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Bargaining structure and strike activity

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Abstract. In this paper we examine the nature of the relationship between bargaining structure and strike activity. In particular, we focus on the implications of the fact that the amount of information revealed by a union's actions depends on the bargaining environment in which it operates. We demonstrate that a union representing workers of more than one firm will face a greater incentive to reject offers than an independent union. This implies that a merger of two unions or the formation of bargaining coalitions will lead to a greater level of strike activity.

Structure de négociation et activités de grève. Les auteurs examinent la nature de la relation entre les structures de la négociation et les activités de grève. En particulier, ils examinent les implications du fait que la quantité d'information révélée par les actions du syndicat dépend de l'environnement de négociation dans lequel le syndicat opère. On montre qu'un syndicat représentant des travailleurs de plusieurs firmes va être davantage incité à rejeter des offres qu'un syndicat indépendant. Voilà qui implique que la fusion de deux syndicats ou la formation de coalitions de négociation va entraîner un niveau plus élevé d'activités de grève.

I. INTRODUCTION

After decades of study, the theoretical literature on the determinants of strike activity remains rather sparse. The major reason for this is the 'Hicks paradox' – since both sides lose during a strike, it is difficult to build a model of rational, pay-off-maximizing agents that results in strike activity in equilibrium.¹ In fact, earlier models chose to circumvent this difficulty by either viewing strikes as accidents (e.g., Kennan 1980; Siebert and Addison 1981; or the 'joint cost' model of Reder

1 Kennan (1986) coined this phrase in his recent survey of the strike literature. He provided the following concise explanation of the Hicks paradox: 'if one has a theory which predicts when a strike will occur and what the outcome will be, the parties can agree to this outcome in advance, and so avoid the costs of a strike. If they do this, the theory ceases to hold.'

and Neumann 1980) or by simply taking it as given that in order to extract a better settlement from management, workers had to strike (e.g., Hicks 1963; Cross 1965; or Ashenfelter and Johnson 1969). In the latter case, strike activity is assumed (rather than derived as an equilibrium outcome), and the process by which a strike leads to an improved contract is never explicitly modelled. A serious problem with both approaches is that, since the bargaining process is not modelled (and no explanation for strikes is provided), predictions about strike behaviour must rely on ad hoc conjectures about how outside factors influence the negotiations.²

Recently, there have been attempts to explicitly model the bargaining process in a manner that admits the possibility of strikes in equilibrium³ (see, e.g., Hayes 1984; Morton 1983; Fudenberg, Levine, and Ruud 1983; and Tracy 1984).⁴ In these studies, firms and unions are imperfectly informed about the pay-off functions of their opponents and may therefore make equilibrium proposals that, in some instances, will be rejected (and thus strikes occur).⁵ Such proposals and their subsequent rejections reveal information about the unknown parameters, which in turn influence the new proposals. As a result, strike activity is determined by three basic elements: factors that affect the pay-off functions, the initial amount of private information held by bargaining agents, and the rate at which information is transmitted (or revealed) during the bargaining process.⁶

2 For example, Kennan (1986) points out that 'the empirical content of the Ashenfelter and Johnson model comes almost exclusively from intuitive guesses about the determinants of the workers' resistance curve ... [I]f workers were rational in the model ... [they] could obtain large wage increases if they would just read the *American Economic Review*.'

3 The Hicks paradox is avoided in these models by assuming that agents possess private information.

4 These studies were made possible by recent advances in non cooperative game theory. In particular, they follow approaches developed in recent papers concerned with abstract bargaining problems in the presence of incomplete information. Among the path-breaking papers are Fudenberg and Tirole (1983), Sobel and Takahashi (1983), Cramton (1984), and Rubinstein (1985). The model in this paper is similar in spirit to Cramton's.

5 It could be argued that private information should not lead to costly disagreement, since the parties could avoid the inefficient outcome by revealing their private information before negotiations begin (e.g., firms could open their accounting books or conduct a pre-strike survey of union members). This argument can be avoided by defining incomplete information as information that cannot be obtained and/or verified. In the examples listed above, workers may misrepresent their true preferences in the pre-strike survey. Opening the accounting books may give union negotiators the right information, but, as pointed out by Ashenfelter and Johnson (1969), the union leaders may not be able to pass the same amount of information to the level of the rank and file.

6 There is a related issue in the bargaining literature, known formally as the 'Coase conjecture,' which is relevant here. According to the Coase conjecture, in a bargaining game with one-side incomplete information, incomplete information (or uncertainty) may not cause a significant delay in reaching an agreement (see, e.g., Bulow 1982 and Stokey 1981 on the formulation of the Coase conjecture and Gul, Sonnenschein, and Wilson 1986 on the related bargaining issue). However, this result should not be interpreted as saying that uncertainty cannot cause delay (or strikes). Instead, as indicated by a number of studies (e.g., Hayes 1984; Cramton 1984; Ausubel and De-neckere 1989; Admati and Perry 1987; Hart 1989), delay can be avoided only if counteroffers can be formulated and made a split second after a rejection *and* there is only one-sided incomplete information (the combination makes the Rubinstein offer-counteroffer bargaining mechanism efficient). In this paper we shall ignore this issue, since we agree with Hart (1989), who argues that it is reasonable to assume some delay between offers.

In this paper, we investigate the relationship between bargaining structure and strike activity. The term 'bargaining structure' is used here to refer to whether agents on the same side of the market bargain independently or as a coalition. This factor has not been important in previous studies of strike activity, since virtually all of the recent models have focused on *bilateral* negotiations, ignoring the impact of related contract settlements on the bargaining behaviour of a particular firm and union.⁷ In reality, however, a given employer may bargain with several different unions, or the unions may negotiate with a number of firms in the same or related industries. In such a situation, changes in bargaining structure affect the outcome of negotiations by altering the determinants of strike activity listed above. For instance, if a union represents the employees of several different firms, the firms can collect information about the union's pay-off function by observing its behaviour in negotiations with other firms. Actions taken by a coalition of unions (or a merged union)⁸ will therefore reveal a different amount of information than actions taken by independent unions. The major goal of this paper is to investigate how these differing levels of information transmission affect strike incidence and duration.⁹ To examine this issue with as few distractions as possible, we first abstract from other influences bargaining structure may have on negotiations (e.g., changes in the initial amount of private information and spill-over effects across pay-off functions created by contract settlements).¹⁰ We then discuss how these other factors are likely to affect our results.¹¹

7 Assuming that contract settlements in related industries are not important is a strong assumption. It is especially troublesome when the simple models are used to calibrate the strike activity of the entire economy since there are a substantial number of cases of coalition bargaining in related industries in most western economies.

8 Throughout the paper, we treat a merger as a more formal way of creating a coalition. Therefore, we do not distinguish between coalitions and mergers.

9 It is important to note that this issue cannot be addressed in the older models of strike activity discussed in the opening paragraph. The reason for this is that, since the bargaining process is not modelled explicitly, it is impossible to predict how changes in bargaining structure will affect the amount of information revealed through negotiations. In fact, as Kennan (1986) points out, the behaviour assumed in most of these early models is not consistent with rational, pay-off-maximizing behaviour under *any* bargaining mechanism. See Kennan (1986) for a detailed discussion of the problems with many of these models.

10 These two factors can be explained as follows. First, mergers (or coalition formation) may affect the initial amount of uncertainty present in the negotiations. For example, if two unions agree to pool their strike funds, the firms' initial beliefs concerning the strengths of the unions will be altered. Second, when firms produce in related product markets, wage settlements create spillover effects (by altering the firms' relative competitive positions in the product market) that have important implications for the outcome of negotiations. The implications of these facts are outlined below.

11 The term 'coalition bargaining' may refer to a number of distinctly different bargaining arrangements. For example, several unions may form a coalition to bargain with a single employer, or a coalition of unions might form to bargain with several firms. In this paper, since our primary focus is on how the number of firms observing union behaviour influences strike behaviour, we are concerned only with the latter case. In addition, we distinguish between the cases in which the firms produce in the same industry (industry-wide bargaining) and the case in which the firms' products are unrelated. As we stress below, this is done to separate out the impact of differences in the level of information transmission due to different coalition structures from effects due to product market interaction.

With respect to information transmission, our results indicate that when a single bargaining agent represents the interests of workers at more than one firm, incentives are created that lead to a greater expected level of strike activity. To understand the forces behind this result, consider a simple two-period model in which two unionized firms bargain over wages with their union. Assume that the firms produce in distinct product markets so that their pay-off functions are not interdependent¹² and that the union's default level of utility is not known to the firms. Finally, assume that each firm makes one offer each period that its union may either accept or reject. If the first offer is accepted, the contract lasts two periods, so that no further bargaining takes place in period two. If the first offer is rejected, a strike occurs, and, in the second period, the firm makes a second offer.

There are two properties of the agents' equilibrium strategies that lead to our result. First, in responding to the initial offer, the union sometimes finds it optimal to reject wage offers that lead to more than its default level of utility. In doing so, the union leaves the firm with the impression that it is relatively strong and therefore extracts a better settlement in the second period. By sacrificing utility in the first period, the union increases its utility in the next period. Second, as a firm contemplates increasing its offer, it realizes that higher wages increase the probability that a strike will be averted but reduce its pay-off if the offer is accepted. The optimal offer is the wage that just balances these two opposing forces.

Now, compare the unions' incentive to reject a given wage offer if they act as separate entities with their incentives if they form a coalition (or merge). In the former case, each firm obtains information about its own union's default utility value by observing its bargaining behaviour. However, if the unions form a coalition (or merge), the firms may also gather information by observing the negotiations between the coalition and the other firm. For example, GM may gather information about the UAW by observing it bargaining with Ford or Chrysler. Any action taken by a coalition will therefore have a bigger impact, since it will affect the behaviour of all firms it bargains with. This immediately implies that a coalition is more likely to reject any given offer (since, in doing so, it can increase the future offers made by *all* firms it negotiates with). The firms realize this and take this fact into account in calculating their optimal offers. In fact, since increasing the wage now leads to a smaller increase in the probability of acceptance, the firms will offer lower wages. The lower wage offers coupled with the greater propensity to reject leads to the result that strike activity is greater in the presence of coalitional bargaining. We argue below that this result also applies to industry-wide bargaining arrangements.

Examples of coalition bargaining satisfying our criteria include bargaining in the U.S. chemical industry since 1965 and the electrical equipment industry since 1966. In fact, in 1964 the AFL-CIO's Industrial Union Department (IUD) established a special division whose primary task was to coordinate the bargaining efforts of local unions within an industry (the Collective Bargaining Services Division). Once created, this division often went far beyond simply coordinating bargaining efforts by organizing coalitions consisting of previously independent bargaining agents from the same industry (see Chernish 1969 for details).

12 As we stress below, this assumption is made to simplify the analysis. We always keep the effect of product market interaction in mind. See section v for a detailed discussion of this issue.

The formal model, which closely mimics the model outlined above, is introduced in the next section. In section III, we solve for the equilibrium strategies under the assumption that the unions bargain independently and then calculate measures of expected strike activity. In section IV, we solve for the equilibrium strategies under the assumption that the unions form a coalition so that there is a single bargaining agent representing labour's interests. We argue that, in this case, the level of uncertainty about the union's pay-off function is reduced. To guarantee that the results derived in this section are independent of this assumption, we first calculate the equilibrium level of strike activity holding the level of uncertainty fixed at a level equal to that in section III. We show that, in this case, coalition bargaining leads to a higher level of strike activity. We then allow the level of uncertainty to adjust and show that, while the level of strike incidence is still higher than it is when the unions bargain independently, strike duration may be reduced by the coalition. This implies that the effect on total strike activity is ambiguous when the change in bargaining structure reduces the amount of uncertainty in the bargaining process.

Throughout sections III and IV we maintain the assumption that the firms produce in separate product markets in order to highlight the role of information transmission with as few distractions as possible. This assumption clearly rules out many important and interesting cases, including the case of industry-wide bargaining. When firms produce in related product markets, wage settlements affect their relative competitive positions in the market. The nature of these wage spill-over effects and their impact on equilibrium compensation and profits have recently been exposed and examined by Davidson (1988) and Horn and Wolinsky (1988). However, both papers use complete information models so that strikes cannot occur in equilibrium. In Section V, we make use of their results to infer how our results will be altered by product market interaction. We argue that in the important case of industry-wide bargaining, our results easily generalize (although this may not be true for other types of product market interaction). Finally, we close the paper by discussing topics for future research in section VI.

II. THE MODEL

Our basic two-period model consists of a pair of unionized firms that produce in separate produce markets. Each firm bargains with its union over how to divide the firm's revenue which, without loss of generality, we assume to be equal to \$1 in each period that it produces.¹³ In each period, if the negotiations have not already

¹³ We assume throughout that the amount of revenue to be divided between the firm and the union (i.e., the 'size of the pie' in bargaining terminology) is independent of the wage. In reality, when the wage increases, a profit-maximizing firm responds by reducing output, which alters its level of revenue. Our model could be extended to allow for such effects by making the size of the pie a decreasing function of the wage. Such an extension would greatly complicate the analysis, however, without adding any new insights. Clearly, the primary economic force driving our results is that in the presence of coalition bargaining the incentive to deceive increases. This force would not disappear or even be diminished by allowing the wage to affect revenue.

been completed, each firm makes an offer that its union may accept or reject. Once an offer of x is accepted, the firm earns $1 - x$ and the union receives x in each remaining period. If an offer is rejected, the firm remains idle for that period and earns no income, while union i receives a default level of utility denoted by s_i . Second period earnings are discounted by both parties by a common factor $\delta \in (0, 1)$ and all agents are assumed to be risk neutral.

Incomplete information is introduced by assuming that each union's default level of utility is not known by the firm. For simplicity, we assume that the firm's initial prior for s_i is uniform on $[0, 1]$. As the firm observes the behaviour of its union, it updates its beliefs using Bayes's rule. Finally, all agents are assumed to be rational, expected-pay-off maximizers.

It is important to note that we are assuming that bargaining takes place simultaneously at the two firms.¹⁴ This means that each firm must reveal its offer without knowing the other firm's offer. Under independent bargaining, after both offers have been revealed, each union must then respond without knowing what the other union will do. In the case of coalition bargaining (on labour's side), the union must announce its decisions concerning the two offers simultaneously. There are benefits and costs associated with this assumption. On the positive side, this guarantees that our results do not depend on first-mover advantages. On the negative side, this rules out the possibility of 'pattern bargaining' in which the union settles with one firm in order to pattern later contracts after the initial one. Allowing the timing of the negotiations to be determined endogenously would provide a richer model but is beyond the scope of this paper.¹⁵

We solve for equilibrium by backwards induction. First we derive the agents' optimal strategies in the last period, assuming that the first-period offer has been rejected. We then solve for the equilibrium strategies in the first period, taking these final-period strategies as given.

A Bayesian Nash equilibrium consists of a set of strategies that maximize each agent's expected pay-off, taking the strategies and beliefs of all other agents as given. In this setting, firm i 's strategy consists of a first-period offer w_i and a second-period offer $w_i(R)$ that will be made if the first offer is rejected. The strategy of a typical union consists of a reservation wage for each period. Any offer above the reservation wage for that period is accepted and any wage below that level is rejected. To rule out equilibria supported by non-credible threats, we require the equilibrium strategies to be sequentially rational (Kreps and Wilson 1982). That is, given the agents' beliefs, equilibrium strategies must be optimal at all stages of the game.

14 The simultaneous move assumption need not imply that the bargaining at the two firms is going on at the same exact time. Instead, it is an assumption concerning the information available to bargaining agents at the time of the negotiations. To be explicit, it implies that when one set negotiations is taking place, the agents are unaware of any proposals made (or settlements reached) in the related negotiations.

15 For a first crack at developing a sequential bargaining model in this spirit see Cheung (1989, chap. 3).

III. INDEPENDENT BARGAINING

Since we have assumed that the firms do not compete with each other in the product market and since, in this case, s_i and s_j are not related in any way, the equilibrium strategies in market i are not affected by the negotiations in market j . In solving for equilibrium, we may therefore focus on one market and ignore the actions of the agents in the other market. This will not be the case when the unions join forces. In that case, the outcome of the negotiations in market i will reveal information about the union that firm j will use in formulating its offers.

1. *The final period*

The union's problem in the last period is simple. If it accepts the firm's offer, it receives a pay-off of $w_i(R)$. If it rejects the offer, it receives s_i . Therefore, in the last period the union's reservation wage is equal to its default level of utility.

To solve the firm's problem we must begin by describing its second-period beliefs concerning the value of s_i . These beliefs depend upon the union's reaction to the first-period offer. In general, the firm's first-period offer will be rejected by the union if s_i is high and accepted if s_i is low. Let s^* denote the value of s_i that makes the union indifferent between accepting and rejecting the first-period offer. Then, from Bayes's rule, whenever the firm's first-period offer is rejected, its second-period beliefs are represented by the uniform distribution over $[s^*, 1]$.

If we let $x \in [s^*, 1]$ denote any arbitrary offer, then we may write the firm's second-period expected pay-off as

$$E\pi_i(x) = \frac{x - s^*}{1 - s^*} (1 - x). \quad (1)$$

The first term represents the probability of acceptance, while the second term represents the firm's pay-off if the offer is accepted. $w_i(R)$, the firm's optimal second-period offer, is the value of x that maximizes this expression. From the first-order conditions we obtain

$$w_i(R) = \frac{1}{2}(1 + s^*). \quad (2)$$

2. *The first period*

Consider the problem of union i in the first period, when the firm has made a wage offer of w_i . If the union accepts the offer, it earns w_i in both periods. Therefore, the value of accepting w_i is given by

$$V(A) = (1 + \delta)w_i \quad (3)$$

If the union rejects the offer, it receives s_i in the first period and $\max [s_i, w_i(R)]$ in the second period (since it rejects any second-period offer below s_i). Therefore, the value of rejecting w_i is given by

$$V(R) = s_i + \delta \max [s_i, w_i(R)]. \quad (4)$$

s^* is defined to be the value of s_i that equates $V(A)$ and $V(R)$. To solve for s^* , we begin by noting that from (2) it follows that $\max [s^*, w_i(R)] = w_i(R)$. With this in mind, we use (2), (3), and (4) to obtain

$$s^* = \max \{0, [2w_i(1 + \delta) - \delta]/(2 + \delta)\}. \quad (5)$$

Since $V(R)$ is increasing in s_i , it follows that if $s_i < s^*$, the union will accept the offer and if $s_i > s^*$, the union will reject w_i . That is, if $s_i < s^*$ the union's reservation wage is below w_i and if $s_i > s^*$ the union's reservation wage is above w_i .

There are two properties of the union's equilibrium strategy that are worth noting. First, a union may reject a wage offer even if the offer is above its default level of utility (i.e., $s^* < w_i$ so that if $s_i \in [s^*, w_i]$, the union rejects the offer even though the wage offered is above s_i). In doing so, the union leaves the firm with the impression that it is relatively strong and therefore extracts a higher wage in the second period. The second noteworthy property is that for extremely low wages $s^* = 0$. This implies that the union will reject w_i regardless of the value of s_i . In such a case, the firm learns nothing about the value of s_i by observing the union's reaction to the initial offer and enters the last period with its prior unchanged. This type of equilibrium is commonly referred to as a 'pooling equilibrium.' On the other hand, equilibria in which $s^* > 0$ are called 'semi-separating,' since the union's first-period behaviour will reveal some, but not all, information about the actual value of s_i .

Now, consider the firm's problem. Let y denote any first-period offer by the firm. Then the firm's expected profit as a function of y is

$$E\pi_t(y) = Pr\{y \text{ is accepted}\}(1 + \delta)(1 - y) + \delta Pr\{y \text{ is rejected}\}E\tilde{\pi}_t(w_i(R)). \quad (6)$$

The probability that y is accepted is equal to $s^*(y)$ and $E\tilde{\pi}_t(w_i(R))$, $w_i(R)$, and $s^*(y)$ are given by (1), (2), and (5). Substituting these values into (6) and optimizing, we obtain w_i , the optimal first-period offer

$$w_i = \frac{4 + 6\delta + \delta^2}{2(1 + \delta)(4 + \delta)}. \quad (7)$$

In summary, in the first period the firm offers w_i (from (7)) and the union accepts if $s_i \leq s^*$ (from (5)). If the offer is rejected, the firm makes a second-period offer of $w_i(R)$ (see (2)) and the union accepts if $s_i \leq w_i(R)$.

3. Strike activity

We calculate three measures of strike activity: strike incidence, strike duration, and total strike activity. Strike incidence is measured by the number of strikes that occur during the two periods (a two-period strike counts as one strike). Strike duration is equal to the average length of the strikes that occur and total strike activity is measured by the number of work days lost due to work stoppages.

A strike occurs at firm i in the first period if the firm's initial offer is rejected. This occurs with probability $1 - s^*(w_i)$ which, from (5) and (7), is equal to $(2 + \delta)/(4 + \delta)$. Since s_i and s_j are independent, the probability that both firms are idle in the first period is $(1 - s^*)^2$. Expected strike incidence (ESI) *per firm* is therefore equal to

$$\text{ESI} = \frac{1}{2} \{2(1 - s^*)^2 + 2s^*(1 - s^*)\} = \frac{2 + \delta}{4 + \delta}. \quad (8)$$

A strike occurs in the second period if both the first-period offer and $w_i(R)$ are rejected. The probability that $w_i(R)$ is rejected if offered is equal to one-half. Expected strike duration (ESD) is therefore equal to one and one-half periods.

Finally, expected total strike activity *per firm* (ESA) is equal to the product of ESI and ESD; or,

$$\text{ESA} = \sum_i \text{Pr} \{i \text{ days of strike activity}\} i = \frac{3(2 + \delta)}{2(4 + \delta)}. \quad (9)$$

Expected strike incidence and expected strike activity are both increasing functions of δ . Intuitively, as the firm and union become more patient, they both become less anxious to settle on a wage quickly. This leads the firm to offer a lower wage in the first period and results in more strike activity. The result that expected strike duration is always equal to one and one-half periods is an artifact of the two-period and uniform distribution assumptions. This fact is discussed in greater detail in the next section.

IV. COALITION BARGAINING

In this section we assume that the employees of both firms are represented by the same bargaining agent. This implies that each time the union negotiates with one of the firms, information about its default level of utility will be revealed to both firms. This creates a link between the firms that would not exist otherwise.

The coalition's utility is assumed to be equal to the sum of the utilities achieved in the two industries. We denote the union's default level of utility by s_m . This value represents the utility derived by the union in industry i if firm i is currently idle. Thus, if the union accepts one offer (w_i) and rejects the other (w_j) its utility is equal to $s_m + w_i$; if it rejects both it receives $2s_m$; and, if it accepts both, it earns $w_i + w_j$.

In the previous section we assumed that s_i and s_j were independent random variables uniformly distributed on $[0, 1]$. In order to compare the levels of strike activity under the two bargaining structures holding the level of uncertainty constant, we begin by assuming that s_m is uniformly distributed on $[0, 1]$. However, one reason that the unions might choose to form a coalition (or merge) is to reduce risk. For example, if we interpret s_i as the value of the independent unions' strike funds, the coalition might combine s_i and s_j and then distribute the sum equally

across industries.¹⁶ This would imply that the firms' initial prior for s_m should be triangular on $[0, 1]$. This would also be the case if the coalition attempts to represent the preferences of its average member.¹⁷ To understand the extent to which our results depend on our assumption that s_m has the same distribution as s_i and s_j , we also calculate measures of strike activity under the assumption that the level of risk is reduced by the formation of the coalition.

1. Coalition bargaining without risk sharing

a. The final period

The union's behaviour in the last period does not reveal any valuable information to the firms, since there are no subsequent periods in which to make use of the new information. Thus, as in section III, in the last period the union simply compares the wage offer with its default level of utility. The offer is accepted if and only if it is greater than s_m .

The firms' last-period problem differs in one fundamental way from the problem faced under independent bargaining. In particular, under coalition bargaining there are cases in which the unions' first-period behaviour leads the firm to rule out values of s_m in the lower *and* upper ends of the support. This generally occurs when one wage is accepted and the other is rejected. In such a case, the firm enters the final period with beliefs concerning s_m represented by the uniform distribution on $[\underline{s}, \bar{s}]$. If, on the other hand, both initial offers are rejected, the firms' problem is qualitatively identical to the problem faced when they bargain independently. In this case the union's first-period behaviour allows the firm to rule out extremely low values for s_m , and their posterior distribution is uniform on $[\bar{s}, 1]$.

To determine the firm's last-period offer we may write the firm's expected pay-off as

$$E\tilde{\pi}_i(x) = Pr\{x \text{ is accepted}\}(1 - x), \quad (10)$$

where x is any arbitrary offer. The firm chooses x to maximize this expression. If both first-period offers have been rejected, $Pr\{x \text{ is accepted}\} = (x - \bar{s})/(1 - \bar{s})$ and the optimal offer is

$$w_i(R, R) = \frac{1}{2}(1 + \bar{s}). \quad (11)$$

If, on the other hand, w_j has been accepted, $Pr\{x \text{ is accepted}\} = (x - \underline{s})/(\bar{s} - \underline{s})$ and firm i 's optimal second-period offer is

$$w_i(R, A) = \min\left(\frac{1}{2}(1 + \underline{s}), \bar{s}\right). \quad (12)$$

16 This assumes that the unions are of equal size.

17 As in fn 16, this assumes that the unions are of equal size.

b. The first period

Consider the problem of the coalition in the first period when faced with offers of w_1 and w_2 , with $w_1 \leq w_2$. If the union accepts both offers, it earns $w_1 + w_2$ each period. Therefore, the value of accepting both offers is

$$V(A, A) = (1 + \delta)(w_1 + w_2). \quad (13)$$

If the union accepts w_i and rejects w_j , it receives $w_i + s_m$ in the first period and $w_i + \max \{s_m, w_j(R, A)\}$ in the final period. Therefore, the value of accepting one offer and rejecting the other is

$$V(R, A) = (1 + \delta)w_i + s_m + \delta \max \{s_m, w_j(R, A)\}. \quad (14)$$

Note that it is never in the union's interest to accept a wage lower than one it rejects. This follows from the fact that $w_2 \geq w_1$ implies $V(R, A) \geq V(A, R)$.

Finally, if the union rejects both wage offers, it receives $2s_m$ in the first period and $2 \max \{s_m, w_i(R, R)\}$ in the second period. The pay-off from rejecting both offers is therefore

$$V(R, R) = 2s_m + 2\delta \max \{s_m, w_i(R, R)\}. \quad (15)$$

It is important to note that $V(R, R)$ and $V(R, A)$ are increasing functions of s_m with $V(R, R)$ increasing at a faster rate. This implies that if the strategy (R, R) dominates (R, A) for some value of s_m , then it dominates it for all higher values of s_m as well. This will also be true if either (R, R) or (R, A) dominates (A, A) for some value of s_m (since $V(A, A)$ is independent of s_m).

A typical union will compare $V(A, A)$, $V(R, A)$, and $V(R, R)$ and choose the action that leads to the greatest pay-off. The resulting equilibrium strategy depends, of course, on the values of s_m , w_1 , and w_2 . For $w_2 < 1$ there are four possibilities. First, $V(R, R)$ could dominate $V(R, A)$ and $V(A, A)$ for all values of s_m . In this, the only possible pooling equilibrium, the wage offers are so low that the union rejects both offers regardless of the value of s_m .

In all other cases the optimal strategy depends on the value of s_m . One possibility is depicted in figure 1. In this case, all three strategies may be observed in equilibrium, since a weak union would accept both offers, a strong union would reject both offers, and a union of intermediate strength would accept the high wage and reject the low. In the other types of semi-separating equilibria, one of the strategies is always dominated by the upper envelope of the two remaining strategies and is therefore not expected to be observed in equilibrium. In order to guarantee that the union's reaction is optimal, it is necessary to specify beliefs for the firm if a dominated strategy is observed. For simplicity, we assume that if an unexpected rejection (acceptance) is observed, the firm conjectures that $s_m = 1$ (0).¹⁸

18 These off-the-equilibrium-path conjectures are the only conjectures that satisfy the Intuitive Criterion recently introduced by Cho and Kreps (1987).

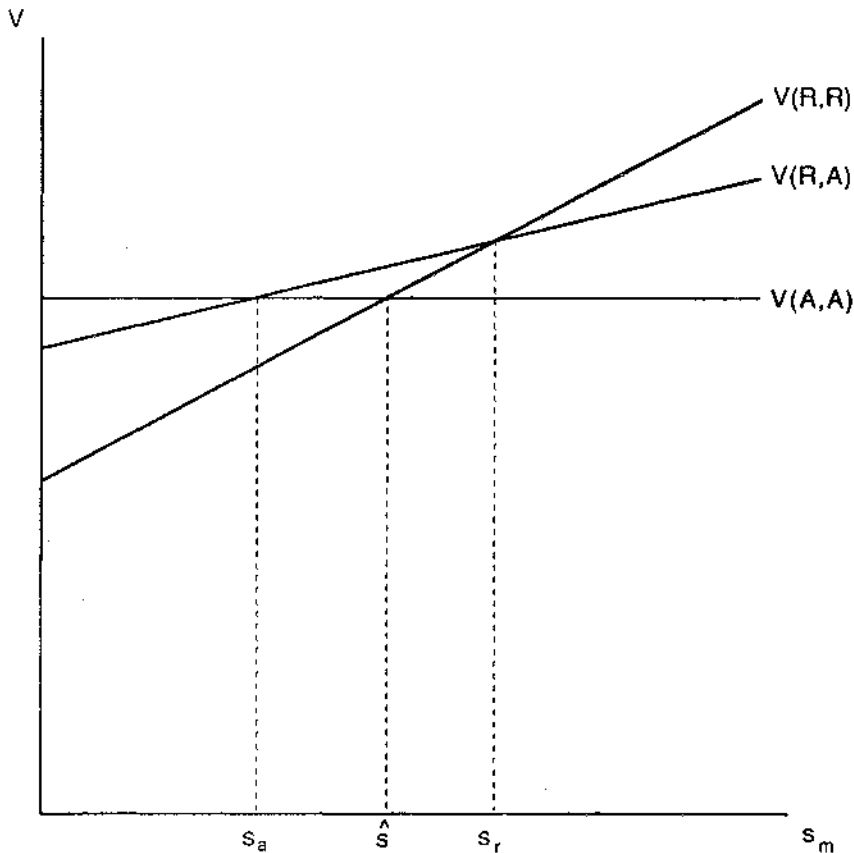


FIGURE 1

The pooling equilibrium occurs when $V(R, R) \geq \max \{V(A, A), V(R, A)\} \forall s_m$. Owing to the monotonicity of $V(R, R)$ and $V(R, A)$ in s_m , this inequality is least likely to hold when $s_m = 0$. Using (11)–(15), we find the inequality reversed if $w \equiv w_1 + w_2 \geq \delta/(1 + \delta)$.¹⁹ Therefore, a pooling equilibrium in which the union rejects both offers exists if and only if $w \leq \delta/(1 + \delta)$.

To determine which of the possible semi-separating equilibria is appropriate for a given wage vector, define s_a to be the value of s_m that equates $V(A, A)$ and $V(R, A)$; s_r , the value that equates (R, R) and (R, A) ; and \hat{s} , the value that equates (R, R) and (A, A) . These values can be calculated using equations (11)–(15). Provided that the values are positive (and less than one), their ordering then tells us which type of semi-separating equilibrium applies. For example, if $s_a < \hat{s} < s_r$,

19 If the union accepts either wage, the firm will enter the last period believing that the union's default level of utility is zero. The firm's last-period offer then becomes zero. On the other hand, rejecting both wages leaves the firm's prior unchanged and leads to a second-period offer of one-half. Therefore, if $s_m = 0$, $V(A, A) = (w_1 + w_2)(1 + \delta)$; $V(R, R) = \delta$; and $V(R, A) = w_2(1 + \delta)$.

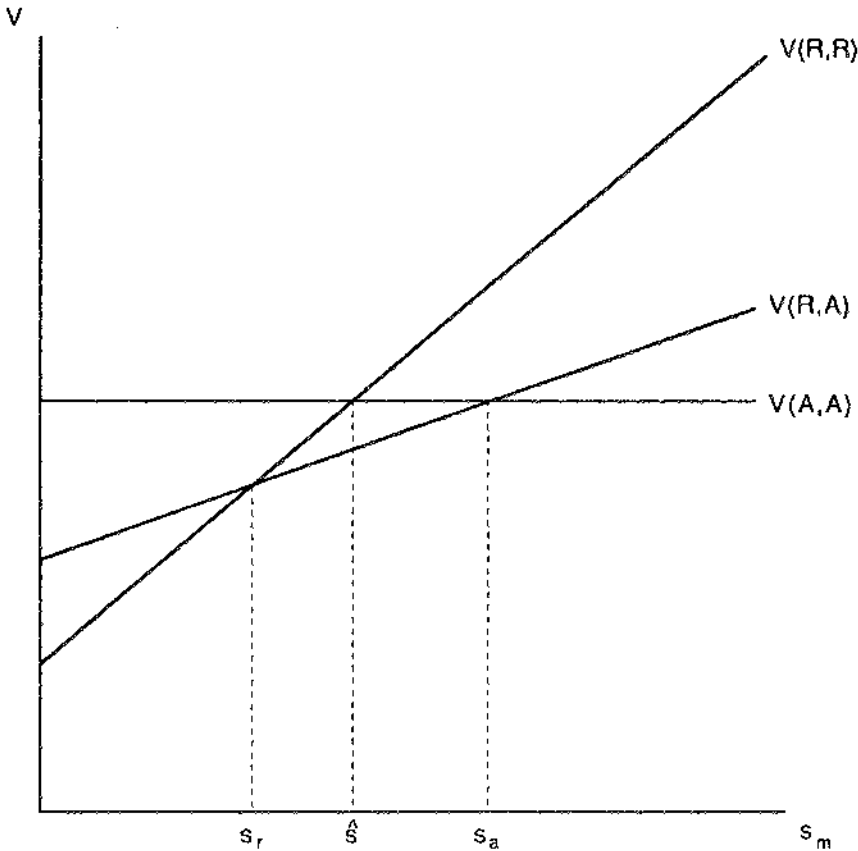


FIGURE 2

(as in figure 1), all three strategies will be observed in equilibrium. In this case, if the union accepts the high wage and rejects the low, the firm will enter the second period with beliefs represented by the uniform distribution on $[\underline{s}, \bar{s}]$ with $\underline{s} = s_a$ and $\bar{s} = s_r$. If both wages are rejected, the firms' posterior distribution will be uniform on $[\bar{s}, 1]$ with $\bar{s} = s_r$. On the other hand, if $0 < s_r < \hat{s} < s_a < 1$, then $V(R, A)$ is dominated by the upper envelope of $V(A, A)$ and $V(R, R)$ (see figure 2). In this case, if the firm observes that both first-period offers have been rejected, its posterior distribution will be uniform on $[\bar{s}, 1]$ with $\bar{s} = \hat{s}$.

The wage offers under which each type of equilibrium apply are derived in the appendix. Figure 3 summarizes the case $\delta = 0.5$. Region *a* represents the wage vectors that lead to the pooling equilibrium. In this region both wages are so low that the union rejects both regardless of its default level of utility. In region *b*, w_1 is so low that it is never optimal to accept it (i.e., $V(A, A)$ is dominated). Therefore, if $s_m < s_r$, the union accepts w_2 and, if $s_m > s_r$, both wages are rejected. Throughout

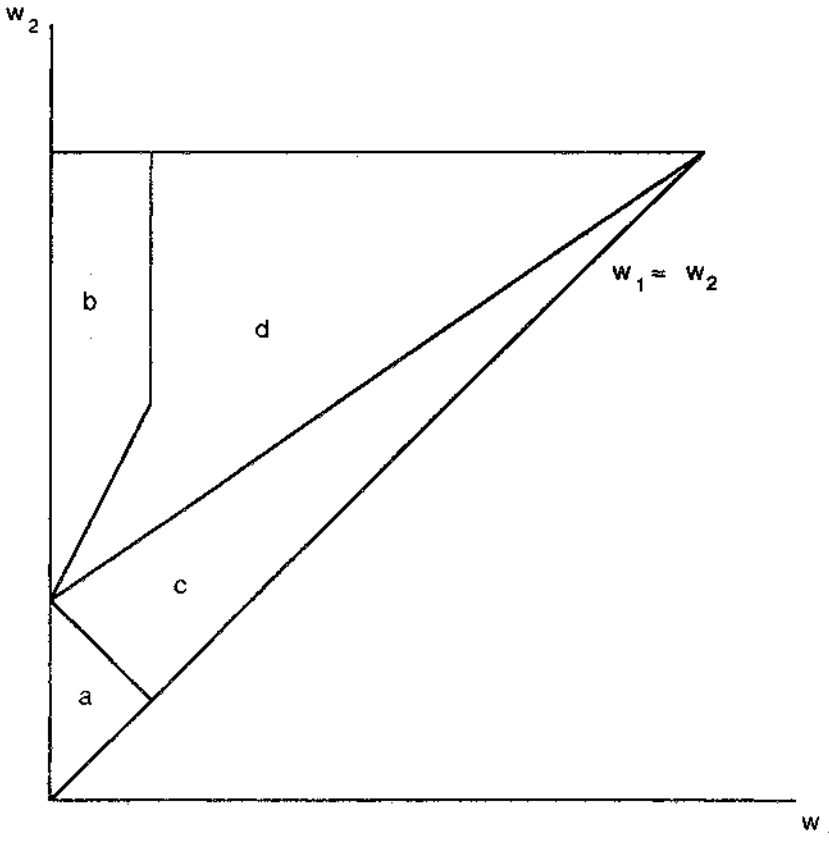


FIGURE 3

this region s_r is increasing in w_2 . In region c , the firms' offers do not differ much, and it is therefore never optimal to accept one while rejecting the other. This is the case depicted in figure 2 and discussed above. Throughout the region, \hat{s} is increasing in both wages. Finally, region d represents those wage vectors that generate the semi-separating equilibrium depicted in figure 1. In this region, s_r is increasing in w_2 and s_a is increasing in w_1 and decreasing in w_2 . The qualitative features of figure 3 remain the same for other values of the discount factor. However, little insight would be gained by explicitly calculating the boundaries of the regions and the critical values of s_m in the text. The interested reader is referred to the appendix.

There are two features of the optimal first-period strategies worth mentioning. First, as in the case of independent bargaining, each firm can increase the probability that its wage will be accepted by increasing its offer. This follows from the fact that $s_a(s_r)$ is increasing in $w_1(w_2)$ in regions b and d and that \hat{s} is increasing in both wages in region c . Second, if the offers are similar (but not identical) it is

never optimal for the union to reject one wage and accept the other. The reason for this is simple. Accepting a wage offer is essentially a sign of weakness, while rejections are made either to feign strength or because the union is actually strong. Therefore, if the union accepts one offer, it reveals itself to be relatively weak, and the value of rejecting the other offer is significantly reduced (firm j 's second-period offer falls from $w_j(R, R)$ to $w_j(R, A)$ when w_i is accepted). Thus, unless the offers are significantly different, (R, A) will not be an optimal response. As we shall see shortly, it is this feature of the union's strategy that leads to the increased strike activity.

We are now in position to describe the firms' first-period problem. Let $Pr_i(A, R)$ denote the probability that the union accepts firm i 's first period offer and rejects firm j 's. Define $Pr_i(A, A)$, $Pr_i(R, A)$, and $Pr_i(R, R)$ in an analogous manner. Then the expected profit for firm i as a function of y , its own offer, and z , the offer firm i expects firm j to make, can be expressed as

$$\begin{aligned}
 E\pi_i(y|z) = & [Pr_i(A, A) + Pr_i(A, R)](1 + \delta)(1 - y) \\
 & + \delta Pr_i(R, A) Pr\{w_i(R, A) \text{ is accepted}\}(1 - w_i(R, A)) \\
 & + \delta Pr_i(R, R) Pr\{w_i(R, R) \text{ is accepted}\}(1 - w_i(R, R)).
 \end{aligned}
 \tag{16}$$

The probability of acceptance depends on the position of (y, z) in figure 3. For example, if (y, z) lies in region a , then $Pr_i(R, R) = 1$ and all other probabilities are equal to zero. If, on the other hand, (y, z) lies in region d with $y > z$, then $Pr_i(A, A) = s_a$, $Pr_i(A, R) = s_r - s_a$, $Pr_i(R, A) = 0$, and $Pr(R, R) = 1 - s_r$ (if $y < z$, $Pr_i(A, R)$ and $Pr_i(R, A)$ are reversed and if $y = z$, $Pr_i(A, R) = Pr_i(R, A) = \frac{1}{2}$). The other cases are handled in a similar manner. Therefore, since s_a , s_r , \hat{s} , and the boundaries that define the regions in figure 3 depend on both wages, firm i 's expected pay-off depends on the wage it expects firm j to propose. This is not the case when the unions bargain independently, since in that case firm i learns nothing about its union's strength from observing the negotiations at firm j .

In a Nash equilibrium both firms must be maximizing their expected pay-off given their conjecture about their opponent's wage offer, and both firms' conjectures must be correct. If we let $w_i^*(w_j)$ denote the value of y that maximizes (16) when $z = w_j$, then the equilibrium first period offers, \hat{w}_i and \hat{w}_j , must satisfy $w_i^*(\hat{w}_j) = \hat{w}_i$ and $w_j^*(\hat{w}_i) = \hat{w}_j$. $w_i^*(w_j)$ is simply firm i 's reaction curve and \hat{w}_i and \hat{w}_j represent the wages defined by the intersection of the two reaction functions. These reaction curves are downward sloping and cross only once, so that the equilibrium is unique. Moreover, they cross at the 45° line, so that the equilibrium is symmetric.

The negative slope of the reaction function is a direct result of the informational externality that exists in the presence of coalition bargaining. To see this, consider firm i 's problem when it expects firm j to offer w' instead of w with $w' > w$. When w' is offered firm i knows that it will learn more about the likelihood that the union is strong than when w is offered (by observing the union's reaction). This reduces the incentive for firm i to offer a high wage and increases the value

of the information provided by a low offer. Therefore, firm i 's response is to lower its wage offer. In a sense, this results from the fact that firm i is able to free ride from the information provided by the union's reaction to firm j 's offer.

Since equilibrium is symmetric, an analytic solution for the wages can be derived by examining the expected pay-off functions in the neighborhood of the 45° line. From figure 3 it is apparent that when the offers do not differ by much, only regions a and c are relevant. However, it is not optimal for the firm to offer a wage in region a , since wages in this region are rejected with probability one. Moreover, such rejections provide the firm with no new information concerning the union's strength. This leaves us with region c . In this region, the union accepts both offers if $s_m \leq \hat{s}$ and rejects both if $s_m > \hat{s}$ where, from section one of the appendix, $\hat{s} = [w(1 + \delta) - \delta]/(2 + \delta)$. Using (11), expected profit over region c can now be simplified to

$$E\pi_i(y|z) = \hat{s}(1 + \delta)(1 - y) + \frac{\delta}{4}(1 - \hat{s})^2. \quad (17)$$

If we set the derivative of (17) equal to zero and solve we obtain

$$\hat{w}_i = \frac{2 + 4\delta + \delta^2}{2(1 + \delta)(3 + \delta)}. \quad (18)$$

Comparing (18) with (7), we find that the first-period wage offers are lower under coalition bargaining. To understand why, we begin by comparing the union's reaction with a given wage vector under the two bargaining structures. In particular, suppose that the firms make identical first-period proposals and that the offered wage vector lies in region c of figure 3. From section III we know that such a wage offer would be accepted by an independent union if $s_i < s^*$ with $s^* = [2w_i(1 + \delta) - \delta]/(2 + \delta)$. Therefore, from the firm's point of view, the offer will be accepted with probability s^* . Turn next to the case of coalition bargaining. From above, such a proposal would be accepted by the coalition if $s_m < \hat{s}$ with $\hat{s} = [(w_1 + w_2)(1 + \delta) - \delta]/(2 + \delta)$, and, from the firm's point of view, \hat{s} represents the probability that its proposal will be accepted. When the initial offers are identical, it is interesting to note that $s^* = \hat{s}$. Thus, at first glance, it appears that the union's behaviour is independent of the bargaining structure. However, appearances can be deceptive and, in this case, they are. The union's behaviour begins to differ as soon as the proposals begin to diverge. To see this, simply note that s^* increases at a faster rate than \hat{s} as w_2 rises above w_1 . Intuitively, as w_2 increases, union two is free to accept the better offer without fear of harming the workers at firm one *only* when the unions bargain independently. In the case of coalition bargaining, an acceptance of w_2 would signal weakness and would lead to a lower second-period offer by firm one. The union would like to accept firm two's offer but cannot do so without hurting firm one workers. This would not be the case if the unions bargained independently, since, in that case, an acceptance by union two provides no information concerning the strength of union one. A coalition therefore faces a stronger incentive to reject

proposals. This implies that the information a firm might gain by increasing its offer is greatest when the unions bargain independently. Finally, since the only reason that firms increase their wage offers is to gain information and increase the probability of acceptance, the firms will offer lower wages under coalition bargaining.

c. Strike activity

We are now in a position to calculate the three measures of strike activity and compare them with their counterparts under independent bargaining. Under coalition bargaining, the probability that both firms are idle in the first period is equal to $1 - \hat{s}$, the probability that the initial offers are rejected. Expected strike incidence per firm is therefore equal to

$$ESI = \frac{1}{2} \{2(1 - \hat{s})\} = \frac{2 + \delta}{3 + \delta}. \quad (19)$$

Comparing (19) and (8) we find that strikes are more frequent under coalition bargaining. This result follows from the fact that the firms, knowing that a coalition is more likely to reject their proposed wages, offer lower wages in the presence of coalition bargaining.

A strike occurs at both firms in the second period if both the first-period offers and $w_i(R, R)$ are rejected. If offered, $w_i(R, R)$ will be rejected with probability one-half. Expected strike duration is therefore equal to one and one-half periods, just as it is under independent bargaining. The fact that strike duration is independent of the bargaining structure is misleading, however, since it is an artifact of the two-period model and uniform distribution assumptions. Since there are no subsequent periods in which to learn about s_m and since it is equally likely that s_m lies anywhere in the interval $[\bar{s}, 1]$, the optimal second-period offer lies half-way between \bar{s} and 1. If we had a more elaborate n -period model, there would be a value to shading the second-period offer towards the lower end of the support in an effort to gather information and in the hope that the lower offer would be accepted. The same forces that led to the result that strike incidence is greater under coalition bargaining would then lead the firms to shade more when facing a coalition of unions than when facing independent unions. In a more elaborate model, then, we would expect strike duration to be greater under coalition bargaining.

Since expected strike incidence is increased by coalition bargaining and since expected strike duration is independent of the bargaining structure, it follows that expected total strike activity per firm is greater under coalition bargaining. This is confirmed by comparing (9) with (20), the appropriate measure when the unions have a common bargaining agent.²⁰

$$ESA = \frac{3(2 + \delta)}{2(3 + \delta)}. \quad (20)$$

²⁰ At this point, before considering the case of coalition bargaining with risk sharing, we wish to offer a comment concerning the interpretation of our model. Up to this point we have focused on the effects of coalition bargaining when the coalition consists of unions that represent workers at different firms. However, workers in many industries are organized by their craft, with unions

2. *Coalition bargaining with risk sharing*

At the beginning of this section we argued that the formation of a coalition might alter the distribution of the union's default level of utility and reduce the amount of risk inherent in the bargaining process. If this is the case, we might expect a reduction in the amount of strike activity. In this subsection we show that, at least in one important case, this may not be true. We do so by assuming that the firms' initial prior for s_m is triangular on $[0, 1]$. Two cases in which such an assumption might be appropriate were outlined at the beginning of section iv. Since the uniform distribution on $[0, 1]$ may be obtained by a mean preserving spread of this distribution, this assumption captures the notion that uncertainty is reduced.

The analysis is carried out as in subsection iv.1 except, of course, a different initial prior is used. The form of the triangular distribution leads to expressions more complex than their counterparts in the case of the uniform distribution. The details of the equilibrium strategies are therefore relegated to subsection 2 of the appendix. For our present purposes, it is sufficient to report that the nature of the equilibrium strategies remains the same, although the firms' first-period offers tend to be higher and their second-period offers lower. This follows from the fact that the triangular distribution has more mass centred around the mean. Both offers are therefore drawn closer to the mean after the coalition forms.

The measures of expected strike incidence and expected strike activity as a function of the discount factor are provided in figure 4. The solid lines represent the measures under coalition bargaining, and the dashed line represents the case of independent bargaining. The total number of strikes increases, owing to the change in bargaining structure, while total strike activity falls. The first result remains true, even though the total amount of uncertainty present in the bargaining process has been reduced. We argue below that the latter result would be reversed in a model with more than two periods of bargaining.

In the appendix, we demonstrate that expected strike duration decreases to one and one-third periods when the coalition forms. This is a byproduct of the fact that the triangular distribution has more mass centred around the mean. Since there is so little mass in the upper end of the distribution, the probability that the firms' second-period offers will be rejected is significantly reduced. In our two-period model, this reduction in expected strike duration more than compensates for the increase in expected strike incidence, as evidenced by the fact that total strike activity falls (see figure 4). In a more elaborate n -period model the forces leading to greater strike incidence in the first period would cause an increase in the number of strikes expected in every period but the last. Therefore, we suspect that in a model with more than two periods of bargaining, total strike activity will

cutting across firms. In such a case, coalitions may form in order to coordinate the bargaining activities of the many craft unions in a given industry. Our model is clearly flexible enough to handle such a situation. Rather than interpreting our model as a model of unionized firms bargaining with their unions, interpret it as a model of firms bargaining with two craft unions. When the coalition forms, the firm may learn about the union's pay-off function by observing the union's behaviour each time it represents one set of workers. Therefore, coalition bargaining by craft unions at a given firm (or a given industry) will lead to an increase in strike activity.

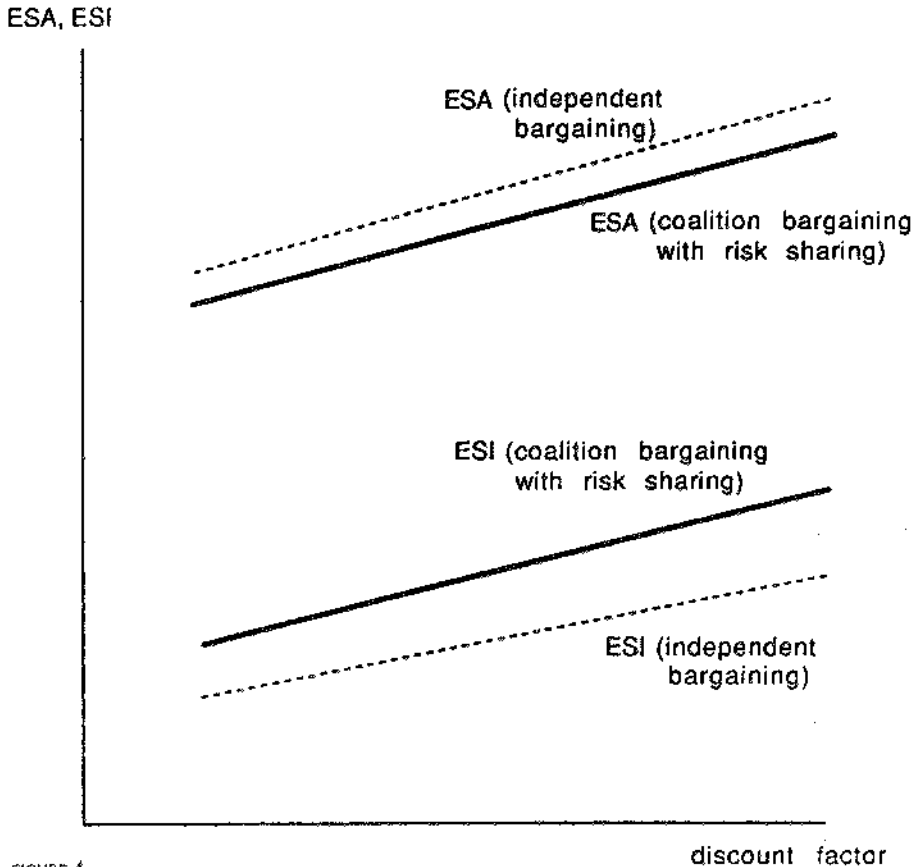


FIGURE 4

be increased by coalition bargaining even if the formation of the coalition reduces the level of uncertainty inherent in the bargaining process.

V. INDUSTRY-WIDE BARGAINING

In sections III and IV we assumed that the firms produce in separate product markets. This implies that the wage paid by firm i does not affect the size of the pie to be divided between firm j and its workers. This assumption might be especially troublesome if we want our theory to apply to coalitions formed by unions in the same industry. In this section we argue that, when the firms produce substitutes, additional forces are at work that actually strengthen our results. Our results therefore apply to the important case of industry-wide bargaining. However, if the firms produce complements, they work in the opposite direction, thereby weakening our results.

We produce in two steps. First, we remind the reader that our main result, that

strike activity is increased by coalition bargaining, is due to the fact that a coalition faces a greater incentive to reject offers than an independent union. Briefly, a rejection by an independent union can increase future offers by a single firm only while a rejection by a coalition of unions increases the future wage offers of all of the firms the coalition bargains with. As we showed above, this higher rejection rate translates into greater strike activity. Other forces that increase the coalition's value from rejecting offers will therefore reinforce our results.

This leads to the second step, where we consider whether this propensity to reject offers is strengthened or weakened when the firms produce in related produce markets. To do so, we make use of recent results provided by Davidson (1988) and Horn and Wolinsky (1988), who use complete information models to study the impact of bargaining structure on wages, prices, and profits. Their results can be summarized by considering a model of two unionized firms that compete in related product markets and bargain over wages with their respective unions. Let $R_i(w_i, w_j)$ denote the revenue earned by firm i when the negotiations result in wages w_i and w_j . If the firms produce substitutes (complements), R_i will be an increasing (decreasing) function of w_j . This follows from the fact that an increase in firm j 's wage retards j 's competitive position in its product market. If firm i produces a substitute, its competitive position is enhanced and its revenue increases. If firm i produces a complement, the demand for its product falls and revenue declines.

Now, negotiations are aimed at splitting revenue between the firm and its workers. When the goods are substitutes, as would be the case under industry-wide bargaining, wage settlements generate positive externalities across unions. That is, an increase in w_i increases the size of the pie to be split by firm j and its workers (R_j). When the unions bargain independently, they ignore this externality and are too willing to settle for any given wage. If they form a coalition, the externality is internalized and they hold out for higher wages. Therefore, when the goods are substitutes, product market interaction increases the coalition's incentive to reject offers (relative to the incentives faced by independent unions). We conclude that industry-wide bargaining increases strike activity.

The argument is reversed when the firms produce complements. In this case, since revenue at one firm is decreasing in the other firm's wage, a negative externality is created by wage settlements. Coalition bargaining internalizes the externality, but this reduces the incentive to reject offers. Therefore, when the firms produce complements, extending our model to allow for product market interaction would add new forces that would counteract those uncovered and discussed in section IV. In this case, the effect of coalition bargaining on strike activity would be ambiguous.

VI. CONCLUSION

We have used a simple non-cooperative bargaining model with one-sided incomplete information to study the relationship between bargaining structure and strike activity. In particular, we focused on the implications of the fact that the amount of

information revealed by a union's actions depends on the bargaining environment in which it operates. We demonstrated that a union representing workers at more than one firm faces a greater incentive to reject wage offers than an independent union. This implies that the formation of a bargaining coalition on labour's side will lead to a greater level of strike activity.

There are (at least) two avenues for future research suggested by our findings. First, we have used a two-period model because of its tractability. Although we have conjectured as to how our results would be affected, we have not yet worked out a satisfactory extension to n -periods. However, our model clearly indicates that at any point in the bargaining process, provided that the firms' priors are independent of the bargaining structure (as in section IV.1), a coalition always faces a greater incentive to reject offers. Therefore, assuming that the initial priors for independent and coalition bargaining are the same, we would expect more rejections, and therefore more strikes, in the early stages of the negotiations under coalition bargaining. Moreover, since the firms would be offering lower wages during these early stages, less information would be revealed when the coalition strikes than when an independent union strikes. This implies that there would be more uncertainty remaining present in the latter stages of the negotiations under coalition bargaining, resulting in increased strike incidence. At this point, verification of our conjectures remains a topic for future research.

The second area for future research concerns coalition bargaining by firms. In a recent empirical paper, Rose (1986) found that coalition bargaining on the employers' side led to an increase in strike activity in Canada. This appears to be consistent with our theory. To see this, suppose that some parameters of the firm's profit function is unknown but that there is complete certainty concerning the union's pay-off function. In such a setting, low (high) wage offers will be taken by the union as a sign that the size of the pie to be split is small (large). It will obviously be in the firm's interest to mislead the union into believing that the pie is small. Since offers by a coalition of firms will affect the pay-off received by all firms, it is clear that under coalition bargaining the incentive to deceive (offer low wages) is greater. Therefore, the same forces that lead to greater strike activity in our model would appear to lead to greater strike activity in the presence of multi-unit bargaining on the employers' side. However, we stress that these conjectures have not yet been confirmed.

Finally, it is important to note that the model we have employed differs from most previous attempts to study strike behaviour in one fundamentally important way. Prior to the early 1980s, virtually all models of strike behaviour avoided modelling bargaining behaviour explicitly. In fact, it has been argued that most of these models are inconsistent with rational bargaining behaviour (see fn9 and the discussion in Kennan 1986). Therefore, these models could not be used to investigate how changes in the bargaining environment affect strike activity. Our model is patterned after recent models of non-cooperative bargaining. The fact that we have been able to address the issue of the relationship between bargaining structure and strike activity in such a simple setting demonstrates the potential value of these new models.

APPENDIX

1. *The uniform case*

We begin by assuming $w_1 \leq w_2 < 1$. As discussed in the text, this leaves us with four possibilities:

$$V(R, R) \geq \max \{V(A, A), V(R, A)\} \quad \forall s_m \in [0, 1]. \tag{A1}$$

This is a pooling equilibrium in which the union rejects both wages regardless of the value of s_m . This inequality is least likely to hold when $s_m = 0$. Therefore, suppose that $s_m = 0$. If the union rejects both wages, the firm enters the last period with its prior unchanged. Therefore, $w_i(R, R) = \frac{1}{2}$ and $V(R, R) = \delta$. If the union accepts either wage, the firm enters the last period with $\underline{s} = \bar{s} = 0$. Therefore, $w_i(R, A) = 0$ and $V(A, A) = (1 + \delta)(w_1 + w_2) \geq V(R, A) = (1 + \delta)w_2$. If the inequality holds $\forall s_m \in [0, 1]$, it must therefore be the case that $[\delta/(1 + \delta)] \geq w_1 + w_2$.

$$V(R, A) \geq \max \{V(A, A), V(R, R)\} \quad \forall s_m \in [0, s_r] \tag{A2}$$

$$V(R, R) \geq \max \{V(A, A), V(R, A)\} \quad \forall s_m \in [s_r, 1].$$

This is a semi-separating equilibrium in which the union rejects w_1 regardless of the value of s_m and accepts w_2 only if it is sufficiently weak. If the union rejects both wages, the firm's second-period beliefs are uniform on $[s_r, 1]$. If the union plays (R, A) , the firm's second-period beliefs are uniform on $[0, s_r]$. Therefore, s_r solves $V(R, R) = V(R, A)$, or, $2s_r + \delta(1 + s_r) = w_2(1 + \delta) + s_r(1 + \delta)$, implying that $s_r = w_2(1 + \delta) - \delta$.

For this equilibrium to be appropriate it must be the case that $0 < s_r < 1$ and $V(R, A) \geq V(A, A)$ for $s_m = 0$. $s_r \in (0, 1)$ if $w_2 \in [\delta/(1 + \delta), 1]$ and the latter inequality holds if $w_1(1 + \delta) \leq \delta w_1(R, A) = \delta \min \{\frac{1}{2}, w_2(1 + \delta) - \delta\}$. The values of w_1 and w_2 satisfying these constraints are depicted in figure 3.

$$V(A, A) \geq \max \{V(R, A), V(R, R)\} \quad \forall s_m \in [0, \hat{s}] \tag{A3}$$

$$V(R, R) \geq \max \{V(R, A), V(A, A)\} \quad \forall s_m \in [\hat{s}, 1].$$

In this semi-separating equilibrium (A, R) is never optimal and both wages are accepted if the union is sufficiently weak. If the union plays (R, R) the firms' second-period beliefs are uniform on $[\hat{s}, 1]$. Therefore, \hat{s} solves $V(A, A) = (w_1 + w_2)(1 + \delta) = 2\hat{s} + \delta(1 + \hat{s}) = V(R, R)$, or,

$$\hat{s} = \frac{(w_1 + w_2)(1 + \delta) - \delta}{2 + \delta}.$$

There are two cases to consider, depending on the relative ranking of $V(R, R)$ and $V(R, A)$ when $s_m = 0$. Suppose first that $V(R, R) \geq V(R, A)$ when $s_m = 0$. This occurs if $w_2 \leq \delta/(1 + \delta)$. If this is the case, $\hat{s} \in (0, 1)$ whenever $w_1 + w_2 \in$

$[\delta/(1 + \delta), 2]$. Now, suppose $V(R, R) \leq V(R, A)$ when $s_m = 0$. This occurs when $w_2 \geq \delta/(1 + \delta)$. In this case, we must have $V(A, A) \geq V(R, A)$ at $s_m = 0$ and $s_m = \hat{s}$ or, $w_1 \in [0, \hat{s}]$. The values of w_1 and w_2 satisfying these constraints are depicted in figure 3 of the text.

$$V(A, A) \geq \max \{V(R, A), V(R, R)\} \quad \forall s_m \in (0, s_a) \tag{A4}$$

$$V(R, A) \geq \max \{V(A, A), V(R, R)\} \quad \forall s_m \in (s_a, s_r)$$

$$V(R, R) \geq \max \{V(A, A), V(R, A)\} \quad \forall s_m \in (s_r, 1).$$

For this case to be valid, we must have

- (i) $V(A, A) \geq V(R, R)$ at $s_m = 0$
- (ii) $V(R, A) \geq V(R, R)$ at $s_m = 0$
- (iii) $V(R, R) \geq V(A, A)$ at $s_m = 1$
- (iv) $V(R, A) \geq V(A, A)$ at $s_m = 1$.

The first condition requires $w_1 + w_2 \geq [\delta/(1 + \delta)][1 + s_r]$; the second requires $w_2(1 + \delta) + \delta \min [\frac{1}{2}(1 + s_a), s_r] \geq \delta(1 + s_r)$; and the last two hold for all $w_1 < 1$.

Finally, we require $s_a < s_r$ (this guarantees $\hat{s} \in (s_a, s_r)$). s_r solves $V(R, R) = V(R, A)$ or $2s_r + \delta(1 + s_r) = w_2(1 + \delta) + s_r(1 + \delta)$ or $s_r = w_2(1 + \delta) - \delta$. s_a solves $V(A, A) = V(R, A)$ or $(w_1 + w_2)(1 + \delta) = w_2(1 + \delta) + s_a + \delta \min [\frac{1}{2}(1 + s_a), s_r]$. As before, the values of w_1 and w_2 satisfying (i)–(iv) and $s_a < s_r$ are depicted in figure 3.

For the case $w_2 = 1$, the union always accepts the high wage. The problem of whether or not to accept $w_1 < 1$ is analogous to the union’s problem discussed in section 3 and is therefore left to the interested reader.

2. The triangular case

The original prior is of the form

$$f(x) = \begin{cases} 4x & \text{if } 0 \leq x \leq \frac{1}{2} \\ 4(1 - x) & \text{if } \frac{1}{2} \leq x \leq 1. \end{cases}$$

The firms’ optimal second-period offers become

$$w_i(R, R) = \begin{cases} 1 - \frac{1}{6}\sqrt{6(1 - 2\bar{s}^2)} & \text{if } 0 \leq \bar{s} \leq \frac{1}{2} \\ 1 - \frac{\sqrt{3}}{3}(1 - \bar{s}) & \text{if } \frac{1}{2} \leq \bar{s} \leq 1 \end{cases}$$

and

$$w_i(R, A) = \begin{cases} \bar{s} & \text{if } \underline{s} \leq \bar{s} \leq \frac{1}{2} \\ \min \left\{ 1 - \frac{1}{6} \sqrt{6(1 - 2s^2)}, \bar{s} \right\} & \text{if } \underline{s} \leq \frac{1}{2} \leq \bar{s} \\ \min \left\{ 1 - \frac{\sqrt{3}}{3} (1 - \underline{s}), \bar{s} \right\} & \text{if } \frac{1}{2} \leq \underline{s} \leq \bar{s}. \end{cases}$$

The union's optimal first-period response is derived in the same manner outlined in subsection 1 of the appendix. For completeness, we report the conditions under which each case is appropriate. Detailed computations may be obtained from the authors.

$$V(R, R) \geq \max \{V(A, A), V(R, A)\} \quad \forall s_m \in [0, 1]. \tag{A5}$$

This case applies if

$$w_1 + w_2 \leq \frac{2\delta}{1 + \delta} \left[1 - \frac{1}{\sqrt{6}} \right]$$

$$V(R, A) \geq \max \{V(A, A), V(R, R)\} \quad \forall s_m \in [0, s_r] \tag{A6}$$

$$V(R, R) \geq \max \{V(A, A), V(R, A)\} \quad \forall s_m \in [s_r, 1].$$

where

$$s_r = \begin{cases} m_1(w_2) & \text{if } w_2 \in \left[\frac{1.18\delta}{1 + \delta}, \frac{1 + 1.85\delta}{2(1 + \delta)} \right] \\ \frac{w_2(1 + \delta) - 0.8453\delta}{1 + 0.1547\delta} & \text{if } w_2 \in \left[\frac{1 + 1.85\delta}{2(1 + \delta)}, \frac{0.59 + 0.94\delta}{1 + \delta} \right] \\ \frac{w_2(1 + \delta) - 0.2535\delta}{1 + 1.1547\delta} & \text{if } w_2 \in \left[\frac{0.59 + 0.94\delta}{1 + \delta}, 1 \right] \end{cases}$$

$$m_1(w_2) =$$

$$\frac{3(1 - \delta)\{w_2(1 + \delta) - 2\delta\} + \delta \sqrt{6(1 - \delta)^2 - 4[10\delta^2 - 12\delta(1 + \delta)w_2 + 3w_2^2(1 + \delta)^2]}}{3(1 - \delta)^2 + 4\delta^2}$$

This case applied if $w_1 \leq [\delta/(1+\delta)] s_r$, when $w_2 \in [1.18\delta/(1+\delta), 0.59+0.94\delta/(1+\delta)]$, or $w_1 \leq 0.59\delta/(1 + \delta)$ when $w_2 \in [0.59 + 0.94\delta/(1 + \delta), 1]$.

$$V(A, A) \geq \max \{V(R, A), V(R, R)\} \quad \forall s_m \in [0, \hat{s}] \tag{A7}$$

$$V(R, R) \geq \max \{V(R, A), V(A, A)\} \quad \forall s_m \in [\hat{s}, 1],$$

where

$$\hat{s} = \begin{cases} m_2(w_1 + w_2) & \text{if } (w_1 + w_2) \in \left[\frac{1.18\delta}{1+\delta}, \frac{1+1.42\delta}{1+\delta} \right] \\ \frac{(w_1 + w_2)(1+\delta) - 0.8453\delta}{2[1+0.5774\delta]} & \text{if } (w_1 + w_2) \in \left[\frac{1+1.42\delta}{1+\delta}, 2 \right] \end{cases}$$

$$m_2(w_1 + w_2) =$$

$$\frac{3[(w_1 + w_2)(1 + \delta) - 2\delta + \delta\sqrt{6 - 10\delta^2 + 12\delta(w_1 + w_2)(1 + \delta) - 3(w_1 + w_2)^2(1 + \delta)}]}{2(3 + \delta^2)}$$

This case is appropriate if $w_2 \leq 1.18\delta/(1 + \delta)$ or $w_2 \geq 1.18\delta/(1 + \delta)$ and $w_1 \geq \hat{s}$.

$$V(A, A) \geq \max \{V(R, A), V(R, R)\} \quad \forall s_m \in [0, s_a] \quad (A8)$$

$$V(R, A) \geq \max \{V(A, A), V(R, R)\} \quad \forall s_m \in [s_a, s_r],$$

$$V(R, R) \geq \max \{V(A, A), V(R, A)\} \quad \forall s_m \in [s_r, 1],$$

where

$$s_r = \min \left\{ m_3(w_2), \frac{(1 + \delta)w_2 - 0.8453\delta}{1 + 0.1547\delta} \right\}$$

and

$$s_a = \begin{cases} w_1(1 + \delta) - \delta s_r & \text{if } s_r \leq \frac{1}{2} \text{ or if } s_r \geq \frac{1}{2} \text{ and either} \\ & w_1(1 + \delta) - \delta s_r \leq \frac{1}{2} \text{ and } f(w_1, s_r) \geq 0 \text{ or} \\ & w_1(1 + \delta) - \delta s_r \geq \frac{1}{2} \text{ and } g(w_1, w_2) \geq 0 \\ \frac{6[w_1(1 - \delta) - \delta] + \delta\sqrt{6 - 10\delta^2 + 24w_1(1 + \delta)\delta - 12w_1^2(1 + \delta)^2}}{2(3 + \delta^2)} & \\ & \text{if } w_1(1 + \delta) - \delta s_r \geq \frac{1}{2} \text{ and } f(w_1, s_r) \leq 0 \\ \frac{w_1(1 + \delta) - 0.4226\delta}{1 + 0.5774\delta} & \text{if } w_1(1 + \delta) - \delta s_r \leq \frac{1}{2} \text{ and } g(w_1, w_2) \leq 0 \end{cases}$$

with

$$m_3(w_2) =$$

$$\frac{3(1 - \delta)[(1 + \delta)w_2 - 2\delta] + \delta\sqrt{6(1 - \delta)^2 - 4[10\delta^2 - 12\delta(1 + \delta)w_2 + 3(1 + \delta)^2w_2^2]}}{3(1 - \delta)^2 + 4\delta^2}$$

$$f(w_1, s_r) = 2s_r^2(3 + \delta^2) - 4s_r[3 + \delta(1 + \delta)w_1] + 5 + 2w_1^2(1 + \delta)^2$$

$$g(w_1, w_2) = [0.58(1 + \delta)w_1 + 0.42][1 + 0.15\delta] - [(1 + \delta)w_2 - 0.85][1 + 0.58\delta].$$

This case applies if $w_2 \in [1.18\delta/(1 + \delta), 2]$ and $w_1 \in [\delta/(1 + \delta) \min(0.59, s_r), s_r]$.

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