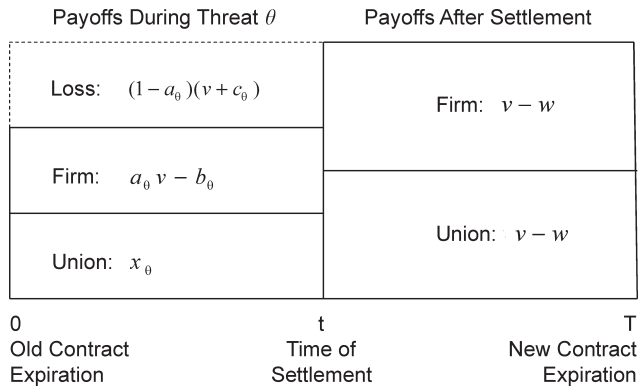

Figure 3: Payoffs From Bargaining Outcome.

$$U(t,w,\theta) = x_\theta D(t) + w\,[1 - D(t)]$$

and the firm's payoff is

$$V(t,w,\theta) = y_\theta(v)D(t) + (v-w)[1 - D(t)]$$

Following the choice of threat, the players alternate making wage offers with a minimum time t^0 between offers. Associated with each period of disagreement, then, is the discount factor $\delta = e^{-rt^0}$. The union makes the initial offer one period before contract expiration (at time $-t^0$). After an offer is made, the other player has two possible responses: (i) a counteroffer, in which case the game continues, or (ii) acceptance, in which case the game ends with trade occurring at the offered wage for the remainder of the contracting period T. As in Anat R. Admati and Motty Perry (1987), the response can occur at any time after the minimum time t^0 between offers.[12] Suppose that in round i the offer w_i is made after a wait Δ_i *beyond* the minimum time t^0 between offers. Then, after n rounds of play, the history ρ^n is given by $\{\theta, \Delta_i, w_i\}_{i=1,\ldots,n}$. Throughout the paper, when we refer to an offer being accepted or a counteroffer being made immediately, we mean that the action is taken with no additional wait beyond the minimum time between offers (i.e., $\Delta_i = 0$).

[12]This assumption leads to the outcome in which a firm signals its private information through the dispute duration (Admati and Perry, 1987; Cramton, 1991, 1992). It has been criticized on the grounds that it enables each bargainer to commit to not revising an offer until a counteroffer is made. In particular, if the firm rejects the union's initial offer, the union has an incentive to lower its offer, assuming the firm's strategy is stationary (i.e., the firm's willingness to accept a particular price is not influenced by the union's revision). If, however, we allow nonstationary strategies, then the signaling outcome can be approximated as a perfect Bayesian equilibrium in the alternating-offer game with a fixed time between offers when the time between offers is small (Lawrence M. Ausubel and Raymond J. Deneckere, 1991). We have chosen this extensive form, despite its shortcomings, because of its relative simplicity and because it has an equilibrium with sensible qualitative properties

A pure strategy σ_u for the union specifies a threat choice and, after each history ρ^n at which it is the union's turn to move, a wait Δ_{n+1}, and whether to accept w_n or make a counteroffer w_{n+1}. Similarly, define σ_v to be a pure strategy for the firm with a valuation v, and let $\sigma = \{\sigma_u, \sigma_v \forall v \in [l, h]\}$ be a strategy profile for the players. (Only pure strategies are considered.) The strategies σ result in an outcome $\langle t, w, \theta \rangle$, which depends on the firm's valuation v. Let $F(\cdot \mid \rho^n)$ denote the union's belief about the firm's valuation after the history ρ^n.

A *perfect Bayesian equilibrium* for this game is the collection $\{\sigma(\rho^n), F(\cdot \mid \rho^n)\}_{\rho^n}$ of strategies and beliefs, such that after every history ρ^n each player's strategy is optimal given his current beliefs and the other's strategy and the beliefs are consistent with Bayes's rule.

We assume that the minimum time between offers t^0 is arbitrarily small. This is the interesting case, since in practice one observes a minimum time between offers that is small relative to plausible discount rates. Moreover, it can be shown that under full information each bargainer has an incentive to respond as quickly as possible to the other's offer. All the formulas change continuously as the minimum time between offers shrinks to zero and indeed are insensitive to changes in the time between offers. Hence, the limiting results as $t^0 \to 0$ closely approximate the results with small t^0. The formulas when $\delta < 1$ are easily calculated but are omitted for brevity.

The equilibrium takes a simple form. If w^0 is sufficiently low (below a cutoff level $\widetilde{w}$), the union decides to strike; otherwise ($w^0 \geq \tilde{w}$), the union decides to hold out. The cutoff level $\tilde{w}$ depends on r, T, F, and the threat payoffs (x_θ, y_θ) for $\theta \in \{H, S\}$. A second cutoff level $m \in (l, h)$ is determined by the union's initial offer. The firm accepts the union's initial offer if its valuation is above m and otherwise rejects the offer.

The equilibrium is constructed by first looking at the subform after a threat $\theta \in \{H, S\}$ is chosen.

Proposition 1. *Let $\theta = (x_\theta, y_\theta)$ be the threat chosen by the union, where $y_\theta = a_\theta v - b_\theta$ and $c_\theta = (b_\theta - x_\theta) / (1 - a_\theta)$. In the limit as the time between offers goes to zero, there is a perfect Bayesian equilibrium with the following form:*

(i) The union makes an immediate offer of $w(m) = x_\theta + \frac{1}{2}(1 - a_\theta)(m + c_\theta)$, where $m(c_\theta) \in (l, h)$ maximizes

$$(m + c_\theta)[1 - F(m)] + \int_l^m \frac{(v + c_\theta)^2}{m + c_\theta} dF(v) \tag{1}$$

(ii) The firm accepts the offer if $v \geq m$. Otherwise, if $v < m$, the firm waits until $(m - v)/(m + c_\theta)$ of the contract period has passed before offering $w_\theta(v) = x_\theta + \frac{1}{2}(1 - a_\theta)(v + c_\theta)$, which is accepted immediately by the union.

(iii) The union's expected payoff from the threat θ is U_θ, the firm's expected payoff is V_θ, and the expected loss is L_θ, where

$$U_\theta = x_\theta + (1 - a_\theta)(m + c_\theta)\left[1 - F(m)\right]$$

$$V_\theta = a_\theta E(v) - b_\theta + (1 - a_\theta)\int_m^h (v + c_\theta)\, dF(v)$$

$$L_\theta = (1 - a_\theta)\left\{c_\theta - (m + 2c_\theta)\left[1 - F(m)\right] + \int_l^m v dF(v)\right\}$$

Proof: For simplicity, only the equilibrium path is derived here; see Cramton and Tracy (1991a) for details. The wage $w_\theta(v) = x_\theta + \frac{1}{2}(1 - a_\theta)(v + c_\theta)$, is the Rubinstein (1982) wage in the complete-information game between the union and a firm with valuation v in the limit as the time between offers goes to zero. The fact that only Rubinstein offers are made follows from arguments presented in Admati and Perry (1987). Suppose that the union makes the initial offer $w_\theta(m)$. This is acceptable to a firm with $v \in [m, h]$. Then a firm with $v \in [l, m)$ waits long enough to signal its type (see Cramton and Tracy, 1991a). Hence, the type of firm $v(t)$ that makes an offer at time t must satisfy the following incentive condition:

$$\begin{aligned} &y_\theta(v)D(t) + \{v - w_\theta[v(t)]\}[1 - D(t)] \\ &= \max_\tau (y_\theta(v)D(\tau)) + \{v - w_\theta[v(\tau)]\}[1 - D(\tau)] \end{aligned}$$

Taking the derivative with respect to τ yields the first-order condition

$$r\{v - w_\theta[v(t)] - y_\theta(v)\} + w'_\theta[v(t)]\left\{1 - e^{-r(T-t)}\right\} = 0$$

where

$y_\theta(v) = a_\theta v - b_\theta$
$w_\theta[v(t)] = x_\theta + \frac{1}{2}(1 - a_\theta)(v + c_\theta)$
$v - w_\theta[v(t)] - y_\theta(v) = \frac{1}{2}(1 - a_\theta)(v + c_\theta)$
$w' = \frac{1}{2}(1 - a_\theta)v'$.
Hence, the first-order condition becomes

$$r(v + c_\theta) + v'\left(1 - e^{-r(T-t)}\right) = 0.$$

This is a separable first-order differential equation with initial condition $v(0) = m$, which by integration has the unique solution

$$v(t) = (m + c_\theta)[1 - D(t)] - c_\theta$$

Solving for $D(\cdot)$ and restating in terms of v, yields

$$D(v) = (m - v)/(m + c_\theta)$$

for $v \in [l, m]$. Notice that the duration of the dispute as given above only depends on the threat (x_θ, y_θ) through the relative payment difference $c_\theta = (b_\theta - x_\theta)/(1 - a_\theta)$.

It remains to determine the union's initial offer $w_\theta(m) = x_\theta + \frac{1}{2}(1 - a_\theta)(m + c_\theta)$. The union selects $w_\theta(m)$ (i.e., selects m) to maximize its expected payoff. Since the firm accepts $w_\theta(m)$ if $v \in [m, h]$, the union gets $w_\theta(m)$ with probability $1 - F(m)$. Otherwise, the firm rejects the offer, and agreement occurs at the wage $w_\theta(v) = x_\theta + \frac{1}{2}(1 - a_\theta)(v + c_\theta)$ after payoffs have been discounted by $1 - D(v) = (v + c_\theta)/(m + c_\theta)$, resulting in a discounted ex post payoff of

$$x_\theta + \frac{1}{2}(1 - a_\theta)\frac{(v + c_\theta)^2}{m + c_\theta}.$$

Taking the expectation with respect to v results in the union's expected payoff

$$U(m) = x_\theta + \frac{1}{2}(1 - a_\theta)\left\{(m + c_\theta)[1 - F(m)] + \int_l^m \frac{(v + c_\theta)^2}{m + c_\theta} dF(v)\right\}$$

Taking the derivative with respect to m yields the first-order condition

$$1 - F(m) - \int_l^m \left(\frac{v + c_\theta}{m + c_\theta}\right)^2 dF(v) = 0 \tag{2}$$

Since $U'(l) > 0$, $U'(h) < 0$, and $U(\cdot)$ is continuous in m, an interior maximum is guaranteed, and the first-order condition (2) must be satisfied at the maximum. Hence, we can substitute (2) into the formula for the union's expected payoff to yield $U_\theta = x_\theta + (1 - a_\theta)(m + c_\theta)[1 - F(m)]$. The firm's expected payoff and the expected loss are calculated similarly. ■

The holdout cost $(1 - a_H)$ is exogenous in our model; but a main motivation for $a_H < 1$ is that the workers *choose* to slow down production during a holdout. How much should the workers slow down? As much as possible. This follows from Proposition 1. The union's expected payoff from a holdout is $U_H = w^0 + (1 - a_H)m[1 - F(m)]$, since the firm pays the workers w^0 during a holdout. Hence, the union's expected payoff increases linearly in the holdout cost $1 - a_H$. The union's bargaining power during a holdout stems solely from its ability to reduce efficiency. In practice, two things constrain the union's ability to disrupt production. One is the expired contract, which still applies during a holdout. The workers have an incentive to slow down as much as possible but must stay within the rules of the contract to avoid being cited for an unfair labor practice. This gives meaning to the expression "work to rule." A second constraining force on the union is the threat of a lockout by the firm if the union disrupts production too much.

Our next proposition states a comparative-static result about how dispute incidence and dispute duration change with changes in the threat $\theta = (x_\theta, y_\theta)$ or the distribution of v. This comparative static is important for empirical work, since it leads to testable predictions about how dispute incidence and dispute duration vary with economic or policy changes.

Proposition 2. *Suppose that $m(c_\theta)$ uniquely maximizes (1). Dispute incidence $F(m(c_\theta))$ and dispute duration $D(v, c_\theta) = [m(c_\theta) - v]/[m(c_\theta) + c_\theta]$ decrease as c_θ increases or as the distribution of v shifts to the right.*

Proof: Dispute incidence $F(m(c_\theta))$ decreases as c_θ increases if and only if $dm/dc_\theta < 0$. To show this, consider the first-order condition

$$1 - F(m) = \int_l^m \left(\frac{v + c_\theta}{m + c_\theta}\right)^2 dF(v)$$

which must be satisfied at the interior maximum. Taking the derivative with respect to c_θ and solving for dm/dc_θ yields

$$\frac{dm}{dc_\theta} = \frac{\int_l^m \frac{(v+c_\theta)(v-m)}{(m+c_\theta)^3}\left(\frac{f(v)}{f(m)}\right) dv}{1 - \int_l^m \frac{(v+c_\theta)^2}{(m+c_\theta)^3}\left(\frac{f(v)}{f(m)}\right) dv}$$

However, the second-order condition, which is a strict inequality since $m(c_\theta)$ is the unique maximizer, is

$$\int_l^m \frac{(v + c_\theta)^2}{(m + c_\theta)^3} \frac{f(v)}{f(m)} dv < 1$$

Hence, the denominator in the expression for dm/dc_θ is positive, and the numerator is negative (recall $c_\theta > -l$), so $dm/dc_\theta < 0$. To show that dispute duration also decreases, take the derivative of $D(v, c_\theta)$ with respect to c_θ:

$$\frac{dD}{dc_\theta} = \frac{\frac{dm}{dc_\theta}(v + c_\theta) + (v - m)}{(m + c_\theta)^2} < 0$$

where the inequality follows because both terms in the numerator are negative.

Now consider an outward shift of $s > 0$ in the distribution F. Then firm value $v' = v$+s is drawn from the distribution G with $G(v + s) = F(v)$. The union chooses m' to satisfy the first-order condition

$$1 - G(m') = \int_{l+s}^{m'} \left(\frac{v' + c_\theta}{m' + c_\theta}\right)^2 dG(v').$$

Equivalently, the union can choose $m = m'$ to satisfy

$$1 - F(m) = \int_l^m \left(\frac{v + s + c_\theta}{m + s + c_\theta}\right)^2 dF(v)$$

and make an initial offer of $w_\theta(m + s)$. Hence, an outward shift of the distribution has the same effect as an increase in c_θ: dispute incidence and dispute duration decrease. ■

The appropriate notion of uncertainty in this bargaining problem is the standard deviation of the pie the parties are bargaining over relative to the

expected size of the pie. An increase in c_θ, as a result of a change in the threat, has the effect of shifting the distribution of v to the right when we normalize the bargaining problem so that the threat is at (0, 0). Hence, an increase in c_θ or an outward shift in the distribution of v has the effect of reducing the level of uncertainty. With this interpretation, Proposition 2 is intuitive. A reduction in the level of uncertainty decreases dispute incidence and dispute duration. Dispute incidence, however, always exceeds $\frac{1}{2}$ and converges to $\frac{1}{2}$ in the limit as uncertainty vanishes. This follows from the first-order condition (2), which represents the union's trade-off between postponed agreement and a higher expected wage.[13]

In what follows, we assume that the strike threat is such that the wage payment made by the firm is equal to the amount received by the workers.

ASSUMPTION S:

$$b_S = x_S.$$

This is a reasonable assumption in many cases: (i) production stops and workers are not paid, (ii) production stops and workers are paid UI benefits that are financed by the firm through higher UI taxes, and (iii) strikers find temporary jobs that pay the nonunion wage and production continues at reduced efficiency with replacement workers paid the nonunion wage. Surprisingly, under Assumption S, both dispute incidence and dispute duration are invariant to the threat chosen. Even when strike costs are 100 times larger than holdout costs, information is signaled as quickly through a holdout as through a strike. This result is stated in Proposition 3.

Proposition 3. *Under Assumption S, the dispute incidence $F(m)$ and dispute duration $D(v, m)$ are the same, regardless of the threat chosen by the union, and do not depend on the current wage or the dispute cost. In particular, $D(v, m) = 1 - v/m$, where m maximizes (1) Moreover, the equilibrium wage falls during the dispute at a rate that is proportional to the dispute cost $1 - a_\theta$.*

Proof: Assumption S implies that with either threat $c_\theta = 0$. Since $D(v, m)$ only depends on the threat $\theta = (x_\theta, y_\theta)$ through c_θ, both threats have the same dispute duration. Similarly, since $m(c_\theta)$ only depends on the threat through c_θ, the dispute incidence $F(m)$ is the same with either threat. Finally, $w'(t) = \frac{1}{2}(1 - a_\theta)v'(t) = -\frac{1}{2}(1 - a_\theta)mD'(t)$. Thus, since $D(t)$ is independent of θ, wages decline at a rate that is proportional to the dispute cost $1 - a_\theta$. ■

Proposition 3 may seem counterintuitive based on the following reasoning. Bargaining costs are borne for the firm to signal its profitability. The total cost

[13] When the data are disaggregated to the industry level, dispute incidence is sometimes below 50 percent, which is inconsistent with a strict interpretation of our model. If, however, there is a positive fixed cost of initiating a dispute, then dispute incidence would be zero for cases with little uncertainty. This could lead to an aggregate dispute incidence of less than 50 percent.

that must be incurred to signal a given level of profitability should not depend on the rate at which costs are incurred. Hence, the dispute duration should be inversely proportional to the dispute cost, to make the total dispute cost invariant to the rate at which costs are incurred.

We consider this intuition to represent one reason why holdouts have received little attention in the literature on wage bargaining. Based on this reasoning, one might argue that, since holdout costs are small relative to strike costs, the role of holdouts in contract negotiations should be insignificant. This intuition, however, is wrong.

The key to the correct intuition is recognizing that equilibrium wages fall at a rate that is proportional to the dispute cost: $w'(t) = \frac{1}{2}(1 - a_\theta)v'(t)$. The rate $v'(t)$ at which firms signal themselves is determined from an incentive constraint, which requires a firm to wait until the marginal benefit of postponed agreement is equal to the marginal cost. The marginal benefit is the improved terms of agreement (lower wages), and the marginal cost is the loss from waiting. Both the marginal benefit and the marginal cost of waiting increase linearly with the dispute cost $1 - a_\theta$. Increasing the dispute cost by a factor of 100 increases the costs of waiting by a factor of 100 but also increases the benefits of waiting by the same factor. Hence, both sides of the trade-off equation change in lockstep, and the rate at which firms signal themselves is invariant to the rate at which dispute costs are incurred.

Essential to the invariance result is our "linear threat" assumption: that the value of the work force during a dispute is $a_\theta v$, where a_θ does not depend on v. With this assumption, the optimization problem for firm v is the same under either threat. The bargaining problem under a holdout is simply a rescaling of the bargaining problem under a strike. With the threat θ, t is chosen to maximize

$$(a_\theta v - x_\theta)D(Tt) + \left[v - x_\theta - \frac{1}{2}(1 - a_\theta)v(t)\right][1 - D(t)]$$

since $w_\theta[v(t)] = x_\theta - \frac{1}{2}(1 - a_\theta)v(t)$. Ignoring terms that do not depend on t yields

$$-(1 - a_\theta)\left\{vD(Tt) + \frac{1}{2}v(t)[1 - D(t)]\right\}$$

Thus, the optimal wait $t(v)$ for firm v is the same under either threat.

It is possible for wages to fall below w^0 after a long strike if $w^0 > x_S + \frac{1}{2}(1 - a_S)l$. This is reasonable, since after an impasse the terms of the expired contract are no longer binding on the firm when the workers return. Thus, the union cannot switch from strike to holdout and be assured a wage of w^0. In practice, wages sometimes fall below w^0 even without a strike. This may happen during concessionary bargaining as a result of a threat by the firm to lay off part of the work force if concessions are not made. Our model ignores this possibility.

Proposition 3 implies that the total bargaining costs are proportional to how far the threat point is from the Pareto frontier. Assuming $a_S < a_H$, total

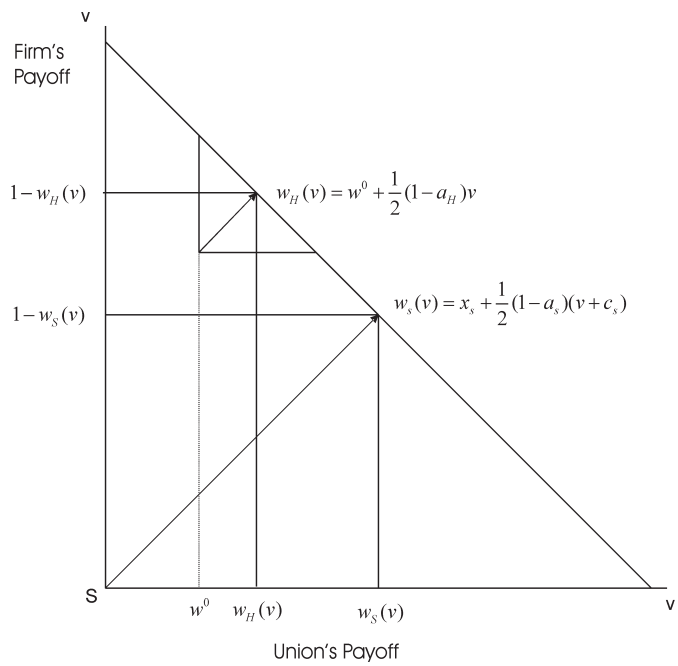

Figure 4: The *Ex Post* Outcomes For Strike Threat And Holdout Threat.

bargaining costs are higher if the strike threat is chosen, rather than the holdout threat.

The intuition for which threat is chosen is now straightforward. The union decides to strike if the higher bargaining costs associated with a strike are compensated for by a higher wage if the strike threat is chosen. This is illustrated in Figure 4, which shows the ex post outcome for both threats. If the strike threat (S) is chosen, then settlement occurs at the wage $w_S(v)$; if the holdout threat (H) is chosen, then settlement occurs at the wage $w_H(v)$, which is less than $w_S(v)$ due to the low current wage. The union decides to strike if and only if the current wage is below the cutoff $\tilde{w}$, so that the expected wage under the strike threat is sufficiently greater than the expected wage under the holdout threat to make up for the higher bargaining costs associated with a strike.

Proposition 4. *Under Assumption S, if $w^0 < \tilde{w}$, the union chooses to strike; if $w^0 \geq \tilde{w}$, the union chooses to hold out, where $\tilde{w} = x_S + (a_H - a_S)m[1-F(m)]$ and m maximizes (1).*

Proof: From Proposition 1, the expected payoff to the union given the threat θ is

$$U_\theta = x_\theta + (1 - a_\theta)(m + c_\theta)[1 - F(m)]$$

where m maximizes (1). Since $c_\theta = 0$ by Assumption S, the union prefers strike

over holdout if and only if $U_S > U_H$, or $w^0 < x_S + (a_H - a_S)m[1 - F(m)]$. ■

The model offers new insights into the determinants of strike activity. The overall incidence of strikes depends on both the incidence of disputes and the fraction of disputes that involve a strike. The level of dispute activity depends on the amount of uncertainty. The composition of disputes between holdouts and strikes depends on w^0 and the location of the support of the distribution of v. Table 2 suggests that most of the variation in strike activity across years is due to changes in the composition of dispute activity, rather than to changes in the level of dispute activity. The model predicts that the composition of disputes will shift toward more strikes in the following situations: (i) after a period of uncompensated inflation, which causes a drop in w^0 in real terms, (ii) after a decline in the local unemployment rate, which increases the workers' reservation wage in the strike threat, and (iii) after an increase in the firm's demand, which improves profitability by shifting the distribution of v outward.

These predictions about strike activity are consistent with several empirical findings based on U.S. and Canadian negotiations. A robust finding in the literature is that the incidence of strikes decreases with the degree of real wage growth over the period of the last contract. This relationship has been demonstrated by Ashenfelter and Johnson (1969), Cynthia L. Gramm (1986), Martin J. Mauro (1982), and Susan B. Vroman (1989) using U.S. data, and by Morley Gunderson et al. (1986) using Canadian data. In a related finding, McConnell (1989) and Vroman (1989) show that the probability of a strike is positively related to the amount of uncompensated inflation over the previous contract. The role played by local labor-market conditions is consistent with findings that strike incidence in the United States is an increasing function of both trend growth in local employment and positive deviations about this trend (Tracy, 1986). Finally, the model offers an explanation for why strike incidence may be procyclic (Alan Harrison and Mark Stewart, 1989a,b; Kennan, 1986). In expansions, strike incidence increases due to the upward shift in v, while the current wage is fixed at w^0.

2.1 An Example with Uniform Uncertainty

We now turn to an example in which the uncertainty about the firm's profitability is given by the uniform distribution on $[l, h]$. Our purpose is to show that it is possible for the model to reproduce the key features of the data when we make plausible assumptions about the model's parameters.[14] We use the uniform distribution, since in this case the equilibrium can be derived in closed form. Numerical calculations with other distributions, such as a truncated normal distribution, suggest that our distributional assumption is not crucial to the results.

[14] A more detailed comparison of the model and empirical results is presented in Cramton and Tracy (1991a).

Proposition 5. *In the equilibrium with uniform uncertainty under assumption S, the union selects the strike threat if* $w^0 \leq \tilde{w}$ *, where*

$$\tilde{w} = x_S + (a_H - a_S)m\frac{h-m}{h-l}$$

$$m(l,h) = \frac{1}{4}\left[k + h(1 + h/k)\right]$$

$$k = \left[4\sqrt{l^3(h^3+4l^3)} + h^3 + 8l^3\right]^{\frac{1}{3}}$$

The union's initial offer $w_\theta(m)$ *is accepted by the firm if* $v \geq m$ *and otherwise rejected.*

Proof: With the uniform distribution, expression (1) in Proposition 1 is a strictly concave function in m, so the unique maximizer of (1) is given by the first-order condition (2). Substituting into (2) yields

$$h - m = \int_l^m \frac{v^2}{m^2} dv$$

since $c_\theta = 0$ by Assumption S. Simplifying this expression yields the cubic equation

$$3hm^2 - 4m^3 + l^3 = 0$$

which has a single real solution given in the proposition. The threat decision then follows from Proposition 4, and the initial offer follows from Proposition 1. ■

Once m is determined it is a simple matter to calculate other features of the equilibrium (see the Appendix for details) and to show how the bargaining outcome changes as we vary the parameters of the model. We assume that v is uniform on $[l, 2-l]$, so that v has a mean of 1 and a variance of $(1-l)^2/3$ Thus, by varying l, we can vary the level of uncertainty without changing the mean of the distribution. In particular, the standard deviation increases linearly from 0 as $1-l$ increases from 0. We refer to $1-l$ as the level of uncertainty for $l \in [0,1]$. For calculations that depend on r and T, we assume an interest rate of 10 percent and a contract length of 2.7 years, the mean contract length in our sample.

One critical parameter that cannot be estimated directly from the data is the level of uncertainty $1-l$. It is important, therefore, to look at how the bargaining outcome changes with the level of uncertainty. Figure 5 shows the dispute incidence and dispute duration as the level of uncertainty increases from 0. A remarkable feature of this model is that the incidence and duration depend only on l and not on the choice of threat or any other parameters of the model. The dispute incidence increases from $\frac{1}{2}$ to $\frac{3}{4}$ as we move from little uncertainty to maximal uncertainty. The dispute duration is measured as the fraction of the contract period spent in dispute conditional on a dispute. This

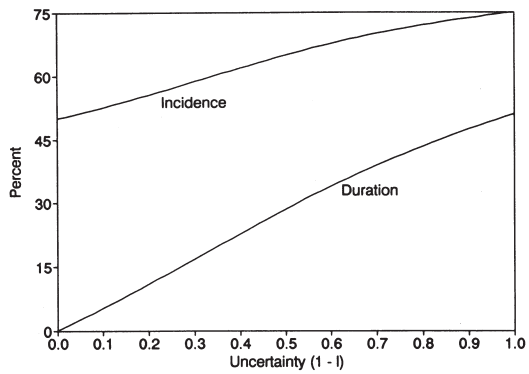

Figure 5: Dispute Incidence And Duration.

fraction is zero with no uncertainty, and it increases to just over 0.5 as the uncertainty increases to 1. With $l = 0.93$, the incidence of dispute is 52 percent, and the average dispute duration is 32 days (assuming that contracts last 2.7 years), compared with an empirical incidence of 57 percent and duration of 37 days. The fact that both incidence and duration roughly fit the data when $l = 0.93$ lends support to the model, since l is the only free parameter. A strike incidence of 10 percent would result if the distribution of w^0 were such that 20 percent of the unions prefer the strike threat (the corresponding holdout incidence would be 41 percent). This is in rough agreement with the empirical strike and holdout incidences of 10 percent and 47 percent. Finally, the strike and holdout durations would both be 32 days, compared with an empirical strike duration of 27 days and a holdout duration of 32 days.

For a given bargaining pair, the settlement rate increases with time. Hence, to explain the flat settlement rate observed in the data, we must introduce heterogeneity about the degree of uncertainty. In particular, assume that there are 26 equally sized subpopulations of firms, where $l = 0.75$ for the first subpopulation, $l = 0.76$ for the second, and on up to $l = 1$ for the last. Figure 6 shows the aggregate weekly settlement rate from dispute over the first 100 days of the dispute for this case. This range of uncertainty yields an aggregate settlement rate (the solid line in the figure) that is roughly consistent with the empirical settlement rate (the dashed line).

As seen in Figure 2, the empirical settlement rate during a strike is slightly higher than the settlement rate during a holdout. This would occur in our model if there is heterogeneity about the degree of uncertainty. As uncertainty increases, the strike threat becomes less attractive relative to the holdout threat, due to the large bargaining costs associated with a strike. With more uncertainty, then, the union is more apt to choose the holdout threat. The union's threat choice thus leads to a selection bias in which observed strikes should on average involve less uncertainty and have higher settlement rates than observed

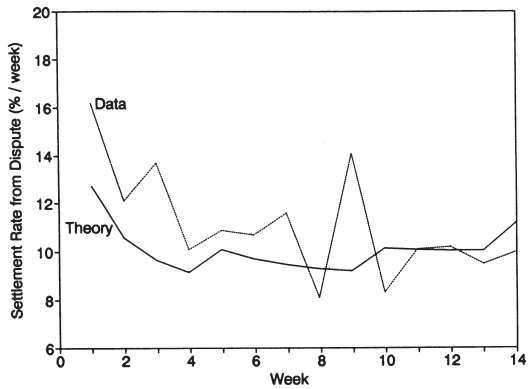

Figure 6: Weekly Settlement Rate From Dispute.

holdouts.

To make predictions about wages and payoffs, we must specify particular threat parameters. We use parameter values that are consistent with a union wage differential of 14 percent (H. Gregory Lewis, 1986). In particular, we assume that, during a strike, the workers get temporary jobs at the nonunion wage, and the firm employs replacement workers at the nonunion wage. In this case, the 14-percent union wage differential implies a decline in productivity during a strike of about 25 percent ($a_S = 75$ percent). Further, we assume that the current wage splits the expected firm value about equally between the union and the firm. Since the expected value is 1, we use $w^0 = 0.43$ with x_S about 14 percent less ($x_S = 0.35$). Finally, assume that the decline in productivity during a holdout is 6 percent ($a_H = 94$ percent).

Figure 7 shows the average decline in wages during a dispute. The rate at which wages fall depends on the threat chosen by the union. Under the strike threat, the percentage decline in wages per 100 days of strike is 3.0 percent and increases slightly with uncertainty. Under the holdout threat, the decline in wages is roughly one-third of the decline under a strike. Hence, the model predicts that we should observe a larger decline in wages during a strike than during a holdout. The predicted decline in wages during a strike (3.0 percent with $l = 0.93$) is consistent with McConnell (1989) using U.S. data, but inconsistent with David Card (1990), who found no decline in wages using Canadian data.

Now consider how the *ex ante* allocation of the gains from trade varies with the current wage. In the strike threat, the current wage does not affect the bargaining outcome. In the holdout threat, the union's share of the gains increases linearly with w^0. The firm, then, has an incentive to maintain a low current wage. This implication of the model provides an explanation for why the firm might offer retroactive wage increases or lump-sum payments. These forms of

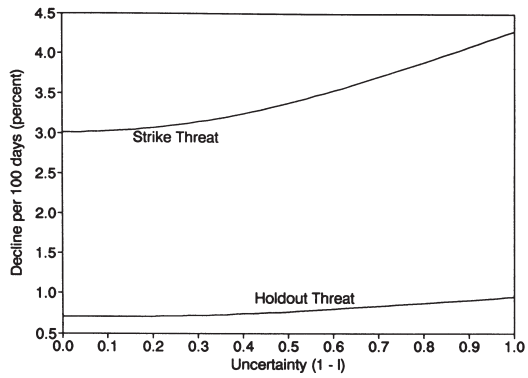

Figure 7: Average Wage Decline During Dispute.

compensation enable the firm to offer the union the same total payoff while maintaining a lower base wage. The lower wage reduces the union's advantage in the next contract negotiation.

Figure 8 shows the *ex ante* allocation of the gains from trade as we vary the union's uncertainty about the firm's profitability. For low levels of uncertainty, $\tilde{w} > w^0 = 0.50$, and so the union chooses the strike threat. As the uncertainty increases, the losses associated with a strike increase, but the split of the remaining gains is roughly constant at 46 percent for the union and 52 percent for the firm. Also, as the uncertainty increases, the strike cutoff $\tilde{w}$ decreases slightly as a result of the increasing strike costs. Eventually, $\tilde{w} < w^0$, and the union does better with the holdout threat than with the strike threat. At this point $(1 - l \approx 0.62)$, the firm's payoff increases discontinuously. This discontinuity raises the following question: might the firm want to raise the current wage to avoid a strike? We address this question below.

2.2 Should the Firm Avoid a Strike by Raising the Current Wage?

A potential criticism of our model is that we do not allow the firm to avoid a strike by raising the current wage. Because of the discontinuous increase in the firm's ex ante payoff when the union switches from the strike threat to the holdout threat, the firm may have an incentive to raise the current wage to $\tilde{w}$ to avoid a strike. Here, we allow this possibility in the context of our uniform example. An important feature of this analysis is recognition that the firm's willingness to offer $\tilde{w}$ may signal information to the union. Hence, a firm's incentive to raise the current wage depends on what the union will infer about the firm's profitability if the current wage is raised.

First suppose that raising the current wage does not change the union's belief. The union thinks that v is drawn from the distribution F regardless of

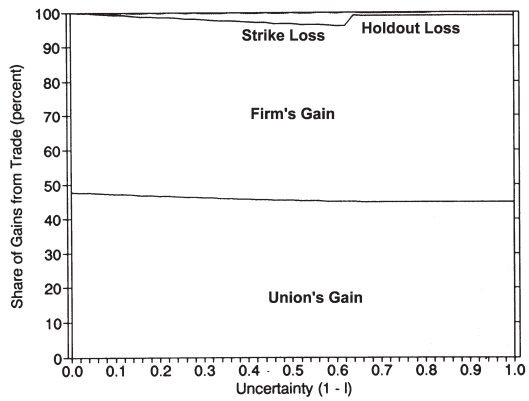

Figure 8: *Ex Ante* Allocation Of Gains From Trade.

whether the current wage is raised. In this case, the firm can avoid a strike by raising the current wage to $\tilde{w}$. With $w^0 = \tilde{w}$, the net gain from avoiding the strike is

$$\Delta(v) = V_H(v) - V_S(v) = \begin{cases} (a_H - a_S)m\left[F(m) - \frac{1}{2}\right] & \text{if} v \geq m \\ (a_H - a_S)\left(v - \frac{v^2}{2m}\right) - m\left[1 - F(m)\right] & \text{if} v < m \end{cases}$$

Note that $\Delta'(v) = 0$ for $v \geq m$, and $\Delta'(v) = (a_H - a_S)(1 - v/m) > 0$ for $v < m$, so the net gain is strictly increasing in v for $v < m$ and constant for $v \geq m$. For the uniform example, it is easy to verify that for $l > 0.54$ the net gain from avoiding a strike is positive for all v. Hence, with passive beliefs and l sufficiently large, it is a perfect Bayesian equilibrium for every type of firm to raise the current wage to $\tilde{w}$ and avoid a strike. This equilibrium breaks down, however, if the support of v extends below 0.54: a firm with $v < 0.54$ prefers not to avoid a strike.

As an alternative, suppose that avoiding a strike by raising the current wage signals to the union that the firm's profitability is high. In particular, suppose the union believes that v is between l and z if the wage is not raised or between z and h if the wage is raised, where $l \leq z \leq h$. Such a belief is reasonable, since highly profitable firms gain more from avoiding a strike. In this case, there is an additional cost to avoiding a strike: raising the current wage signals to the union that they should expect a higher wage. For this to be an equilibrium, it must be that the firm prefers not to raise the wage if $v \in [l, z]$ and prefers to raise the wage if $v \in [z, h]$; but this condition is not satisfied for any $z \in [l, h]$. The signaling cost of raising the wage is too high; all firm types prefer to be thought to be in the interval $[l, z]$ by not raising the wage. To see this consider a firm with $v \in [z, h]$. By not raising the wage, the union thinks that $v \in [l, z]$ and so offers $w_S(m)$, where $m \in (l, z)$; but this wage is lower than any wage

that a firm of type v could get by signaling that $v \in [z, h]$, regardless of how long the firm holds out. Hence, if the union infers that the firm has a high v if it raises the current wage, then the only equilibrium response is for no firm type to raise the current wage.

An alternative to unilaterally raising the wage to avoid a strike is for the firm to index the current wage by incorporating a cost-of-living provision in the contract. With unanticipated inflation, indexation more closely maintains the workers' real wage and hence reduces the union's incentive to strike, compared with a nonindexed contract.[15] Thus, indexation may reduce bargaining costs by averting some strikes, but the cost is higher wages in future contracts. Extending the model to a sequence of negotiations would allow for an analysis of this trade-off.

2.3 Switching Threats During Negotiations

So far, we have assumed that the union selects the threat (strike or holdout) at the beginning of negotiations and sticks with the chosen threat until an agreement is reached. Here, we consider how our results change if we allow the union to switch threats during negotiations. Full-information models of wage bargaining in which the union picks the threat each period have been studied by Fernandez and Glazer (1991) and Haller and Holden (1990). They show that the threat choice leads to multiple equilibria in the bargaining game. The indeterminacy comes from the firm's belief about which threat will be chosen in the future. If the firm expects the union to strike in the future, one equilibrium results; if the firm expects the union always to hold out, then another equilibrium appears. Hence, one effect of allowing a threat choice in each period is that it leads to multiple equilibria.

One way to resolve this multiplicity is for the union to commit *ex ante* to its most preferred threat path, allowing for threats that involve periods of holdout and periods of strike. This possibility is considered in detail in Cramton and Tracy (1991b); for brevity, we only summarize the results here. The main result is that under Assumption S ($c_S = 0$) within the class of *ex ante* threat paths, the union's optimal threat is either the continuous strike threat or the continuous holdout threat. The union cannot improve its payoff by adopting a strike deadline or by switching to holdout after a period of strike. Our model then is unaffected by this extension of the possible threats available to the union.

A second possibility is that the union may prefer to switch threats after the firm has made a revealing offer.[16] For example, if the settlement wage under the strike threat is higher than the settlement wage under the holdout threat, the

[15] Bruce E. Kaufman (1981) argued that indexation would lower the probability of a strike by reducing the role of divergent price expectations as a source of uncertainty in bargaining. Gramm (1986), Gramm et al. (1988), and Mauro (1982) find no significant effect of indexation on strike incidence; however, these studies also include controls for the change in real wage over the previous contract.

[16] See Cramton and Tracy (1991b) for details.

union may wish to hold out until the firm has made a revealing offer and then switch to the strike threat to get the higher strike wage. In equilibrium, the firm anticipates this possibility, which alters the incentives to reveal information and, hence, the duration of the dispute. When the current wage w^0 is near $\tilde{w}$ (the point at which the union is indifferent between the strike threat and the holdout threat), the union prefers to adopt a threat of holding out until the firm makes a revealing offer and then to switch to the strike threat if the firm's valuation is sufficiently high. In our benchmark case, this threat is preferred to either the strike threat or the holdout threat for only a narrow range of w^0: w^0 must be no more than 0.4 percent below and no more than 0.8 percent above $\tilde{w}$. For w^0 in this range, wage settlements are higher, dispute durations are nearly three times longer, and dispute incidence is slightly reduced from what it would be under the holdout threat. However, outside this narrow range of w^0 the union finds it best to adopt the strike threat or the holdout threat, and the analysis is the same as before.

3 Conclusion

Disputes are a common feature of U.S. collective bargaining. In our sample data, 57 percent of the contract negotiations involve a dispute. However, less than a quarter of these disputes ever take the form of a strike. The overwhelming majority of disputes involve a holdout in which the old contract is extended until a settlement is reached. This important institutional feature has been largely overlooked in the theoretical literature on union contract negotiations. In this paper, we address this shortcoming by presenting a bargaining model that allows the union the choice of strike or holdout. Although no attempt is made in this paper to test the model, we demonstrate the model's ability to reproduce many basic features of the data.

Expanding the union's choice of threats to include holdouts as well as strikes puts new emphasis on the role of the current wage under the expired contract. The model predicts that the composition of disputes will shift from holdouts to strikes when: (i) there has been a significant amount of uncompensated inflation during the previous contract term, which decreases the worker's wage in the holdout threat; (ii) there has been a decline in the local unemployment rate, which increases the worker's reservation wage in the strike threat; and (iii) there has been an increase in the firm's demand, which improves profitability, thereby widening the gap between the current wage and the settlement wage. These predictions concerning strike incidence are consistent with several empirical findings based on U.S. and Canadian negotiations.

Appendix A

Below, we derive the formulas used in the uniform example in Section 2.1. The dispute incidence is $(m-l)/(h-l)$. If a dispute occurs ($v < m$), its duration

is found by solving for $t(v)$ in the formula

$$D(v) = 1 - \frac{v}{m} = \frac{1 - e^{-rt(v)}}{1 - e^{-rT}}$$

to yield

$$t(v) = -\frac{1}{r} \log \left[j + (1-j)\frac{v}{m} \right]$$

where $j = e^{-rT}$. The expected duration, then, is

$$\begin{aligned} \bar{t} &= \int_l^m t(v) \frac{dv}{m-l} \\ &= \frac{1}{r} \left[1 + \frac{jm + (1-j)l}{(1-j)(m-l)} \log \left(j + (1-j)\frac{l}{m} \right) \right] \end{aligned}$$

The settlement rate from dispute is

$$R(t) = \frac{-v'(t)}{v(t) - l} = r \frac{v + m\frac{j}{1-j}}{v - l}$$

since from the formula for $D(v)$

$$v' = -r(v + m\frac{j}{1-j}).$$

In practice, there is heterogeneity among bargaining pairs about the level of uncertainty. Let $L = \{\underline{l}, ..., \overline{l}\}$ be the various levels of uncertainty in the population and assume that there are equal numbers of bargaining pairs from each level of uncertainty. Let $R_l(t)$ be the settlement rate at time t for subpopulation $l \in L$, and let $P_l(t)$ be the fraction of population $l \in L$ remaining in dispute at time t. The aggregate settlement rate, then, is found by weighting the settlement rates for each subpopulation by the subpopulation's size relative to the total population still in dispute at time t:

$$\overline{R}(t) = \frac{\sum_{l \in L} P_l(t) R_l(t)}{\sum_{l \in L} P_l(t)}$$

where

$$P_l(t) = \frac{v_l(t) - l}{h - l}.$$

The percentage wage decline during the threat θ is

$$\begin{aligned} \omega_\theta &= -\frac{w'_\theta(v)}{w_\theta(v)} = \frac{-\frac{1}{2}(1 - a_\theta)v'}{\frac{1}{2}(1 - a_\theta)v + x_\theta} \\ &= r \frac{v + m\frac{j}{1-j}}{v + i} \end{aligned}$$

where

$$i = \frac{2x_\theta}{1 - a_\theta}$$

and the average percentage decline in wages is

$$\begin{aligned}\overline{\omega}_\theta &= \int_l^m \omega_\theta(v) \frac{dv}{m-l} \\ &= r\left(1 + \frac{\frac{j}{1-j}m - i}{m-l} \log \frac{i+m}{i+l}\right).\end{aligned}$$

The union's expected payoff is calculated from Proposition 1 to be

$$U_\theta = x_\theta + (1 - a_\theta)m\frac{h-m}{h-l}$$

Similarly, we can calculate the firm's expected payoff to be

$$V_\theta = a_\theta \frac{h+l}{2} - b_\theta + \frac{1}{2}(1 - a_\theta)(h+m)\frac{h-m}{h-l}$$

and the expected loss to be

$$L_\theta = (1 - a_\theta)\left[\frac{1}{2}(m+l)\frac{m-l}{h-l} - m\frac{h-m}{h-l}\right].$$

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