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ABSTRACT

How Asymmetrically Increasing Joint Strike Costs Need Not Lead to Fewer Strikes*

The "joint costs" model states that the incentive to strike is inversely related to the total costs associated with workers' and firms' strike activities. Not only has this model been tested with mixed results, but also the joint costs model is problematic in explaining several stylized facts in the strike literature because higher strike costs do not always yield a lower incidence of strike activity. This paper illustrates how the joint cost model can yield these counterintuitive results. It shows that strike incidence need not *decrease* when joint strike costs *increase*. The innovation is to raise union and firm joint strike costs in an *asymmetric* way. Increasing a particular side's strike costs necessarily decreases its incentive to strike. However, in response, the other side's incentive can increase, since under a number of circumstances it holds out with a higher probability in order to collect the relatively larger expected rents coming about because the other side's implicit threat point decreases. To illustrate this, we model contract negotiations as a simple one-period game. (No need for more complex repeated games such as attrition since our point is only to show as simply as possible why the joint-costs model yields ambiguous results.) We use standard Hicksian concession curves to derive a payoff matrix. The payoff matrix results in contract negotiations following along the lines of a "game of chicken". The solution to the game yields no one stable pure Nash-equilibrium strategy, but instead a mixed strategy so that choices become probabilistic depending upon union and firm concession curve parameters. The results indicate that increasing *either* party's strike costs can have *ambiguous* effects on strike incidence. This ambiguity may explain why higher strike costs need not always lead to fewer strikes, and thus may account for the mixed success observed in studies that empirically test the joint costs model with strike incidence data. Although couched in terms of strikes, the results are equally applicable to other negotiation situations.

JEL Classification: J51, J52, C72, C78

Keywords: strike activity, joint strike costs, game of chicken

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I.1 Introduction

Over the last 50 years the rate of union membership declined, as did the incidence of strike activity. Similarly analyses of union activity, particularly strikes, are now occupying a smaller proportion of the economics and industrial relations literature (*Godard, 2011 and Brym, Bauer and McIvor, 2013*). Nevertheless, there still remain a number of unanswered questions. Explaining these is important because the same theory which explains firm-worker relations can be used to understand other type of negotiation interactions and outcomes. Although couched in terms of strike incidence, this paper's results are equally applicable to other bargaining and potential conflict situations, such as domestic conflict (e.g. household divorce) or international relations (e.g. the decision a country faces to impose trade restrictions or even go to war).

In this paper, we revisit the "joint costs" theory of strikes by linking elements of this model with imperfect information and union/firm misperceptions. Our purpose is to reconcile the model's failure to explain a number of empirical observations on strikes and to correctly account for certain "stylized facts" in strike literature. In so doing, we show how higher worker or firm strike costs need not always lead to fewer strikes, as the joint cost model predicts. Instead, under certain conditions, raising joint strike costs can actually yield higher, rather than lower, strike incidence. What drives the result is **asymmetrically** increasing strike costs, a consideration not explored in depictions of the joint-strike model (e.g. *Sopher, 1990*).

I.2 Literature Review

A voluminous literature has appeared in the past 50 years on strikes and their possible explanations. Figuring prominently in the strike literature canon, the "joint costs" model (*Reder and Neumann, 1980 and Kennan, 1980a)* is an intuitively attractive model deriving from basic economic principles that lead to straightforward predictions which can be easily tested: it argues that the incentive to strike is inversely related to the total costs associated with both a union's and a firm's strike activities. Variables that increase either party's strike costs decrease strike activity, ceteris paribus; while the reverse holds for factors decreasing strike costs. Kennan suggests that "this approach yields useful empirical predictions, which may be summarized by the statement that the probability of settling a strike … depends on the total cost of the strike to both parties." Hence, "for the trade union, increasing either the strike fund, the availability (or level) of unemployment insurance, or the opportunity of finding employment elsewhere will increase the likelihood of a strike. For the employer, increasing inventory … will lower the cost of a strike for the firm, thereby strengthening the firm's resistance to worker claims and the length of strikes."

The "joint costs" model has been tested empirically with mixed results. *Reder and Neumann (1980)* use inventory variations, shipment variations, and value added per worker to represent aspects of strike costs. First, they posit that joint strike costs vary inversely with the intra-industry variation in finished goods inventory (because intra-industry inventory variations proxy a firm's ability for pre- and post-strike substitution in production). Second, they posit that joint strike costs vary directly with overall shipment variations (because a smooth delivery rate decreases a firm's production and delivery costs). Third, they posit that joint strike costs vary directly with the relative wage, as denoted by the relative value added per worker. Based on these three assertions, they predict that strikes vary directly with the variation in inventories, inversely with the variation in shipments, and inversely with the relative value added per worker.

Employing U.S. manufacturing data during 1953-73, Reder and Neumann find strike activity to be *inversely* related to shipment variability and relative wages (with the results for the former not always statistically significant), and strike activity to be *directly* related to inventory variability, as predicted. However, using Canadian manufacturing data for 1962-1982, *Cousineau and Lacroix (1986)* are unable to find a significant relationship between strike probability and joint strike costs (as proxied by the coefficient of variation of the ratio of inventories to sales). Whereas, *Kennan (1980b)* found some empirical support that strike duration is directly related to unemployment insurance benefits (which would decrease strike costs), other attempts to test the theory's predictions produced mixed results. Using Canadian manufacturing data and employing output losses to proxy joint strike costs, *Maki (1986)* found only weak evidence of the hypothesized inverse relationship between strikes and output loss. Also with Canadian manufacturing data, *Ahmed (1989)* finds no statistical evidence to support the theoretical prediction of an inverse correlation between output loss and strikes. Employing a laboratory experimental approach, *Sopher (1990)* finds "moderate" support for the joint-cost theory. Using higher levels of unemployment to proxy higher worker strike costs, *Ingram, Metcalf and Wadsworth (1993)* find British strikes to be more likely the higher the unemployment, again contrary to expectations. On the other hand, *Crampton and Tracy (1994*) find that U.S. strike incidence increases with lower levels of unemployment and lower real wages. *Burlow and Buckley (1998)* offer empirical support for the joint costs model using Irish firm-level data, as does *Nicolitsas (2000)* using British data. Finally, *Geraghty and Wiseman (2008)* find evidence that "…variables that decrease a side's cost of striking or increase its opponent's cost are shown to increase its maximum holdout time, and vice versa, and strike duration increases with the value of the prize in dispute…"

In addition to the above mixed success of the "joint costs" model, the theory is problematic in explaining the most important "stylized fact" in the strike literature, namely the empirical regularity of cyclical strike incidence (*Rees, 1952, O'Brien, 1965, Ashenfelter and Johnson, 1969, Gunderson, Kervin and Reed, 1986, Vroman, 1989, Dickerson, 1994, and Huberman, 2002).* As *Hirsch and Addison (1986, p. 104)* observe "indeed, joint strike costs seem likely to increase with the level of economic activity, leading to the incorrect prediction of counter-cyclical strike activity (incidence)."[1] Even on this topic, however, there was some evidence in Canada in 2009 that strike incidence was higher during a deep recession (*Owram, 2009*), supporting a counter-cyclical prediction.

Finally, the two main manifestations of strike activity, incidence and duration, do not seem to respond in the same way to a number of economic variables like the bargaining unit size and the business cycle (*Gunderson and Melino, 1990, Harrison and Stewart, 1993, and Campolieti, Hebdon, and Hyatt, 2005*). With regards to bargaining unit size for example, *Campolieti, Hebdon and Hyatt, 2005,* find that "…smaller bargaining units were less likely to strike that were larger bargaining units, but had longer strikes when they did strike." In addition, *Brym, Bauer and McIvor, 2013,* report that while "…some research also suggests that strike duration is counter-cyclical…after 2001, mean strike duration increased and was not counter-cyclical".

I.3 Model Outline and Predictions

We build as simple a model as we can, to illustrate why the "joint costs" theory could yield ambiguous results with respect to one manifestation of strike activity, namely strike incidence. As a by-product, we show why some strikes may be perfectly rational thus providing an explanation for what *Kennan (1986)* calls the "Hicks Paradox". Our approach

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[1] However, we must point out here that whereas improved cyclical conditions in the product market increase the *joint* costs of the strike, these same improved conditions will also increase the alternative employment opportunities of workers and hence decrease their opportunity strike costs. However, lower unemployment rates and a tighter labor market are likely to increase the opportunity strike costs for employers since it will be more difficult for them to find replacement workers in order to substitute for strikers when the labor market is tight. Thus, *joint* strike costs are *not* expected to be affected by external labor market

begins with standard Hicksian concession curves modified by *Mauro (1982)* to account for imperfect information. From these curves a payoff matrix is derived under alternative union and firm strategies. The resulting payoff matrix implies contract negotiations to follow along the lines of a "game of chicken".[2] A strike occurs when both unions and firms "hold out".

The solution to this game indicates no one pure Nash-equilibrium strategy. Instead each player must adopt a mixed strategy so that choices become probabilistic depending on the payoff matrices, which depend on union and firm concession curve parameters. This mixed strategy implies that each player occasionally holds out. Holding out is perfectly rational and consistent with *Hicks' (1963)* assertion that "a union which never strikes may lose its ability to organize a formidable strike (p. 146)". In addition, the results indicate that each party's strike costs (reflected in rates of concession) have an *ambiguous* effect on strike incidence. What drive the results are asymmetric changes in relative costs. For example, as union strike costs rise, the union holdout probability falls. But if unions hold out less (i.e., concede more), the firm's expected profit from conceding decreases (because by conceding firms have to pay higher wages). Lower expected profits from conceding causes the firm to hold out more. In turn, holding out more potentially increases strike incidence. Whether strikes actually increase depend on *both* union *and* firm hold out probabilities. We show that under plausible circumstances the firm's hold out probability increases more quickly than the union's hold out probability diminishes, which can lead to a greater strike incidence. Thus this asymmetric rise in employee-employer strike costs implies that strike probabilities can rise. (The same holds when firm costs rise more quickly than union costs.) Therefore higher strike costs need not lead to fewer strikes. As such, the approach may account for the mixed success of the "joint costs" theory of strikes in explaining strike incidence.

II.1 The Game

According to Hicks[3], if strikes were costly, both a firm and its workers would pay to renegotiate a contract rather than strike. Workers pay by consenting to accept a wage lower than desired. Firms pay by offering a wage higher than anticipated. Since costs are proportional to strike duration, avoiding longer strikes implies greater union and firm

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conditions, in the same way they are affected by product market conditions, where loss of output affects *both* the firm's and workers' net income by reducing the absolute share of the pie available to them.

[2] Whereas the game of chicken results directly from the Hicks-Mauro concession curve model, it is conceivable that other games describing union-firm interactions are possible, especially in a repeated game setting. For example, **Kennen-Wilson** (1989) use the game of attrition. Though not the point of this paper, we conjecture that asymmetric changes in costs would produce the same results in the attrition model as we show in the game of chicken derived from Hicks-Mauro model.

incentives to concede. Greater incentives to concede yield downward sloping worker resistance and upward sloping firm concession curves (Figure 1). The "union resistance curve" defines the minimum wage a union would accept *now* to avoid a strike of expected duration (s_u) given an initial wage demand W_r. The "firm concession curve" defines the maximum wage the firm would offer *now* to avoid a strike of expected duration (s_f), given the wage it "would have paid…[on its]…own initiative (***Hicks***, p. 141)."

If the firm knows the resistance curve of the union, and the union knows the concession curve of the firm, both sides can avoid a strike by compromising on a wage defined by the intersection of the union resistance and firm concession curves. This wage W^* avoids a strike of duration s^*, thus benefiting both sides. To derive an expression for W^*, assume for simplicity and without loss of generality that the concession curves are linear.

Let W_u be the wage a union would accept now to avoid a strike of expected duration s_u. Then:

$$W_u = W_r - bs_u, \; b > 0 \qquad (1)$$

where W_r is the union's reservation wage (i.e., the wage that the union will accept now in order to avoid a strike of zero expected duration). In essence this wage reflects union "demands" and is determined by what it conceives to be workers' value. The slope, b, of the resistance curve reflects the union's cost of extending the strike one time-period. The greater the strike costs, the more wages the union would be willing to give up to avoid a strike, and hence the greater the magnitude of b.

Let W_f be the wage a firm would offer now to avoid a strike of expected duration S_f. Then:

$$W_f = W_0 + cs_f, \; c > 0 \qquad (2)$$

where W_0 is the maximum wage that the firm would offer now in order to avoid a strike of zero expected duration, and c is the slope of W_f which reflects the firm's costs of prolonging a strike one additional time period.

Setting $s_u = s_f$ and solving for W^*, one obtains

$$W^* = (cW_r + bW_0) / (b + c) \qquad (3)$$

[3] **Hicks** (**1963**, first published in 1932).

which is the wage that the union would accept and the firm would offer *now*, if they both expected a strike of length S* as in Figure 1. Note that if b = c, i.e. if the concession curves have equal slopes, then

$$W^* = ½ (W_r + W_0) \qquad (4)$$

which is the special case when the two parties “split the difference”.

Hicks (1963, p. 146) argues that incomplete or asymmetric information can make W^* initially unattainable, thereby leading to a strike.[4] This can be illustrated easily. As in *Mauro (1982)*, suppose the firm underestimates the minimum union asking wage and overestimates union strike costs. Such misperceptions lead the firm to offer a wage unacceptable to the union. Graphically, this implies that the firm perceives the union resistance curve to be lower and steeper (e.g. W_u^p) than it really is. This leads the firm to offer a wage no higher than W_0^*, the intersection of its perceived union resistance and its own actual concession curve, thinking it acceptable to the union (Figure 1). Algebraically, the firm’s perceived union resistance curve W_u^p can be written as

$$W_u^p = \theta_1 - \theta_2 S_u, \quad \theta_1 < W_r, \text{ and } \theta_2 > b \qquad (5)$$

The degree to which $\theta_1 < W_r$ reflects the firm’s misperception of union reservation wages. The degree to which $\theta_2 > b$ reflects the firm’s overestimate of union strike costs.

Similarly the union would accept a wage no lower than W_r^* (the intersection of perceived firm concession and its own actual resistance curve) if it wrongly perceives the firm concession curve to be higher and steeper (e.g. W_f^p) than it is. Algebraically, the union’s perceived firm concession curve (W_f^p) can be depicted as

$$W_f^p = \phi_1 + \phi_2 S_f, \quad \phi_1 > W_0 \text{ and } \phi_2 > c \qquad (6)$$

where $\phi_{□}$ reflects its overestimate of the firm’s offer wage and ϕ_2 its overestimate of the firm’s strike costs. Such misperceptions lead to an impasse, because with misperceptions, the union now is willing to concede as low a wage as W_r^* (the intersection of its resistance curve, W_u, and what it perceives to be the firm’s concession curve, W_f^p), while the firm now is willing to concede as much as W_0^* (the intersection of its concession curve, W_f, and what it perceives to be the union resistance curve, W_u^p). Since $W_r^* > W_0^*$, an impasse is reached (Figure 1). We believe that it makes sense to model such an impasse as a game[5], though we

[4] Even though **Fernandez and Glazer (1991)** prove that incomplete information is only a sufficient but not necessary condition for a strike, a preponderance of international data (e.g. **Ashenfelter and Currie [1990], Card [1990]**, **Fisher [1991]**, **Vannetelbosch [1997]**, **Barlow and Buckley [1998]**, and **Maulen and Vannetelbosch [1999]**) as well as experimental analysis (e.g. **Forsythe, Kennan, and Sopher [1991]**) link asymmetric information to strikes.

[5] It seems plausible that each side would misperceive the other’s true concession curve by building overly optimistic expectations. Reversing the direction of misperceptions (for example by making the firm perceive a *higher* than true resistance

emphasize that were there no misperceptions as in the typical Hicksian setup described above, a game would not result. With perfect information the two sides would agree on W^* without a strike.[6]

In the game, each player-participant has a choice: concede to the other party's offer (demand) or hold out. If the union concedes while the firm holds out, the union obtains a wage W_0^* for its workers, the highest wage the firm is willing to offer given its expectations about the union's resistance curve. If the firm concedes while the union holds out, the union obtains W_r^*, which is the lowest wage that the union would accept given its expectations about the firm's concession curve. When both sides concede, it is reasonable to assume a wage in-between, e.g.

$$W^* = f\,(W_0^*, W_r^*, b, c) \qquad (7)$$

such that $\partial f / \partial W_0^* > 0$, $\partial f / \partial W_r^* > 0$, $\partial f / \partial b < 0$, $\partial f / \partial c > 0$. However, when both sides cooperate by conceding, they in effect exchange truthful information about each other's concession/resistance curves, which as Hicks observed yields the original settlement obtained by equating W_u and W_f depicted by equation (3). Lastly, when both sides hold out, a strike results yielding a zero wage.

II.2 The Payoff Matrix

Payoffs for the two parties are recorded in Table 1. Union payoffs are denoted as U_{ij}, where i depicts the union's action (concede or hold out) and j the firm's. Thus U_{cc} is the union's payoff when both the union and the firm concede; U_{hc}, the union payoff when the union holds out and the firm concedes; U_{ch}, the union's payoff when the union concedes and the firm holds out; and U_{hh}, the union's payoff when both parties hold out.

Table 1: Payoff Matrix

	Concede (firm)	Hold Out (firm)
Concede (union)	$U_{cc} = W^*$ $\Pi_{cc} = R(L_{cc}) - W^* L_{cc}$	$U_{ch} = W_0^*$ $\Pi_{ch} = R(L_{ch}) - W_0^p L_{ch}$
Hold Out (union)	$U_{hc} = W_r^*$ $\Pi_{hc} = R(L_{hc}) - W_r^p L_{hc}$	$U_{hh} = 0$ $\Pi_{hh} = 0$

curve and the union a *lower* than true firm concession curve) would lead to an atypical "impasse". The union would demand a lower wage than the firm would be willing to offer and we cannot see why they should not settle without a strike.

We assume union objectives are identified with those of the median union voter, an assumption for which there is ample precedent (e.g. see *Hirsch and Addison, 1986, p. 28)* and empirical support (e.g. *Kaufman and Martinez-Vasquez, 1988, 1990).* [7] To satisfy the "median" union voter we assume these demands will mostly concern the wage. A firm's employee-termination (firing) policy which is inversely related to seniority (i.e. a "first-in-last-out" policy) would in general not harm the median voter since he or she will not be under immediate threat of losing his or her job.[8] Unless the median voter is altruistic and concerned about employment of low seniority fellow workers, this assumption enables us to rid ourselves of concern for employment levels in the union objective function, and thus to specify union returns as the median voter's wage under given contingencies.[9] Further the assumption is reasonable given our objective to find plausible circumstances under which increases in joint strike costs might fail to reduce the probability of a strike. From figure 1, union welfare levels U_{ij} are $U_{cc} = W^*$, $U_{hc} = W_r^*$, $U_{ch} = W_0^*$, and $U_{hh} = 0$, where $W_r^* \geq W^* \geq W_0^* > 0$.

The firm's objectives are identified with the profit function $\Pi = R(L) - wL$, where L is employment level and R(L) is the revenue function resulting from an output generated by L workers. Firm payoffs are denoted as Π_{ij}, where again i depicts the union's action and j the firm's. Thus, Π_{cc} is the firm's payoff when both sides concede; Π_{hc}, the firm's payoff when the union holds out and the firm concedes; Π_{ch}, the firm's payoff when the union concedes but the firm holds out; and Π_{hh}, the firm's payoff when both parties hold out. These payoffs are computed by substituting wage and employment levels associated with the union's and firm's action (concede and hold out) into the profit function so that $\Pi_{cc} = R(L_{cc}) – W^*L_{cc}$, $\Pi_{ch} = R(L_{ch}) – W_0^*L_{ch}$, $\Pi_{hc} = R(L_{hc}) – W_r^*L_{ch}$, and $\Pi_{hh} = 0$. Clearly, if the firm holds out while the union concedes, wages are lower than if the firm concedes and the union holds out and as a result profits are higher, so $\Pi_{ch} > \Pi_{hc}$. Both the union and firm conceding yields a wage in between ($W_r^* \geq W^* \geq W_0^*$) so that $\Pi_{ch} \geq \Pi_{cc} \geq \Pi_{hc}$. Clearly a strike yields no production and hence lower profits or even losses, which we simply denote as zero profits. Thus one would expect $\Pi_{ch} \geq \Pi_{cc} \geq \Pi_{hc} > \Pi_{hh}$.

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[6] Again, we do not wish to give reasons justifying incomplete information, but merely fall back on an ample supply of past and current work supporting this contention. Our point isn't to justify existing models, but to show how strikes can rationally occur in the context of such models and how in this framework higher joint strike costs need not always lead to fewer strikes.

[7] Other union objective functions, such as in **McDonald and Solow (1981)** are possible. These affect the payoff matrix and could affect the game's outcome.

[8] **Oswald (1984)** used a similar explanation to analyze the importance of seniority to derive a flat union indifference map over wage and employment levels. Also see **Petrakis and Vlassis (2000)** for an analysis of the relative roles of wages versus employment in bargaining.

A strike depends on the outcome of playing this game. If at most one side holds out, no strike results. Hence, finding the conditions under which the hold out - hold out (H-H) outcome is more likely, will lead us to an explanation of strike incidence the first time the game is played. If no strike results, the game is not played again until a new contract is up for re-negotiation. If, however, a strike results the game is repeated. The duration of the strike will depend on how many H-H solutions one gets as the game is repeated (with adjusted payoffs) during the course of the strike. In this paper we concentrate on strike incidence and one-shot game results and defer the implications of the repeated game for a future research topic.[10]

III.1 Implications and Derivations of Optimal Strategies

After examining both parties' possible options from the previous matrix, we find no dominant strategy. From the point of view of the firm, it is best to hold out ($\Pi_{ch} \geq \Pi_{cc}$) if the union concedes, while it is best to concede ($\Pi_{hc} \geq 0$) if the union holds out. From the point of view of the union, it is best to hold out ($U_{hc} \geq U_{cc}$) if the firm concedes, while it is best to concede ($U_{ch} \geq 0$) if the firm holds out. This leads to two possible pure Nash equilibria, the first being concede-hold out (C-H) and the second being hold out-concede (H-C), and a mixed Nash equilibrium strategy where each side chooses either to concede or hold out with an optimally determined probability.

It is easy to show that the other two pure strategies, i.e. concede-concede (C-C) and hold out-hold out (H-H) are not stable. If both sides concede and settle at W*, an agreement is reached without a strike. This solution, however, is not stable since each party has an incentive to "cheat" by holding out. However, a double hold out strategy spells trouble for both, since a strike occurs and both lose. A strike is a no-trade outcome that shrinks the absolute value of the "pie" to be divided. As a result, this double hold out solution is also unstable. Strikes are indeed a rare phenomenon[11] and some kind of mutual compromise seems to result from most contract negotiations. This would correspond to our concede-concede solution, which although unstable since one side could gain by holding out hoping that its

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[9] In direct evidence on union preferences, **Clark and Oswald (1988)** find that for the U.K. in the late 1980's union leaders prefer to bargain over wage than over employment levels.

[10] See **Kuhn and Gu (1998, 1999)** for a model where learning through sequential bargaining plays an important role in strike and wage outcomes. A similar approach is followed by **Calabuig and Olcina (2000)**, in an infinite horizon repeated game model with incomplete information, where strikes are the result of building a reputation for toughness by each side, and strike incidence is shown to be positively related to firm profitability and negatively related to firm and union strike costs.

[11] See **Kennan and Wilson (1990)**, p. 406.

rival will concede, is often observed because of the threat that the other party will also hold out thus bringing pain to both.

The payoff matrix in Table 1 is consistent with the "game of chicken": all entries are Pareto superior to the hold out-hold out (strike) outcome, but because concede-hold out dominates concede-concede for the firm, and hold out-concede dominates concede-concede for the union, it is in each party's best interest to threaten to take a hold out strategy, hoping that its rival will be scared into conceding. Thus as in the "game of chicken" each party has an incentive to display "toughness" even if each party has no intentions of holding out all the way. To display this "toughness" each side adopts a mixed strategy by choosing to hold out with a probability determined by each side maximizing its expected payoff.

III.2 Derivation of the Firm's and Union's Optimal Strategies

The risk-neutral union maximizes its expected utility by maximizing its expected payoff. If the union concedes, the expected wage will be:

$$W_c = W^*P_f + W_0^*(1 - P_f), \qquad (8)$$

where P_f is the probability that the firm will concede, $W_0^* = (c\theta_1 + \theta_2 W_0) / (\theta_2 + c)$, and W^* is as defined previously. Similarly, if the union holds out, the expected union wage will be:

$$W_h = W_r^*P_f + 0\,(1 - P_f) = W_r^*P_f \qquad (9)$$

where $W_r^* = (\phi_2 W_r + b\phi_1) / (b + \phi_2)$. Then, the union will maximize its expected payoff U:

$$U = P_u W_c + (1 - P_u)\, W_h = P_u\,[P_f W^* + (1 - P_f)\, W_0^*] + (1 - P_u)\, P_f W_r^* \qquad (10)$$

where P_u is the probability that the union will concede.

In a mixed strategy equilibrium, P_u can assume values ranging from 0 to 1, while P_u can be either 0 or 1 if only pure strategies are allowed. To maximize U one derives the following first order condition by differentiating it with respect to the choice variable P_u:

$$\partial U / \partial P_u = W_c - W_h = P_f W^* + (1 - P_f)\, W_0^* - P_f W_r^* = 0, \qquad (11)$$

which expression which does not have P_u as an argument. This implies that an interior solution (i.e. $0 < P_u < 1$) for the union depends on the firm's strategy. Only when P_f is such that the equation is zero is union utility maximized. Otherwise it is optimal for the union to revert to a pure strategy. Solving for the optimal value of P_f, P_f^*, we then get:

$$P_f^* = W_0^* / (W_0^* + W_r^* - W^*) \qquad (12)$$

implying that in equilibrium the firm will choose to concede exactly P_f^* percent of the time. If the firm chose to concede *more* than P_f^* percent of the time, the union's expected wage from conceding would be less than the union's expected wage from holding out (i.e. $W_c < W_h$ or $W_c - W_h > 0$), and hence the union will always choose to hold out; if the firm chose to concede *less* than P_f^* percent of the time, the union's expected wage from conceding would exceed the union's expected wage from holding out (i.e. $W_c > W_h$, or $W_c - W_h > 0$), and hence the union will never choose to hold out. Therefore, in a mixed strategy equilibrium, the firm must choose to concede exactly P_f^* percent of the time, or equivalently the firm must choose to hold out $(1 - P_f^*) = (W_r^* - W^*) / (W_0^* + W_r^* - W^*)$ percent of the time.

In order to get the effects of b and c on $(1 - P_f^*)$, and hence the effect of each party's strike costs as reflected through their concession rates on the likelihood of holding out for the union, we differentiate $(1 - P_f^*)$ with respect to b and c. In Appendix 1 we present the derivations of these partial differentiations where we obtain the following:

$$\partial(1 - P_f^*) / \partial c < 0 \text{ and } \partial(1 - P_f^*) / \partial b > \text{ or } < 0.$$ [12]

Holding the union's strike costs b constant, higher firm costs c have an *unambiguous* negative effect on the firm's hold out probability. However, holding firm costs c constant, higher union costs b have an *ambiguous* effect on the firm's hold out probability. Higher union strike costs can increase the firm's probability of holding out when initial union strike costs are low. However, as the union's strike costs increase, after a point the probability of the firm holding out decreases. As such, initially higher union costs decrease the return to conceding now and can lead to a higher likelihood of holding out! This result may muddle the "joint costs" model's straightforward predictions, as it suggests that higher costs do not *necessarily* lead to a reduced hold out probability. As we will see later when we investigate joint firm-union behavior, this result opens the door to the possibility that higher strike costs may not always reduce strike probability.[13] At this point we cannot make a definitive statement as to how joint strike costs may affect the strike probability since we haven't yet investigated the union's strategy. We need to investigate the union hold out probability since a strike is a *joint* hold out outcome. We derive the union's hold out probability by looking at the firm's profit maximizing behavior, to which we now turn.

Assume the firm maximizes expected profits Π. If the firm concedes, expected profits will be:

$$\Pi_c = P_u\Pi_{cc} + (1 - P_u)\,\Pi_{hc}. \qquad (13)$$

If the firm holds out, its expected profits will be:

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[12] One might argue that union and firm perceptions of each others' costs (W_u^p and W_f^p) change as actual costs b and c increase. However, increasing cost perceptions as one augments actual costs reinforces our conclusions regarding the ambiguity of the joint costs model.

[13] Sections III.3 below illustrates this ambiguity using a simple graphical approach.

$$\Pi_h = P_u \Pi_{ch} + (1 - P_u)\, 0 = P_u \Pi_{ch}. \qquad (14)$$

Then the firm maximizes expected profits Π:

$$\Pi = P_f \Pi_c + (1 - P_f)\, \Pi_h = P_f [P_u \Pi_{cc} + (1 - P_u)\, \Pi_{hc}] + (1 - P_f)\, P_u \Pi_{ch}. \qquad (15)$$

To maximize the above function, one must derive the first order condition:

$$\partial\Pi / \partial P_f = P_u \Pi_{cc} + (1 - P_u)\, \Pi_{hc} - P_u \Pi_{ch} = 0 \qquad (16)$$

and solve for the optimal P_u, P_u^*. We get:

$P_u^* = \Pi_{hc} / (\Pi_{hc} + \Pi_{ch} - \Pi_{cc}). \qquad (17)$

Hence, in a mixed strategy equilibrium, the union must choose to concede exactly P_u^* percent of the time, or equivalently it must choose to hold out exactly $(1 - P_u^*) = (\Pi_{ch} - \Pi_{cc})/(\Pi_{hc} - \Pi_{ch} - \Pi_{cc})$ percent of the time.

To get the effects of b and c on $(1 - P_u^*)$ and hence on the union's likelihood of holding out, we differentiate $(1 - P_u^*)$ with respect to each of these variables (see Appendix 1). We get:

$$\partial(1 - P_u^*) / \partial b < 0 \text{ and } \partial(1 - P_u^*) / \partial c > \text{or} < 0.$$

Hence, higher union costs b, holding firm costs c constant have an *unambiguous* negative effect on the union's probability of holding out. However, higher firm strike costs c, holding union costs b constant have an *ambiguous* effect on the union's likelihood of holding out. At low cost levels, higher costs increase the hold out probability, but at higher cost levels, the effect on holding out becomes negative. It is that ambiguous result that may lead to a lower strike probability as strike costs c increase.

III.3 Joint Union/Firm Equilibrium Strike Behavior

We can now attempt to combine optimal behavior for both sides. A strike results only when *both* sides hold out. Hence, the probability of a strike should be given by the product of each side's hold out probabilities so that P(strike) = P(firm hold out)* P(union hold out) = $(1 - P_f^*)(1 - P_u^*)$, or

$$P(\text{strike}) = [(W_r^* - W^*) / (W_0^* + W_r^* - W^*)]\, [(\Pi_{ch} - \Pi_{cc}) / (\Pi_{hc} + \Pi_{ch} + \Pi_{cc})] \qquad (18)$$

Some implications arise directly from the above equation for strike probability. First, we can verify that the strike probability will be zero if either party has perfect information. For example, when the firm has no misperceptions regarding the union's resistance curve (i.e. curve W_u^p coincides with W_u), then $W_0^* = W^*$ and hence $\Pi_{ch} = \Pi_{cc}$. This implies that $(1 - P_u^*) = 0$ and therefore that P(strike) = 0. Similarly, $W_r^* = W^*$ and hence $(1 - P_f^*) = 0$, if the union has no misperceptions regarding the firm's concession curve (i.e. W_f^p coincides with W_f). Again, P(strike) = 0. Therefore, our model predicts no possibility of a strike when either or both parties have perfect information about each other's resistance/concession curves. This would support Hicks' original argument that implicitly attributed strikes to imperfect information.

Second, when union strike costs b are zero, $W_r^* = W^* = W_r$ and $(1 – P_f^*) = 0$. Hence, P(strike) = $(1 – P_f^*)(1 – P_u^*) = 0$. Therefore, when union strike costs b are zero, there is no possibility whatsoever of a strike because the firm will always concede. On the other hand, when firm strike costs c are zero, then $W_0^* = W^* = W_0$ and hence $\Pi_{ch} = \Pi_{cc}$. This implies that $(1 – P_u^*) = 0$ and also that P(strike) = 0. So, when either union strike costs b or firm strike costs c are zero (or both) there is no possibility of a strike because at least one side will never hold out.

The joint costs theory of strikes predicts how the strike probability changes when union strike costs b and/or firm strike costs c rise. Actually it would predict that any factor raising joint strike costs decreases strike probability. We now show that higher strike costs need not always lead to a lower strike probability.

First let us look at how higher union costs b affect strike probability, holding firm costs c constant. To do that we differentiate the strike probability $[(1 – P_f^*)(1 – P_u^*)]$ with respect to b. Appendix 2 presents the derivation of this partial differentiation where we obtain the following:

$$\partial\, [(1 – P_f^*)(1 – P_u^*)] \,/\, \partial\, b > \text{or} < 0.$$

This result indicates that holding firm costs c constant, higher union strike costs b, have an ambiguous effect on strike probability.

Perhaps a graphical approach is warranted to best illustrate this ambiguous effect of a rise in union strike costs b. In figure 2, W_u and W_f are resistance and concession curves already defined and illustrated in figure 1. They denote the wages the union and firm would accept now to avoid a strike of expected duration s. The difference here compared to figure 1 is that numerous W_u curves are drawn to illustrate the effect of altering the union's strike cost parameter, b. For example, b = 0 reflects zero union strike costs and hence a horizontal $W_u(b_0)$ curve, implying that the union would concede nothing to avoid a strike. As the $W_u(b_i)$ curve gets steeper (i.e. it rotates downward), union strike costs rise (i stands for union strike cost levels). The W_f^p and W_u^p curves denote the union and firm's perceptions of each others' true resistance/concession curves. As already indicated $W_u^p > W_u$ (in absolute terms) and W_f^p

$> W_f$, and as before the union's reservation wage W_r^* is the intersection of its resistance curve W_u, and its perception of the firm's concession curve W_f^p, while the firm's offer wage W_0^* is the intersection of W_f and W_u^p. For our purposes assume W_f^p and W_u^p to be fixed, though clearly it would be reasonable for them to be related to the actual W_f and W_u curves. As can be illustrated, relating them to W_f and W_u would not change the qualitative nature of our results.

Now, let's examine the effect on each party's hold out probability which we relate to strike probability. First analyze firm behavior and begin with b = 0, the case when union strike costs are zero. Here $W_r^* = W^*$. Since the firm's concede probability is $P_f^* = W_0^* / (W_0^* + W_r^* - W^*)$, the firm concedes with probability 1, or it holds out with probability 0, as we showed previously. As union strike costs b increase, $W_f(b_i)$ rotates downwards. The difference $(W_r^* - W^*)$ initially increases, hence increasing the firm's concede probability, or increasing its hold out probability. Eventually, however, the difference between W_r^* and W^* begins to decline, thereby decreasing the firm's hold out probability.

Since a strike is a joint hold out outcome, we cannot predict the effect on strike probability until we analyze how higher union costs b affect the union's hold out probability as well. Recall from equation (17) that the union's concede probability is related to firm profits. Clearly profits are inversely related to wages; the more the firm pays the lower are profits, neglecting efficiency wage arguments which probably don't apply here anyway. Thus, profits can be expressed as $\Pi(w) = 1/(\alpha w)$; for simplicity let $\alpha = 1$. This implies that $P_u^* = (1/W_r^*) / (1/W_r^* + 1/W_0^* - 1/W^*)$. Then, as b begins to rise from 0, again the W_u curve rotates downwards. This decreases W_r^* and W^* (or increases $1/W_r^*$ and $1/W^*$) as indicated in Figure 2 by $W_r^*(b_0) > W_r^*(b_1) > W_r^*(b_2) \ldots$ and $W^*(b_0) > W^*(b_1) > W^*(b_2)\ldots$. As $1/W_r^*$ and $1/W^*$ rise, the probability of the union conceding rises, since both $\partial P_u^* / \partial(1/W_r^*) > 0$ and $\partial P_u^* / \partial(1/W^*) > 0$[14], and therefore the probability of the union holding out falls.

As union strike costs b rise, the union becomes less likely to hold out, but the firm initially becomes more likely to hold out, starting with a hold out (and hence a strike) probability of zero. Therefore, since initially zero, strike probability can only rise as union strike costs increase; and it may continue to do so as long as the percentage increase in the firm hold out probability exceeds the percentage decline in the union hold out probability. Eventually, as

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[14] The derivatives are computed as $\partial P_u^* / \partial (1/W_r^*) = 1 / (1 / W_r^* + 1 / W_0^* - 1 / W^*) - 1 / [(W_r^*) (1/W_r^* + 1/W_0^* - 1/W^*)^2] > 0$ and $\partial P_u^* / \partial (1/W^*) = 1 / [(W_r^*) (1 / W_r^* + 1 / W_0^* - 1 / W^*)^2] > 0$.

both sides' hold out probabilities decrease with higher union strike costs b, strike probability necessarily declines. These patterns are illustrated in figure 5 which will be explained later.

Next, let's examine the impact of increasing firm strike costs c, holding union strike costs b constant. To do that we differentiate the strike probability $[(1 - P_f^*)(1 - P_u^*)]$ with respect to c. Appendix 2 presents the derivation of this partial differentiation where we obtain the following:

$$\partial\, [(1 - P_f^*)\,(1 - P_u^*)] \,/\, \partial\, c < \text{or} > 0.$$

Raising firm strike costs c ambiguously affects the strike probability holding constant union strike costs b. Let us again employ a simple graphical approach to illustrate this possible ambiguity. In figure 3 all curves are as already defined. However, instead of assessing the impact of the union's resistance curve rotating downward, we now consider the impact of the firm's concession curve rotating upward. Again purely for illustration make the assumption about W_u^p and W_f^p being fixed. First, analyze firm behavior. As the firm's strike costs c increase, the W_f curve rotates upward. This increases W_0^* and W^* as indicated in the figure by $W_0^*(c0) < W_0^*(c_1) < W_0^*(c_2)$ …and $W^*(c_0) < W^*(c_1) < W^*(c_2)$…As W_0^* and W^* rise, the probability of the firm conceding also rises. To see this recall from equation (12) that the probability of the firm conceding is $P_f^* = W_0^* / (W_0^* + W_r^* - W^*)$. Since both $\partial P_f^* / \partial W^*$ and $\partial P_f^* / \partial W_0^* > 0$, the firm's probability of conceding increases thus decreasing its hold out probability.[15]

Next we need to see how the union's hold out probability is affected by higher firm strike costs c. When $c = 0$, $P_u^* = 1$, since $1/W_0^* = 1/W^*$; and hence the union holds out with a zero probability. As firm strike costs increase, $W_u(c_i)$ rotates upward. Since W^* rises initially faster than W_0^*, the union's concede probability $P_u^* = (1/W_r^*) / (1/W_r^* + 1/W_0^* - 1/W^*)$ falls as $-1/W^*$ rises faster than $1/W_0^*$ falls. Hence initially, the union's hold out probability increases. Eventually, however, the difference between W^* and W_0^* begins to decline thereby decreasing the union's hold out probability.

Hence, as firm strike costs c rise, the firm becomes less likely to hold out, but the union initially becomes more likely to hold out, starting with a hold out (and hence a strike) probability of zero. So the strike probability can only rise at first and it may continue to do so as long as the percentage increase in the union's hold out probability exceeds the percentage decrease in the firm hold out probability. Eventually, however, as both sides' hold out

[15] The derivatives are computed as $\partial\, P_f^* / \partial\, W^* = W_0^* / (W_0^* + W_r^* - W^*)^2 > 0$ and $\partial\, P_f^* / \partial W_0^* = 1/ [\, (W_0^* + W_r^* - W^*) - W_0^*/ (W_0^* + W_r^* - W^*)^2 > 0$.

probabilities decline with higher firm strike costs c, the strike probability necessarily decreases.

Concession curve estimates are not common, so it is difficult to guess parameters of the relevant curves like W_r^* and W_0^*. Nevertheless, given our concern only with illustrating that the joint costs model need not hold, we merely take reasonable parameter values (based in part on *Farber (1978)* and *Siebert, Bertrand, and Addison (1985)*) and try to simulate strike probabilities. These simulations are presented in Table 2 and in figures 4 and 5 and confirm our models' predictions. Two examples are given: one in which union strike costs b increase, holding constant firm strike costs (left panel of Table 2 and figure 4); and one in which firm strike costs c increase, holding constant union strike costs (right panel of Table 2 and figure 5). Presented are firm and union hold out probabilities $(1 – P_f^*)$ and $(1 – P_u^*)$, as well as the strike probability P(str). As we increase union strike costs b, the union's hold out probability continually declines. On the other hand, higher values for b first increase then decrease the firm's hold out probability. The joint effect is that strike probability first increases (up to 4%) then decreases. Similarly, as we increase firm strike costs c, the firm's hold out probability continually declines. However, higher values for c first increase then decrease the union's hold out probability. The joint effect as firm strike costs c increase is that strike probability first rises (up to 5%) then declines. It is interesting to note that the British strike probability is between 0.8 and 4.9% (*Ingram, Metcalf, and Wadsworth 1993*), though at least in the past somewhat higher in the U.S. (*Gramm*, *1987*).

IV. Concluding Remarks

Motivated by the mixed success of the joint costs model of strike activity, we analyzed union-firm bargaining behavior in the context of Hicksian concession curves. We found both unions and firms to fare best when both concede. They fare worst when both hold out. The union does best when it holds out and when the firm concedes. Firms do best when they hold out while the union concedes. This reward structure yields a payoff matrix comparable to the game of chicken. In "chicken", no single pure Nash equilibrium solution emerges. Instead, there exist two pure Nash equilibria and a mixed Nash equilibrium. The perfectly rational firm and perfectly rational union follow a mixed strategy so that they hold out occasionally to preserve credibility, even if both sides could see a better deal by jointly conceding. Hence, the union or the firm may choose to hold out even if the expected payoff from holding out or conceding in a mixed-strategy equilibrium is less than the payoff when both concede. This result is consistent with *Hicks (1963)*, who reached the conclusion that "the trade union leadership will embark on strikes occasionally, not so much to secure greater gains upon that occasion (which are not very likely to result) but in order to keep the weapon burnished…(p. 146)." In addition, this result links Hicks' concession curves to the *Zeuthen (1930)* bilateral monopoly model, by illustrating that even Hicks' concession curves can yield a bargaining model.

The results show that increasing strike costs in an asymmetric way can have ambiguous effects on strike probability. Increasing one side's strike costs decreases its incentive to strike. However, in response, the other side's incentive can increase, since under many circumstances it bargains harder to collect relatively larger expected rents. As such, the probability of a strike can rise even as joint strike costs increase. This result may account for the mixed success the joint cost strike model has in explaining strike activity. Although couched in terms of strike incidence, the results are equally applicable to other bargaining venues such as household divorce or the decision a country faces to go to war.

APPENDIX 1

In this Appendix we derive the signs for $\partial(1 - P_f^*)/\partial b$, $\partial(1 - P_f^*)/\partial c$, $\partial(1 - P_u^*)/\partial b$ and $\partial(1 - P_u^*)/\partial c$. Recall that the expression for the firm probability of conceding P_f^* was:

$$P_f^* = W_0^*/(W_0^* + W_r^* - W^*)$$

Where $W_0^* = (c\theta_1 + \theta_2 W_0)/(\theta_2 + c)$, $W_r^* = (\varphi_2 W_r + b\varphi_1)/(b + \varphi_2)$, and

$$W^* = (cW_r + bW_0)/(b + c)$$

Then,

$$\partial P_f^*/\partial b = -W_0^*(\Lambda + \Xi)/(W_0^* + W_r^* - W^*)^2,$$

where,

$$\Lambda = (W^* - W_0)/(b + c) \text{ and } \Xi = (\varphi_1 - W_r^*)/(b + \varphi_2)$$

Then,

$$\partial(1 - P_f^*)/\partial b = W_0^*(\Lambda + \Xi)/(W_0^* + W_r^* - W^*)^2 = D_1$$

Now, since $W^* > W_0$, $\Lambda > 0$ and since $\varphi_1 < W_r^*$, $\Xi < 0$. Because $\Lambda + \Xi = D1 \neq 0$, $\partial(1 - P_f^*)/\partial b \neq 0$. Hence, the effect of higher union costs on the firm's hold our probability is ambiguous.

We then derive the sign for $\partial P_f^*/\partial c$ (and $\partial[1 - P_f^*)/\partial c$).

$$\partial P_f^*/\partial c = -W_0^*(\Gamma + \Psi)/(W_0^* + W_r^* - W^*)^2 +$$
$$+ (\theta_1 - W_0^*)/[(\theta_2 + c)(W_0^* + W_r^* - W^*)]$$

where,

$$\Gamma = (W^* - W_r)/(b + c) \text{ and } \Psi = (\theta_1 - W_0^*)/(\theta_2 + c)$$

Then,

$$\partial(1 - P_f^*)/\partial c = W_0^*(\Gamma + \Psi)/(W_0^* + W_r^* - W^*)^2 +$$
$$+ (W_0^* - \theta_1)/[(\theta_2 + c)(W_0^* + W_r^* - W^*) =$$

$$= W_0^*\Gamma/(W_0^* + W_r^* - W^*)^2 +$$
$$+ [\Psi/(W_0^* + W_r^* - W^*)][W_0^*/(W_0^* + W_r^* - W^*) - 1] = D_2$$

Now, since $W^* < W_r$, $\Gamma < 0$ and hence the first term of $\partial(1 - P_f^*)/\partial c$ is negative. The second term is also negative since $[W0^*/(W0^* + Wr^* - W^*) - 1] < 0$ and $\Psi > 0$. Hence $\partial(1 - P_f^*)/\partial c < 0$, which implies that as firm strike costs increase, the firm's probability of holding out declines unambiguously.

Turning to the union, we can find how the union's hold out probability changes as union strike costs b and firm strike costs c change. Recall that the union's probability of conceding P_u^* was:

$$P_u^* = \Pi_{hc}/(\Pi_{hc} + \Pi_{ch} - \Pi_{cc})$$

Where $\Pi_{hc} = R(L_{hc}) – W_r^* L_{hc}$, $\Pi_{ch} = R(L_{ch}) – W_0^* L_{ch}$,

and $\Pi_{cc} = R(L_{cc})- W^* L_{cc}$.

Then,

$$\partial P_u^*/\partial b = -\Pi_{hc}(Z + \Sigma)/(\Pi_{hc} + \Pi_{ch} - \Pi_{cc})^2 +$$
$$+ L_{hc}(W_r^* - \varphi_1)/(b + \varphi_2)(\Pi_{hc} + \Pi_{ch} - \Pi_{cc})$$

where

$$Z = L_{cc}(W_0 – W^*)/(b + c) \text{ and } \Sigma = L_{hc}(W_r^* - \varphi_1)/(b + \varphi_2)$$

and hence,

$$\partial(1 – P_u^*)/\partial b = \Pi_{hc}(Z + \Sigma)/(\Pi_{hc} + \Pi_{ch} - \Pi_{cc})^2 +$$
$$+ L_{hc}(\varphi_1 – W_r^*)/(b + \varphi_2)(\Pi_{hc} + \Pi_{ch} - \Pi_{cc}) =$$
$$= \Pi_{hc}Z/(\Pi_{hc} + \Pi_{ch} - \Pi_{cc})2 +$$
$$+ [\Sigma/(\Pi_{hc} + \Pi_{ch} - \Pi_{cc})][\Pi_{hc}/(\Pi_{hc} + \Pi_{ch} - \Pi_{cc}) – 1] = D_3$$

Now, since $W_0 < W^*$, the sign of the first term of $\partial(1 – P_u^*)/\partial b$ is negative. But so is the sign of the second term, since $[\Pi_{hc}/(\Pi_{hc} + \Pi_{ch} - \Pi_{cc}) – 1] < 0$ and $\Sigma > 0$. Therefore, as the union strike costs b increase, the union's strike probability decreases unambiguously.

Lastly we look at the sign of $\partial(1 – P_u^*)/\partial c$. Now, since

$$\partial P_u^*/\partial c = -\Pi_{hc}(T + Y)/(\Pi_{hc} + \Pi_{ch} - \Pi_{cc})^2$$

then,

$$\partial(1 – P_u^*)/\partial c = \Pi_{hc}(T + Y)/(\Pi_{hc} + \Pi_{ch} - \Pi_{cc})^2 = D_4$$

where $T = L_{cc}(W_r – W^*)/(b + c)$ and $Y = L_{ch}(W_0 - \theta_1)/(\theta_2 + c)$.

Now, since $W_r > W^*$, $T > 0$, and since $W_0 < \theta_1$, $Y < 0$. Because $T + Y \neq 0$, $\partial(1 – P_u^*)\partial c <$ or > 0. Hence, the effect of higher firm costs c on the union's hold out probability is ambiguous.

APPENDIX 2

In this Appendix we derive the signs for $\partial[(1 - P_f^*)(1 - P_u^*)]/\partial b$ and $\partial[(1 - P_f^*)(1 - P_u^*)/\partial c$.

$$\partial P(\text{strike})/\partial b = (1 - P_f^*)[\partial(1 - P_u^*)/\partial b] + (1 - P_u^*)[\partial(1 - P_f^*)/\partial b] =$$
$$(1 - P_f^*)D_3 + (1 - P_u^*)D_1$$

where D_1 and D_3 are as defined and derived in Appendix 1. Now, $(1 - P_f^*) > 0$ and $D_3 < 0$ as we showed in Appendix 1. Hence $(1 - P_f^*)D_3 < 0$. On the other hand, $(1 - P_u^*) > 0$ and $D_1 \neq 0$ as was shown in Appendix 1. Hence $(1 - P_u^*)D_1 \neq 0$. Therefore, if the absolute value of $(\varphi_1 - W_r^*)/(b + \varphi_2)$ is greater than $(W^* - W_0)/(b + c)$, then $D_1 = \partial(1 - P_f^*)/\partial b < 0$, and the joint costs model holds unambiguously since $\partial P(\text{strike})/\partial b = (1 - P_f^*)D_3 + (1 - P_u^*)D_1 < 0$, which is what the joint costs model predicts.

However, if the absolute value of $(\varphi_1 - W_r^*)/(b + \varphi_2)$ is less than $(W^* - W_0)/(b + c)$, then $D_1 = \partial(1 - P_f^*)/\partial b > 0$, and hence $(1 - P_u^*)D_1 > 0$. Then, $\partial P(\text{strike})/\partial b = (1 - P_f^*)D_3 + (1 - P_u^*)D_1$ will depend on the relative magnitudes of $(1 - P_f^*)D_3$ and $(1 - P_u^*)D_1$. If $(1 - P_u^*)D_1$ exceeds the absolute value of $(1 - P_f^*)D_3$, then $\partial P(\text{strike})/\partial b > 0$ and a "paradox" is observed as it suggests that higher union strike costs b, holding firm strike costs c constant may actually increase the probability of a strike!

Next, we derive the sign for $\partial P(\text{strike})/\partial c$, or

$$\partial P(\text{strike})/\partial c = (1 - P_f^*)\partial(1 - P_u^*)/\partial c + (1 - P_u^*)\partial(1 - P_f^*)/\partial c =$$
$$= (1 - P_f^*)D_4 + (1 - P_u^*)D_2$$

where D_2 and D_4 are as defined and derived in Appendix 1. Now, $(1 - P_u^*) > 0$ and $D_2 < 0$ as was shown in Appendix 1. Hence $(1 - P_u^*)D_2 < 0$. On the other hand, $(1 - P_f^*) > 0$ and $D_4 \neq 0$ as was also shown in Appendix 1. Hence $(1 - P_f^*)D_4 \neq 0$. Therefore, if the absolute value of $L_{ch}(W_0 - \theta_1)/(\theta_2 + c)$ is greater than $L_{cc}(W_r - W^*)/(b + c)$, then $D_4 = \partial(1 - P_u^*)/\partial c < 0$, and the joint costs model holds unambiguously since $\partial P(\text{strike})/\partial c = (1 - P_f^*)D_4 + (1 - P_u^*)D_2 < 0$, which is what the joint costs model predicts.

However, if the absolute value of $L_{ch}(W_0 - \theta_1)/(\theta_2 + c)$ is less than $L_{cc}(W_r - W^*)/(b + c)$, then $D_4 = \partial(1 - P_u^*)/\partial c > 0$, and hence $(1 - P_f^*)D_4 > 0$. Then $\partial P(\text{strike})/\partial c = (1 - P_f^*)D_4 + (1 - P_u^*)D_2$ will depend on the relative magnitudes of $(1 - P_f^*)D_4$ and $(1 - P_u^*)D_2$. If $(1 - P_f^*)D_4$ exceeds the absolute value of $(1 - P_u^*)D_2$, then $\partial P(\text{strike})/\partial c > 0$ and a "paradox" is observed as it suggests that higher firm strike costs c, holding union costs b constant, may actually increase the probability of a strike!

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Figure 1

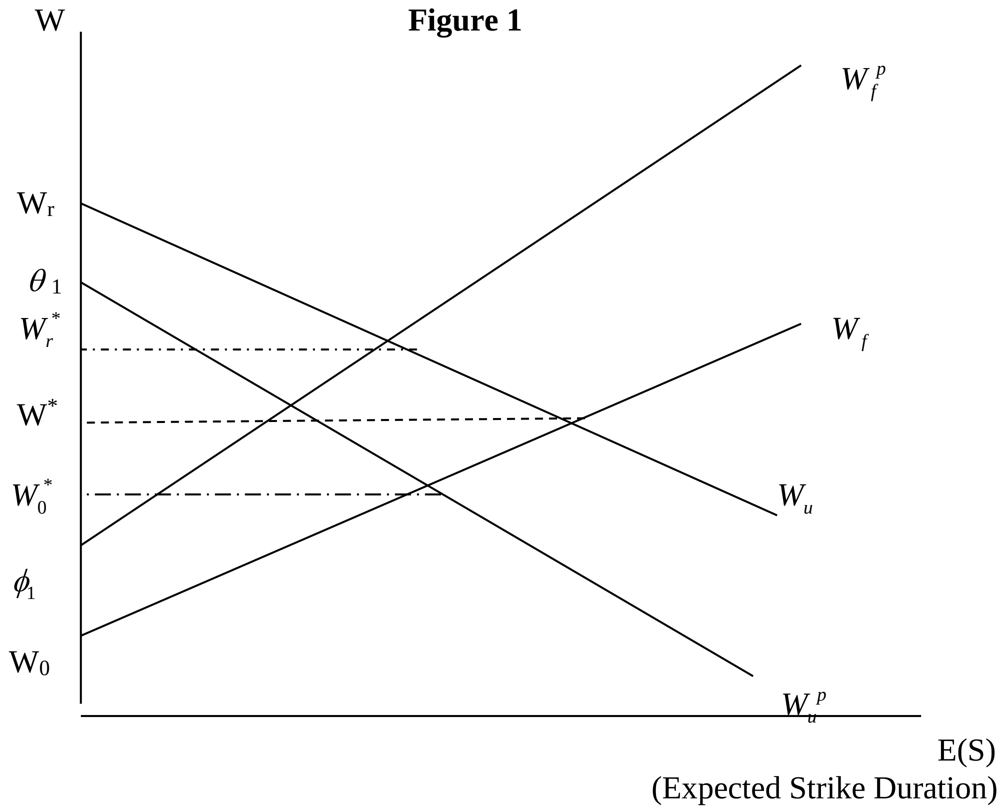
W
W_f^p
W_r
θ_1
W_r^*
W_f
W^*
W_0^*
W_u
ϕ_1
W_0
W_u^p
E(S)
(Expected Strike Duration)

Figure 2

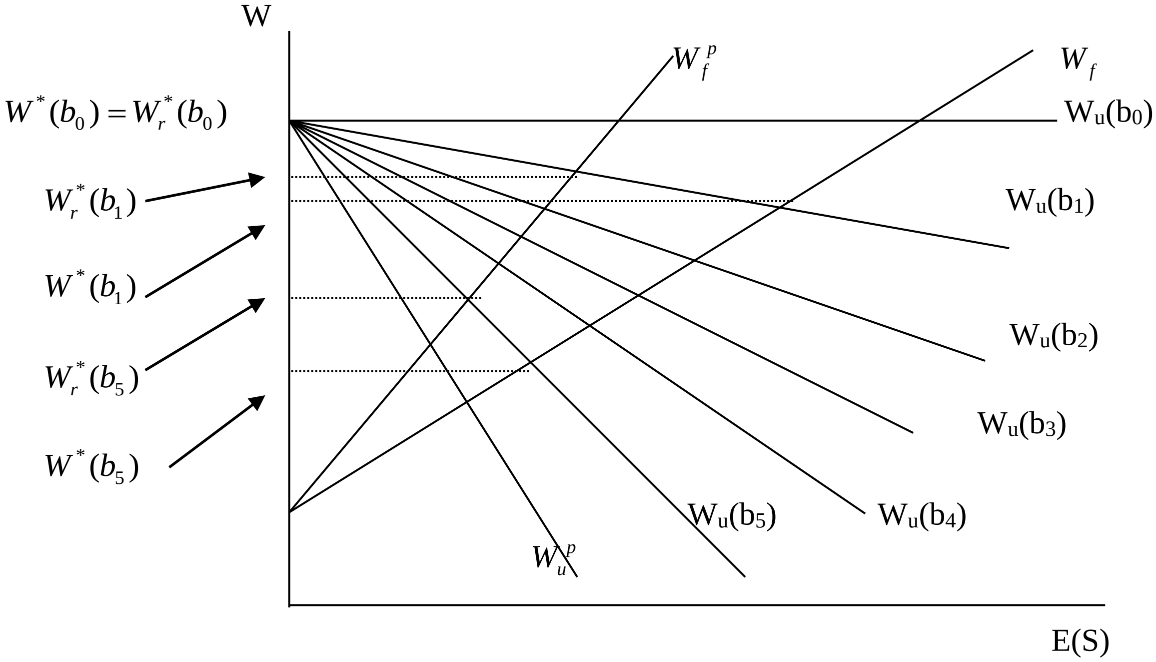

Figure 3

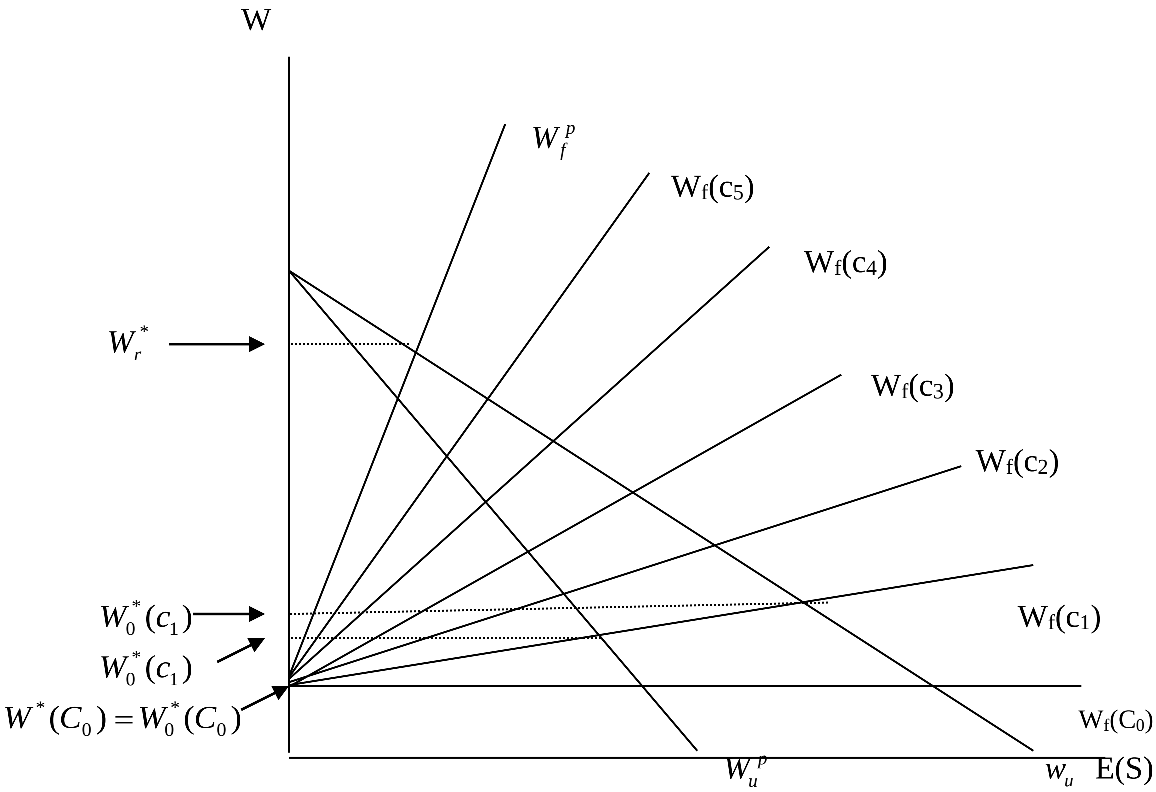

Table 2

The Impact of Changing Costs on Hold Out and Strike Probabilities

Changing Union Strike Costs[16] Changing Firm Strike Costs[17]

Union strike costs (b)	Firm Holdout Prob. $(1-P_f^*)$	Union Holdout Prob. $(1-P_u^*)$	Strike Prob. P(str)		Firm Strike Costs (c)	Firm holdout prob. $(1-P_f^*)$	Union Holdout Prob. $(1-P_u^*)$	Strike Prob. P(str)
0	0	0.35	0		0	0.37	0	0
0.1	0.01	0.34	0.003		0.1	0.36	0.02	0.006
0.2	0.02	0.34	0.01		0.2	0.36	0.03	0.01
0.5	0.04	0.33	0.015		0.5	0.34	0.07	0.02
1.0	0.08	0.31	0.02		1.0	0.32	0.11	0.04
1.5	0.10	0.30	0.03		1.5	0.29	0.14	0.04
2.0	0.12	0.28	0.04		2.0	0.27	0.16	0.04
3.0	0.15	0.26	0.04		3.0	0.24	0.19	0.05
4.0	0.17	0.23	0.04		5.0	0.19	0.21	0.04
5.0	0.18	0.21	0.04		10.0	0.11	0.22	0.02
10.0	0.21	0.13	0.03		15.0	0.06	0.21	0.01
15.0	0.22	0.09	0.02		20.0	0.04	0.20	0.007
20.0	0.21	0.05	0.01		25.0	0.02	0.18	0.004
23.0	0.21	0.04	0.008		28.0	0.01	0.178	0.002
25.0	0.207	0.03	0.006		30.0	0.007	0.174	0.001
28.0	0.203	0.02	0.004		31.0	0.006	0.172	0.001
30.0	0.20	0.01	0.002		33.0	0.002	0.168	0.0003
32.0	0.197	0.005	0.0001		34.0	0	0.166	0

[16] The additional parameters are $W_0 = 15$, $\varphi_1 = 16$, $\varphi_2 = 30$, $W_r = 25$, $\theta_1 = 24$, $\theta_2 = 30$, and $c = 5$.
[17] The additional parameters are: $W_0 = 15$, $\varphi_1 = 16$, $\varphi_2 = 30$, $W_r = 25$, $\theta_1 = 24$, $\theta_2 = 30$, and $b = 5$.

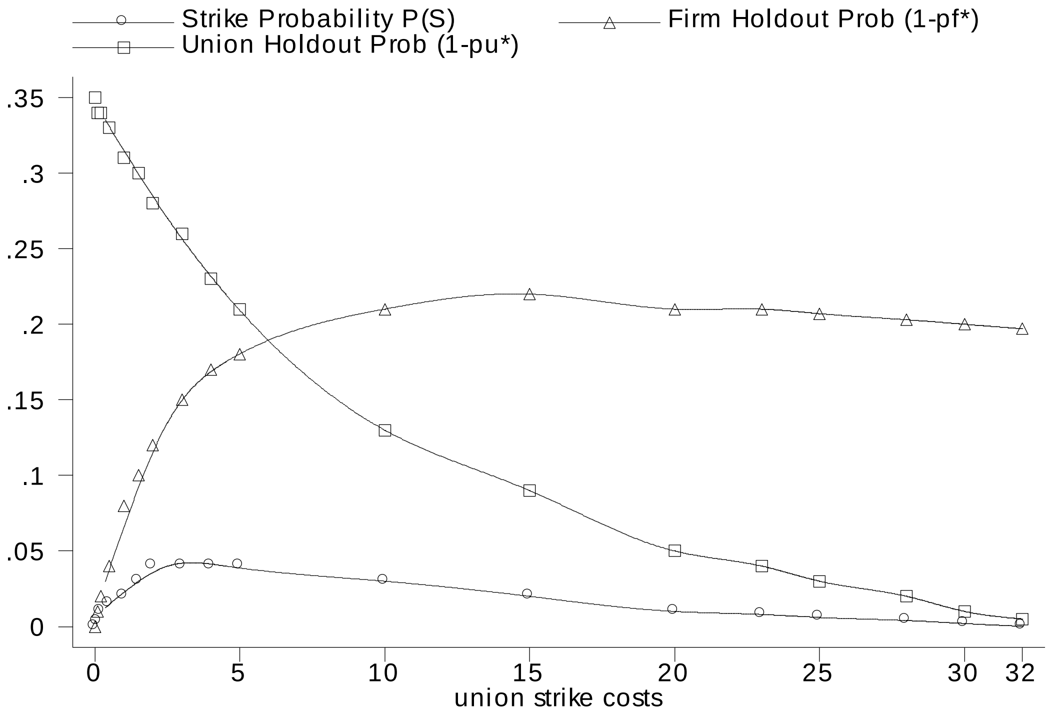

Figure 4

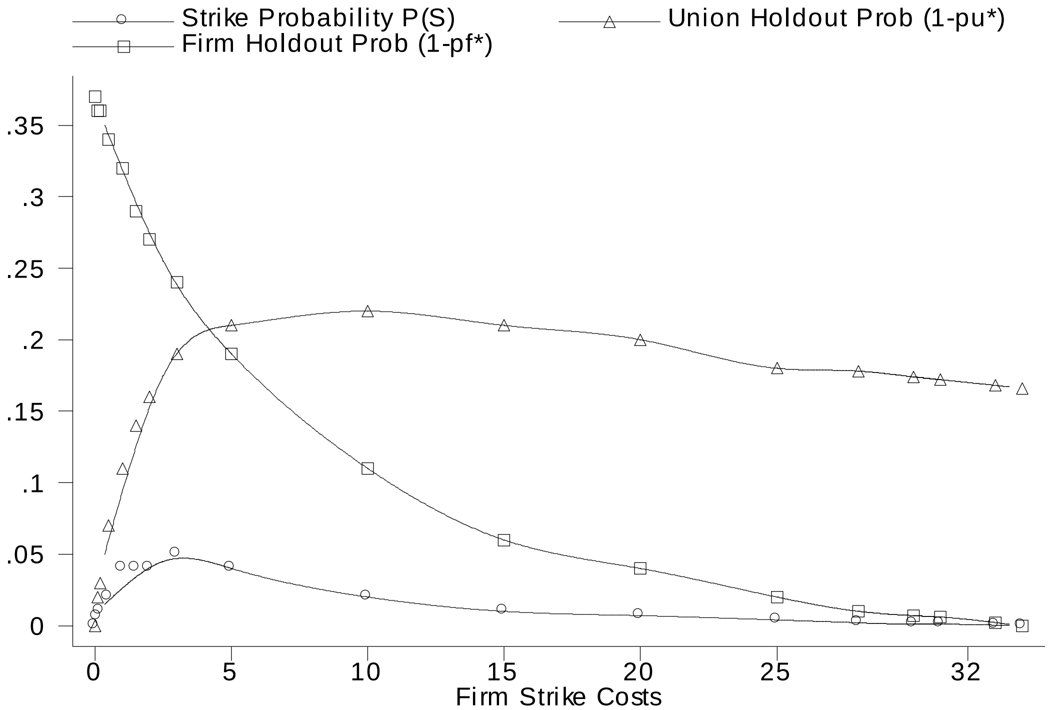

Figure 5