UNION-FIRM BARGAINING AS A REPEATED PRISONER'S DILEMMA *

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1. Introduction

In ordinary discussions it seems quite natural to refer to labour relations as 'good' or 'bad'. The attitude of unions is described as 'obstructive' or 'constructive'; union leaders are 'moderate' or 'militant'. Management is 'progressive' or 'nineteenth century'. These dichotomies have their parallel in economic theory. On the one hand there is the monopoly union model, in which the union fixes the wage and the firm (or firms) picks the corresponding point on the labour demand curve. On the other hand, there is the efficient bargain model in which the union and the firm jointly select a point on the contract curve (by definition the set of Pareto optimal outcomes).

As Leontief (1946) pointed out, the outcome in the monopoly model is not efficient - both parties could be made better off. Though this is widely taken to be a criticism, it means that the monopoly model does correspond to the popular perception of one possible outcome of union-management bargaining. Those who believe that an acceptable outcome must be Pareto optimal will prefer the efficient bargain model. But this in turn can be criticised on the grounds of indeterminacy - the outcome could be at any point on the contract curve. This difficulty is sometimes overcome by assuming a Nash bargaining solution. However, the Nash bargain is (in game theory terminology) a cooperative solution whereas union-firm bargaining is a noncooperative game - it is not possible to make binding commitments in advance. So invoking a Nash bargain without specifying a mechanism by which this can be achieved looks like assuming away the problem.

Our argument in this paper is that union-firm bargaining can be modelled as a Prisoner's Dilemma. The efficient bargain model corresponds to one possible strategy pair in the Prisoner's Dilemma, namely where both cooperate.
and the monopoly model to another, where both defect. As is well known, in a
Prisoner's Dilemma played once the only Nash equilibrium is noncooperation, but
if the game is repeated indefinitely often this is no longer necessarily so.

The plan of the paper is as follows. Section 2 sets out the model and
discusses the monopoly and the efficient bargain solutions. Section 3
demonstrates that these correspond to the strategies in a Prisoner's Dilemma.
In section 4 we analyse the supergame consisting of an infinite repetition of
the Prisoner's Dilemma. We show that the union can, if certain conditions are
satisfied, enforce a particular cooperative solution by adopting a Tit-for-tat
strategy. Thus the indeterminacy in the efficient bargain model can be
resolved. Section 5 illustrates the argument with a numerical example.

2. The Union and the Firm

The model we develop follows closely the approach of McDonald and Solow
(1981). A single firm faces a single union which monopolises the supply of
labour. The union, which seeks to maximise a utility function, sets the wage
and the firm which seeks to maximise its profits must then decide, knowing the
wage, how much labour to employ. The relationship between the parties may be
either noncooperative or cooperative. If it is noncooperative the firm
maximises profits subject to the union-determined wage and the union, knowing
this, sets the wage accordingly. If it is cooperative, the parties will try to
reach an efficient bargain, one which puts them somewhere on the utility-profit
frontier.

The union, which is interested in both the wage and the employment level
of its members, will be assumed to maximise a utility function given by
(following Oswald, 1982 and others):

\[ U = \frac{L}{M}u(w) + (1 - \frac{L}{M})u(s) \quad u'(.) > 0, u''(.) \leq 0 \]  (1)
where $L$ is employment, $M$ is the (fixed) union membership, $w$ the wage paid by the firm and $s$ the reservation wage (perhaps social security benefits). One way to justify this form is to refer to the case where the union wishes to maximise the expected utility of the typical (risk averse or risk neutral) union member, assuming that the latter faces a probability of being employed by the firm equal to $L/M$.\(^4\) Such a utility function gives rise to union indifference curves in $(L,w)$ space which are strictly convex and along such curves $w \to s^+$ as $L \to -\infty$ and $w \to -\infty$ as $L \to 0$ (see Figure 1).

The firm is assumed to produce a single output by means of two inputs, labour $(L)$ and capital $(K)$. It can purchase as much of these inputs as it wishes at the going input prices ($w$ for labour and $r$ for capital). It faces a revenue function $R(L,K)$ which is assumed to be strictly concave in the inputs, either because it faces a downward sloping demand curve for its output or because of diminishing returns to scale in production. The firm's profits ($\Pi$) are then given by

$$\Pi = R(L,K) - wL - rK$$

$$R_L > 0, \quad R_K > 0, \quad R_{LL} < 0, \quad R_{KK} < 0,$$

$$R_{LL}R_{KK} - R_{LK}^2 > 0$$

(2)

where $R_L, R_K, \text{ etc.}$ represent partial derivatives. From (2) we can derive isoprofit lines in $(L,w)$ space which will be strictly concave as shown in Figure 1. The lower the curve, the higher the level of profit.

Two possible scenarios for the firm will be considered: first, noncooperation (profit maximisation subject to the union wage) and second, cooperation, with the union (utility maximisation subject to a profit constraint).
2.2 Noncooperation

Since profits are a strictly concave function of the inputs \( L \) and \( K \) the following familiar conditions are necessary and sufficient for an interior maximum:

\[
\frac{\partial \Pi}{\partial L} = R_L - w = 0 \\
\frac{\partial \Pi}{\partial K} = R_K - r = 0
\]  
(3)

These equations implicitly define the input demand functions

\[
L_N = L_N(w) \\
K_N = K_N(w)
\]  
(4)

where the dependence on \( r \) has been suppressed as \( r \) will be kept fixed throughout the paper. Total differentiation of (3) will show, amongst other familiar facts, that the labour demand curve slopes down. The labour demand curve is depicted in Figure 1 and it is elementary to show that it passes through the \( w \)-maximum points of each isoprofit line. We can also define the maximum profit function

\[
\Pi_N = \Pi_N(w)
\]  
(5)

by substituting (4) into (2). By duality,

\[
\frac{\partial \Pi_N}{\partial w} = -L_N < 0
\]

and

\[
\frac{\partial^2 \Pi_N}{\partial w^2} > 0.
\]  
(6)

If the union does not wish to cooperate and knows that the firm does not wish to either, so that the firm operates on its demand curve for labour, then the union's problem is to maximise the utility attainable in these circumstances. Defining \( U_N \) as the result of this maximisation, we have:

\[
U_N = \max \{ L_N(w)u(w)/M + (1 - L_N(w)/M)u(s) \}.
\]

The first order condition for a maximum is:

\[
\frac{\partial U_N}{\partial w} = -u'(w)L_N/(u(w) - u(s)).
\]  
(7)
Geometrically this corresponds to the tangency of the labour demand curve with the highest attainable union indifference curve (point T in Figure 1). Equation (7) implicitly defines a wage level \( w_N \), which is the union's optimal choice, given noncooperation on both sides. Note that (7) implies \( w_N > s \).

### 2.3 Cooperation

The noncooperative outcome is inefficient – both parties could gain by moving to a point like S in Figure 1, where an indifference curve is tangent to an isoprofit line. Formally, the cooperative outcomes are solutions to the following problem:

\[
\begin{align*}
\text{max} & \quad U \\
\text{w, } L, K \\
\text{subject to} & \quad R(L,K) - wL - rK = \Pi_0 \text{ where } \Pi_0 \text{ is a non-negative constant.}^{6}
\end{align*}
\]

The first order conditions, which are necessary and sufficient here for an interior maximum, are

\[
\begin{align*}
w: \quad & Lu'(w)/M - \lambda L = 0 \\
L: \quad & (u(w) - u(s))/M + \lambda (R_L - w) = 0 \\
K: \quad & R_K - r = 0
\end{align*}
\]

where \( \lambda \) is a Lagrangean multiplier. Eliminating \( \lambda \), there results

\[
\begin{align*}
R_L - w &= - (u(w) - u(s))/u'(w) \quad (8) \\
R_K - r &= 0 \quad (9)
\end{align*}
\]

For each \( \Pi_0 \), due to the strict concavity of the revenue and utility functions, there is a unique solution to the maximisation problem in \( w, L, \) and \( K \). Using that the indifference curves are asymptotic to a horizontal line at \( s \) (see Figure 1), as \( \Pi_0 \) varies we obtain a set of cooperative solutions \( (w, L, K) \) all satisfying \( w > s \). Hence (8) and (9) show that at any such solution the marginal revenue product of capital is equal to the rental on capital but the marginal revenue product of labour is less than the wage.
Denote the cooperative wage $w_C$ and consider the effect of changing $w_C$ on the cooperative level of employment, denoted $L_C(w_C)$. By totally differentiating (8) and (9):

$$
\frac{dL_C(w_C)}{dw_C} = u''(w_C)R_{KK}(u(w_C) - u(s))/u''(w_C)\{R_{LL}R_{KK} - R_{LK}^2\}
$$

$$
\geq 0
$$

(10)

and

$$
\frac{dL_C(w_C)}{dw_C} = 0 \text{ if and only if } u''(w_C) = 0
$$

The contract curve, the locus of points at which (8) and (9) are satisfied, is therefore non-negatively sloped in $(L,w)$ space, as illustrated by the curve labelled $CC'$ in Figure 1.

Cooperative profits are also a function of the cooperative wage, written $\Pi_C(w_C)$. Using (2),

$$
\frac{d\Pi_C(w_C)}{dw_C} = (R_L - w_C)dL_C/dw_C - L_C < 0.
$$

(11)

Similarly, we can consider utility under a cooperative framework as a function of the cooperative wage, $U_C(w_C)$. Using (1),

$$
\frac{dU_C(w_C)}{dw_C} = L_Cu''(w_C)/M + (dL_C/dw_C)(u(w_C) - u(s))/M > 0.
$$

(12)

Equations (11) and (12) show that the utility-profit frontier is negatively sloped throughout.

So far nothing excludes the possibility that $U_C(w_C) < U_N(w_N)$. i.e. cooperation does not pay for the union or that $U_C(w_C) < U_N(w_N)$, cooperation does not pay for the firm. However, that there exists $w_C$ such that both parties are better off than under noncooperation is easily proved. Consider Figure 1 again. Starting from point T and moving down along the indifference curve which passes through T profits necessarily increase, at least initially. Alternatively by moving down the isoprofit line through T utility necessarily
rises, at least initially. Therefore by continuity there exists \( w_C < w_N \), such that \( U_C(w_C) > U_N(w_N) \) and \( \Pi_C(w_C) > \Pi_N(w_N) \).

Comparing the cooperative with the noncooperative outcome we may remark that employment is lower in the latter. To see this, first note that \( L_C(w) \leq L_N(w) \) since if not we could raise both profits and utility by holding \( w \) constant and increasing \( L \) above the cooperative level, contrary to the Pareto optimality of the latter. Since \( w_C < w_N \), \( L_C(w_C) > L_N(w_N) \). However, whether the capital stock is higher or lower under cooperation is uncertain. The lower wage gives an incentive to raise output thus tending to increase the capital stock but also an incentive to substitute labour for capital.

### 2.4 A special case

Later on we shall make use of the special case where the union membership is risk neutral. Here \( u''(w) = 0 \) and the utility function can be written \( u(w) = w \), so (8) becomes

\[
R_L = s. 
\]  
(Equation (9) is unchanged). In other words under cooperation the firm behaves as if it faced a wage level equal to \( s \) and maximised accordingly. As noted earlier \( dL_C/dw_C = 0 \) in this case and it is also true that capital (and consequently output and price) is independent of the wage.

Under non-cooperation, we can solve (7) for the optimal wage:

\[
w_N = \frac{sE_{Lw}}{E_{Lw} + 1} \tag{14} 
\]

where \( E_{Lw} = \frac{w_L}{L_N} (L_N/w) \), the elasticity of the firm's demand for labour.
3. Strategies in the one-shot game

In this section we imagine that the union-firm bargaining game is played once only. The players can communicate but no binding commitments are possible. Each player has two possible strategies - Cooperation (C) or Noncooperation (N). The payoffs to the players (U or H) can be summarised in the following matrix:

<table>
<thead>
<tr>
<th>Firm's Strategies</th>
<th>C</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Union's Strategies</td>
<td>C</td>
<td>U^{CC}, \Pi^{CC}(S)</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>U^{NC}, \Pi^{NC}(R)</td>
</tr>
</tbody>
</table>

Here the first superscript indicates the union's strategy, the second the firm's. The letter in brackets in each cell denotes the point in Figure 2 to which each cell corresponds.

In terms of the notation developed in the preceding section,

\[ U^{CC} = U_C(w_C), \Pi^{CC} = \Pi_C(w_C), \]

\[ U^{CN} = U_N(w_C), \Pi^{CN} = \Pi_N(w_C), \]

\[ U^{NC} = U_C(w_N), \Pi^{NC} = \Pi_C(w_N) \]

and \[ U^{NN} = U_N(w_N), \Pi^{NN} = \Pi_N(w_N) . \]

For example, \( U^{NC} \) means the payoff to the union from setting \( w = w_N \) when the firm cooperates by setting \( L = L_C(w_N) \); \( \Pi^{CN} \) means the payoff to the firm from maximising profits by setting \( L = L_N(w_C) \).

We can now establish:
Proposition 1. In the one-shot game where each player has two strategies, N and C, the payoffs have the form of the Prisoner's Dilemma, that is,
\[ u^{NC} > u^{CC} > u^{NN} > u^{CN} \]
and
\[ n^{CN} > n^{CC} > n^{NN} > n^{NC}. \]

Proof. (i) In the previous section it was proved that there exists \( w_C \) such that
\[ u^{CC} > u^{NN} \]
and \( n^{CC} > n^{NN}. \)
(ii) \( u^{NC} > u^{CC} \) since \( w_N > w_C \) and, from (10), \( L_C(w_N) > L_C(w_C). \) \(^7\)
(iii) \( n^{NN} > n^{NC} \) and \( u^{NN} > u^{CN} \) by definition of an optimum and since \( w_C < w_N. \)
(iv) \( n^{CN} > n^{CC} \) since for a given wage profits are maximised when the firm is on its labour demand curve. This completes the proof, which is illustrated in Figure 2.

Technically the one shot game is not identical to the standard form of the Prisoner’s Dilemma since in the latter the players are assumed to move simultaneously. Here the union moves first and must so to speak declare its hand before the firm needs to do so. However this slight difference in structure has no effect on the solution of the one-shot game. It is immediately apparent that the only Nash equilibrium is where both players play N. So if the game is played only once by rational players the outcome is Pareto sub-optimal. \(^8\)

This argument assumes that only one cooperative wage level is available to the union. But clearly nothing is changed by allowing the union the full range of cooperative wages. It still does not pay the union to cooperate and so the only Nash equilibrium is again with both players playing N.

The reason for assuming throughout this paper that the union moves first can now be discussed. Suppose to the contrary that the union makes its wage demand and the firm its employment offer simultaneously. Suppose that the particular (L,w) pair selected does not lie on the firm’s demand curve. Then
given the union’s choice of \( w \), the firm will regret its choice of \( L \). Whether or not the \((L, w)\) pair lies on the demand curve the union will, with one exception, regret ex post its choice of \( w \) (given the firm’s choice of \( L \)) since utility is increasing in \( w \). The exception arises if we assume that the firm is not forced to operate at a loss, so that it has the option of withdrawing its employment offer if the wage demanded is too high to allow the firm to at least break even. The only possible Nash equilibrium is then at a high wage and zero employment — not a very sensible solution. Though this argument goes some way to justify the "union moves first" assumption there are clearly other possibilities, e.g. both parties make a wage-employment offer simultaneously, which we plan to explore in future work.

4. The Repeated Game

4.1 Approaches to the Repeated Prisoner’s Dilemma

It has long been known that a cooperative outcome which is impossible in a one-shot game may be achievable if the game is repeated. For repetition enables one party to threaten another with punishment for deviating from the cooperative strategy.\(^9\) Recent work suggests several ways in which cooperation might develop in the Prisoner’s Dilemma and has drawn attention in particular to the role of Tit-for-tat as a strategy likely to induce cooperation in the opponent. By Tit-for-tat is meant a strategy of playing C on the first move and then copying whatever the opponent did on his previous move. Firstly, Kreps et al (1982) and Kreps and Wilson (1982) have shown that if one player believes (falsely) that there is a non-zero probability that the other has adopted Tit-for-tat then even if there is only a finite repetition of the game it will pay both players to play C “most” of the time. (See also Radner,1979). Since Tit-for-tat is not a "rational" strategy in a finitely repeated Prisoner’s Dilemma, this conclusion
relies on assuming that it is sensible to believe that your opponent may be "irrational".

Secondly, Smale (1980) has shown that if there is infinite repetition of the game and the players are concerned with their average payoffs then there is a class of strategies called "good" strategies, of which Tit-for-tat is a member, such that (a) a "good" strategy forms a Nash equilibrium strategy pair with itself and (b) the average payoff converges to the cooperative payoff.

Thirdly Axelrod (1981), assuming that players wish to maximise the present value of their payoffs in an infinitely repeated game, has shown (a) that Tit-for-tat played against itself is a Nash equilibrium pair and (b) if strategies evolved in accordance with natural selection then evolution would favour Tit-for-tat as against pure non-cooperation ("All N"), which also forms a Nash equilibrium strategy pair with itself. The reason for the latter result is that Tit-for-tat is almost as good as All N when played against All N but much better against Tit-for-tat. So if a small group of organisms playing Tit-for-tat surrounded by a larger group playing All N compete against one other at random, then those playing Tit-for-tat will prosper at the expense of the others. In a quite different framework a related result is given by Blad (1986). Here a continuous time dynamics is used to describe the evolution of the distribution of players over strategies in a repeated Prisoner's Dilemma game. It is shown that for the natural "stabilised" game a Tit-for-tat type of cooperative strategy is the unique, locally stable, Nash solution, and this result is robust in the sense that small perturbations of the game's payoff matrix do not lead to qualitative changes in the evolution of the game. These are significant results since basic hypotheses about economic behaviour such as profit maximisation have often been justified on evolutionary grounds (e.g. Alchian, 1950).
Fourthly, there is empirical evidence for the success of Tit-for-tat. Rapoport et al (1976) found that when people played against a player programmed to play Tit-for-tat in long repetitions of the Prisoner's Dilemma Tit-for-tat was successful in inducing cooperation. Axelrod (1981 and 1984) invited entries from experts to a computer tournament of strategies. Against highly complex and ingenious opponents the winner was consistently Tit-for-tat.

4.2 Analysis of the Infinitely Repeated Game

Suppose that the game analysed in Section 3 is repeated infinitely often. In the light of the arguments of Axelrod and others just discussed we will consider Tit-for-tat as a candidate strategy for the union. Tit-for-tat by the union means that on its first move the union sets $w < w_n$ and continues to do so if the firm cooperates. If the firm does not cooperate, then the union sets $w = w_n$. If on some subsequent move the firm cooperates then the union on its next move reverts to cooperation too. However, such a strategy is not fully specified since as we have already seen the cooperative wage is not unique. The higher the wage, the better for the union, provided the firm cooperates. But if the wage is pushed too high the firm will cease to find it worthwhile to cooperate. This suggests that from the union's point of view there may be an optimal cooperative wage. The purpose of the discussion which follows is to characterise this optimal wage.

Consider now the firm's optimal response, given that the union is playing Tit-for-tat. Only pure strategies need to be considered since the game is one of perfect information. There are two possibilities: either the firm also plays Tit-for-tat (in which case the outcome will always be cooperation) or the firm attempts to exploit the union. In the latter case, the firm will play $N$ on the first play, receiving $R^{CN}$, then will play $N$ for a further $m$ times ($m = 0, 1,$
... receiving \( \Pi^{NN} \) on each turn and then will play C, receiving \( \Pi^{NC} \). On the next round, the union will play C again and the players are back in the same situation as after the union's first move. The sequence of payoffs to the firm is then as follows:

\[
\Pi^{CN}, \Pi^{NN}, \ldots, \Pi^{NN}, \Pi^{NC}, \ldots
\]

\[\text{m times}\]

It is easy to see that the only strategies for the firm which need to be considered are those which consist of repetitions of the same \( m + 2 \) plays, for if it is optimal to play a particular sequence of moves once against Tit-for-tat, then it is optimal to repeat the sequence, since the game essentially "restarts" after the firm eventually plays C.

We assume that both players wish to maximise the present value of their payoffs. Let the discount factor be \( \delta \), \( 0 < \delta < 1 \). The discount factor can be interpreted either as a pure rate of time discount or as the probability that the game is in fact repeated. In the latter case the players are maximising expected utility or expected profits.

Let \( J_N(m) \) be the present value of the firm's profits under a noncooperative approach:

\[
J_N(m) = \Pi^{CN} + \delta \Pi^{NN} (1 + \delta + \ldots + \delta^{m-1}) + \delta^{m+1} \Pi^{NC} + \delta^{m+2} J_N(m)
\]

\[m = 0, 1, \ldots\]

(15)

The two extreme cases are

\[
J_N(0) = \Pi^{CN} + \delta \Pi^{NC} + \delta^2 J_N(0)
\]

\[= (\Pi^{CN} + \delta \Pi^{NC})/(1 - \delta^2)\]

(16)

and

\[
J_N(\infty) = \Pi^{CN} + \delta \Pi^{NN} (1 + \delta + \delta^2 + \ldots)
\]

\[= \Pi^{CN} + \delta \Pi^{NN}/(1 - \delta).\]

(17)
The present value of a cooperative approach is
\[ J_C = h^{CC}(1 + \delta + \delta^2 + \ldots) = h^{CC}/(1 - \delta) \] (18)
and we can also define the minimum present value which the firm can obtain from
the union, given its outside option, as
\[ J_{\min} = h^{NN}/(1 - \delta). \] (19)

The union is interested in picking the maximum level of \( w \) which still
ensures that \( J_C \geq J_N(m) \), all \( m \), so that it (just) pays the firm to cooperate.
In addition, for cooperation to be worthwhile for the union, it is necessary
that
\[ U_C(w_C) \geq U_N(w_N). \]

In order to characterise the union's optimal \( w \) under Tit-for-tat (if it
exists), consider the gain (or loss) to the firm from one extra play of \( N, J_N(h + 1) - J_N(h) \). From (15),
\[ J_N(h + 1) - J_N(h) = h^{+1}(1 - \delta)(1 + \delta)h^{NN} - h^{CN} - h^{NC}/(1 - \delta^{+1})(1 - \delta^{+3}) \]
\[ h = 0, 1, \ldots \]
which is positive if the expression in square brackets is positive. Since this
expression does not depend on \( h \), it follows that if
\[ (1 + \delta)h^{NN} - h^{CN} - h^{NC} > 0 \]
then the best noncooperative policy is to play C followed by N forever, to
achieve a present value of \( J_N(\infty) \). If the inequality is reversed, i.e. if
\[ (1 + \delta)h^{NN} - h^{CN} - h^{NC} < 0, \]
then the maximum possible non-cooperative payoff is \( J_N(0) \). (In the intermediate
case where this expression is zero, the firm would be indifferent about the
value of \( m \)).
So there are two possible cases to consider, each characterised by a pair of inequalities:

**Case A**

\[
J_N(0) \leq J_N(\alpha) \leq J_C \quad \text{which implies}
\]

A(i): 
\[
(1 + \delta)\pi^{NN} - \delta \pi^{CN} - \pi^{NC} \geq 0
\]

and A(ii): 
\[
\pi^{CN} \leq (\pi^{CC} - \delta \pi^{NN})/(1 - \delta)
\]

from (17) and (18).

**Case B**

\[
J_N(\alpha) \leq J_N(0) \leq J_C \quad \text{which implies}
\]

B(i): 
\[
(1 + \delta)\pi^{NN} - \delta \pi^{CN} - \pi^{NC} \leq 0
\]

and B(ii): 
\[
\pi^{CN} \leq \pi^{CC}(1 + \delta) - \delta \pi^{NC}
\]

from (16) and (18).

Since \(\pi^{NN}\) and \(\pi^{NC}\) are constants, these constraints may be considered as defining linear boundaries in \((\pi^{CN}, \pi^{CC})\) space on or within which any cooperative solution must lie. These boundaries are plotted in figures 3(i) and 3(ii). Note that the slopes of A(ii) and B(ii) exceed one. Now from (6) and (11) \(\pi^{CN}\) and \(\pi^{CC}\) are both monotonically decreasing functions of \(w\); hence we can write \(\pi^{CN} = g(\pi^{CC})\), \(g' > 0\), and this function is also plotted in Figures 3(i) and 3(ii). It is straightforward to show that \(g' \leq 1\), so that the slope of this schedule is flatter than those of A(ii) and B(ii), and since \(\pi^{CN} \geq \pi^{CC}\), it has a positive intercept with the vertical axis.\(^{13}\) It follows that the optimal solution (point 5), which always exists, is a point where either condition A(ii) or condition B(ii) is satisfied as an equality, since it is a point where either \(J_N(\alpha) = J_C\) (Case A) or \(J_N(0) = J_C\) (Case B). At such a point the minimum level of \(\pi^{CN}\) and \(\pi^{CC}\) (and consequently the maximum feasible level of \(w\)) is found.
We define the optimal cooperative wage \( w^* \) as the maximum wage satisfying either A(i) and A(ii) or B(i) and B(ii). However, cooperation may not be the best choice for the union --- noncooperation might be better, in which case we would have \( U_C(w^*) < U_N(w_N) \). To understand how that case might arise, note that the position of the constraints is determined in part by \( \delta \), the discount factor. A reduction in \( \delta \) shifts the A(ii) and B(ii) schedules to the right, causing any intersection with \( g(\cdot) \) to take place at a higher level of both \( n^{CN} \) and \( n^{CC} \) and hence at a lower wage level.\(^{14}\) So the lower is the discount factor (the higher the discount rate) the less the chance that cooperation is the union's best policy.

We can now establish

**Proposition 2.** \(^{15}\) \( w^* \) as defined above exists. If \( U_C(w^*) \geq U_N(w_N) \) then the following strategies form a Nash equilibrium pair in the infinitely repeated game:

(i) The union sets \( w = w^* \) on its first move. On subsequent moves it continues to set \( w = w^* \) if the firm selected \( L \geq L_C(w^*) \) on the previous move. If the firm selected \( L < L_C(w^*) \) on the previous move, the union sets \( w = w_N \).

(ii) If \( w \leq w^* \), the firm sets \( L = L_C(w) \). If \( w > w^* \), the firm sets \( L = L_N(w) \).

**Proof:** We proved above that \( w^* \) exists. If both parties play these strategies the outcome will be \( U_C(w^*) \) and \( U_N(w^*) \) in each period. If the union deviates and sets \( w < w^* \) it will obtain \( U_C(w) < U_C(w^*) \) in each period. If it sets \( w > w^* \) it will obtain \( U_N(w) < U_C(w^*) \) in each period. So it does not pay the union to deviate. We have already constructed \( w^* \) so that the firm's strategy is the best reply to the union's. Hence the two strategies form a Nash equilibrium pair.
Since there are many Nash equilibria, e.g. both players playing "All N" is another, it is worth asking whether Tit-for-tat can meet stronger requirements. Some of the work cited above is relevant here, for example as already noted Blad (1986) finds that Tit-for-tat is stable under perturbations of the payoffs. The perfect equilibrium concept considers another type of stability, namely stability under perturbations of the strategies (Selten, 1975). Actually, Tit-for-tat is not a sub-game perfect (equivalent here to perfect) equilibrium. For consider what would occur if each plays Tit-for-tat, but the firm makes a "mistake" on the third move:

```
punish
Union: C C C N N N N ...
Firm:  C C N N N N N ...
```

As illustrated, after the "mistake" each continues with Tit-for-tat, with the union carrying out its threat to punish the firm for noncooperation. The two parties never succeed in reestablishing cooperation. But if the union decided to "forgive" the firm for its "mistake" there would result:

```
forgive
Union: C C C C C C C C ...
Firm:  C C N C C C C C ...
```

The present value of the union's payoffs after the "mistake" will be higher if the union does not retaliate. Of course, "forgiveness" looks an implausible move on the part of the union, since how can it be sure that the firm made a genuine mistake and is not trying to exploit it? Nevertheless the argument above shows that Tit-for-tat cannot be a perfect equilibrium, since it would not pay the union to carry out its threat.
If, however, genuine mistakes are possible, then it is reasonable for the players to allow for this possibility in their strategies. The natural way to accommodate mistakes is to allow the player who makes a mistake to "apologise". Define "Modified Tit-for-Tat" as follows:

"I play Tit-for-Tat. If I make a mistake which (in the short run) helps me and hurts my opponent, then on my next move I apologise by playing C. Then on the subsequent move I restart Tit-for-Tat by playing C again."

If both players play "Modified Tit-for-Tat", the pattern would be:

```
punish
\downarrow
Union: C C C N C C C C ...
```

```
Firm: C C N C C C C C ...
```

It is easy to see that after the mistake it pays the union to retaliate and (if the discount factor is sufficiently high) the firm to apologise. A similar analysis holds for the case where it is the union which makes the mistake. Therefore "Modified Tit-for-Tat" is a perfect equilibrium. Hence the fact that (simple) Tit-for-Tat is not should not be of any great concern, given that this intuitively reasonable modification suffices to turn it into one.

Do these arguments prove that Tit-for-Tat will be the chosen strategy? No, because there might be some other Nash equilibrium pair of strategies which offer the union a higher present value than does Tit-for-Tat. By the "first move" assumption the union could enforce the choice of this hypothetical alternative. The ideal strategy for the union would be one where the firm cooperates but receives no more than $\pi^N$ per period, its minimax payoff in the one-shot game. It is unclear whether such a strategy exists, but it can readily be seen that the higher is $\delta$ the better is Tit-for-Tat as a strategy. As already noted, a rise in $\delta$ shifts the $A(ii)$ and $B(ii)$ schedules upwards. Since the $g(.)$ schedule is flatter an intersection with either the $A(ii)$ or $B(ii)$
schedules takes place at a lower level of $n^C$, or in other words at a higher wage. So Tit-for-tat, if not the best, may still be a good strategy.

5. A numerical example

5.1 Numerical Solutions for $w^*$

At this point a numerical example may help to illustrate the argument. Assume that the union is risk neutral so that the special case introduced earlier (section 2) applies. Let the firm face a constant elasticity demand curve for its product, so that the inverse demand function is

$$p = x^{-\gamma}, \quad 0 < \gamma < 1$$

and let the production function be Cobb-Douglas:

$$x = L^{1-\sigma} K^{\sigma} \quad 0 < \sigma < 1$$

Profits are therefore

$$\Pi = L^{(1-\sigma)(1-\gamma)} K^\sigma (1-\gamma) - wL - rK \quad (20)$$

From the first order conditions, equations (3), adopting the normalisation $s = r = 1$ and putting $k = K/L$, we obtain that the profit maximising solutions are

$$k_N(w) = \omega/(1 - \sigma) \quad (21)$$

and

$$L_N(w) = \omega^{-\epsilon} \quad (22)$$

where

$$\epsilon = [(1 - \sigma)(1 - \gamma)]^{1/\gamma} [\sigma/(1 - \sigma)]^{(1-\gamma)/\gamma}$$

and

$$\epsilon = (1 - \sigma(1 - \gamma))/\gamma = \delta L W$$

(the elasticity of demand for labour). Consequently, using (14),

$$w_N = \epsilon/(\epsilon - 1). \quad (23)$$

The cooperative solutions derive from equations (9) and (13):

$$k_C(w) = \sigma/(1 - \sigma) \quad (24)$$
\[ L_C(w) = L_N(s) = 0. \quad (25) \]

Noncooperative profits can be found by substituting (21) and (22) into (20):

\[ \Pi^{CN} = \Pi_N(w) = \omega w^{1-\epsilon}/(\epsilon - 1) \quad (26) \]

and

\[ \Pi^{NN} = \Pi_N(w_N) = \omega_N w_N^{1-\epsilon}/(\epsilon - 1). \quad (27) \]

Cooperative profits come from substituting (24) and (25) into (20):

\[ \Pi^{CC} = \Pi_C(w) = (w_N - w)\theta. \quad (28) \]

It follows immediately that

\[ \Pi^{NC} = \Pi_C(w_N) = 0. \quad (29) \]

Under risk neutrality, (1) becomes

\[ U = Lw/M + (1 - L/M)s \]

but it is more convenient to work with the union's aggregate net monetary gain \( V \), defined by

\[ V = M(U - s) = L(w - s). \quad (30) \]

Since \( V \) is a linear transformation of \( U \) it can serve just as well as a utility function.

To recapitulate the previous section, the optimal cooperative wage \( w^* \) is the maximum wage such that

\[ \text{either} \quad \{(1 + \delta) - \delta \Pi^{CN}/\Pi^{NN} \geq 0 \text{ and } \Pi^{CN}/\Pi^{NN} \leq \Pi^{CC}/\Pi^{NN}(1 - \delta) - \delta/(1 - \delta) \} \]

\[ \text{or} \quad \{(1 + \delta) - \delta \Pi^{CN}/\Pi^{NN} < 0 \text{ and } \Pi^{CN}/\Pi^{NN} \leq \Pi^{CC}(1 + \delta)/\Pi^{NN} \} \quad (31) \]
where, using the fact just proved that \( \bar{m}^{\text{NC}} = 0 \), we have rewritten inequalities A(i), A(ii), B(i) and B(ii) to show that they depend only on \( \delta \) and the two ratios \( \bar{m}^{\text{CN}}/\bar{m}^{\text{NN}} \) and \( \bar{m}^{\text{CC}}/\bar{m}^{\text{NN}} \). In turn, consideration of equations (26) - (28) shows that these ratios depend only on \( w \) and \( \epsilon \).

In addition, for cooperation to be worthwhile \( w^* \) must be such that
\[
v^{\text{CC}} \geq v^{\text{NN}} \quad \text{or} \quad v^{\text{CC}}/v^{\text{NN}} \geq 1.
\]

From (30),
\[
v^{\text{CC}} = L_C(w^*)(w^* - s)
\]
and
\[
v^{\text{NN}} = L_N(w_N)(w_N - s),
\]
and so using (22) and (25) we require that
\[
w_N (w^* - 1)/(w_N - 1) \geq 1.
\] (32)

Since we already know from equation (23) that \( w_N \) is determined by \( \epsilon \), we have shown that inequalities (31) and (32) depend (apart from \( w \)) solely on the two parameters \( \delta \) and \( \epsilon \). Thus it is these two parameters which determine \( w^* \) and whether cooperation is superior to noncooperation.

Table 1 contains calculations of the cooperative and noncooperative solutions for a wide range of values of the parameters. In all cases it was found that the cooperative solution, which was calculated by a simple search process, was of the type illustrated in figure 3(i). The conclusions which emerge from the table are:

1. The greater (numerically) the elasticity of demand for labour, the lower are both \( w_N \) and \( w^* \).
2. The greater is \( \epsilon \), the larger is \( w^* \) as a proportion of \( w_N \). Nevertheless the premium over the reservation wage (equal to one) is always substantially less in the cooperative case.
(3) The greater is \( \epsilon \), the greater is \( \pi^{CC}/\pi^{NN} \) — in other words, the larger (relatively speaking) is the bribe which the union has to pay the firm to induce it to cooperate.

(4) Finally, the most interesting result is that, as suggested in the previous section, a low value of \( \delta \) (high discount rate) can make noncooperation the best policy. In fact, for \( \delta = 0.5 \) or 0.95, cooperation is optimal, but for \( \delta = 0.1 \), noncooperation is best for the union. If we are thinking in terms of annual negotiations a value of 0.1 for \( \delta \) might suggest an unrealistically high discount rate. But this is not necessarily so if we recall that \( \delta \) can also be interpreted as the probability that the game is repeated.

5.2 A Comparison with the Nash Bargaining Solution

Since many authors have applied the generalised Nash bargaining solution to the union-firm bargaining problem, it is of some interest to see how this approach compares with ours.\(^{16}\) Let \( J \) be the present value of the stream of profits and, assuming again risk neutrality, let \( W \) be the present value of the union's stream of net monetary gains per period \( V \), given by equation (30). Then the generalised Nash bargain is the solution to the maximisation problem

\[
\max_w J^b W^{1-b} \quad 0 < b < 1
\]  

(33)

where

\[ J = \Pi/(1 - \delta) \]

and

\[ W = V/(1 - \delta). \]

In this formulation it is assumed that in the absence of agreement the firm would earn zero profits and the workers would earn their reservation wage, \( s \).

The parameter \( b \) is often said, though with dubious justification, to represent "bargaining strength".\(^{17}\)
Since only cooperative solutions are on the utility-profit frontier, it is clear that in (33)
\[ \Pi = \Pi^{CC} \]
and, from (30),
\[ V = L_C(w)(w - s) \]
The first order condition for a maximum of (33) is then:
\[ b(dJ/dw) + (1 - b)(J/W)(dW/dw) = 0. \]

Normally we would solve this equation to find the optimal \( w \). But we want to turn the problem round and find the value of the "bargaining strength" parameter \( b \) which corresponds to the optimal wage \( w^* \) found already by our approach. So solving (35) for \( b \), by adopting the same functional forms as in the previous sub-section and making use of (34), (28) and (24), we find that
\[ b = (J/W)/(1 + J/W) \]
where
\[ J/W = (w_N - w^*)/(w^* - 1). \]

Values of \( b \) for different values of the basic parameters \( \delta \) and \( \varepsilon \) appear in Table 1. Surprisingly, as the elasticity of demand for labour rises, so \( b \) falls, i.e. the firm's "bargaining strength" declines and the union gets a larger share of a shrinking cake. More obviously, the firm's "bargaining strength" rises as the discount factor falls.

Thus our approach can rationalise the use of the generalised Nash bargaining formulation, together with its ad hoc "bargaining strength" parameter. It can also show where the latter is likely to break down, as the case when \( \delta = 0.1 \) in Table 1 indicates.
6. Concluding Comments

Two models of unionised labour markets have been discussed and reconciled - the monopoly model and the efficient bargain model. The outcomes predicted by these two models have been shown to correspond to the two alternative strategies in a Prisoner's Dilemma. If the union-firm bargaining game is repeated then we have shown that the chief defect of the efficient bargain model, namely that its outcome is indeterminate, can be removed. We have argued that a Tit-for-tat strategy by the union will produce a solution which is an efficient bargain and which is determinate. We have also identified conditions under which the outcome predicted by the monopoly model will occur. In particular if the discount factor is low (discount rate is high) then cooperation may not be worthwhile. Two empirical implications of the model may be noted. First, in a cross section comparison the more risky is the firm the less likely is cooperation. Second, in a time series analysis, if the future prospects of a firm suffer an unexpected fall this could be interpreted as a fall in the discount factor and could therefore lead to a switch from a cooperative to a noncooperative outcome, resulting in higher wages and lower employment. Our model then provides an alternative explanation for the "end game" phenomenon discussed by Lawrence and Lawrence (1985).18

Finally some comments on the role of uncertainty in reducing the scope for cooperation. We have focussed on only one form of uncertainty — the possibility that the relationship between firm and union will not continue. Others have shown that if the two parties do not have equal access to information then even an efficient contract will not lead to a first best optimum. For example, if the union cannot observe the demand curve for output and the firm is risk averse there will be involuntary unemployment in some states of nature (Grossman and Hart, 1981). The task of analysing this and
other types of uncertainty in repeated games must be left to future work. One
fundamental question will however remain as a puzzle. All models assume some
institutional structures. If such structures produce inefficiencies, why are
they not changed? For example, if inefficiency results from firms having an
incentive to misrepresent the information that only they possess, this could be
avoided if workers owned the firms. In the present model, inefficiencies arise
if there is doubt about the future existence of the firm or more precisely of
the product line on which the union members are employed. If the firm had a
range of products it could offer to retrain and reallocate workers as necessary
thus reducing the probability of its dissolution to a low level. Cooperation
based on profit sharing would then be workable. This is of course the Japanese
model, now widely claimed to be superior (Dore, 1973; Aoki, 1984; Weitzman,
1983). While reasons for slowness in adopting superior institutions can be
conjectured, a rigorous analysis will not prove easy.
References


Footnotes

* We are grateful to Robert Solow and Geraint Johnes for detailed comments on an earlier draft. We should also like to thank seminar participants at the University of Sydney, the Australian Graduate School of Management and the Australian National University for helpful comments. Any errors remain our own.

1. The economic theory of trade unions has been surveyed by Farber (1984), Oswald (1985a) and Parsley (1980).

2. More precisely, binding commitments are possible in noncooperative games provided the mechanisms for making and enforcing such commitments are explicitly modelled in the rules of the game. Whether or not binding commitments can be made in practice depends on the legal structure. They are certainly not possible in the British system because of the legal immunities of trade unions, as has been emphasised by Grout (1984) and (1985). Binmore (1981) has argued that a cooperative solution should be regarded as describing in shorthand form the outcome of a noncooperative game when the game is played (noncooperatively) in the presence of some additional institutional and legal constraints. The multiplicity of cooperative solutions then corresponds to the multiplicity of possible constraints.

3. For an alternative game theory treatment of bargaining, see Shaked and Sutton (1984). Their treatment shows more explicitly the effect of varying degrees of union power on the solution. On the other hand in their setup the interests of the players are diametrically opposed so there is no scope for cooperation.

4. Oswald (1985b) has recently argued that layoffs and redundancies are not typically determined by random draw, as assumed in (1), but rather by seniority.
So union policy will usually be unconcerned with employment, as most union members most of the time face no risk of losing their jobs. However, as we show below, the main argument of this paper would still go through with a more general utility function than (1), provided the union shows some concern for employment (perhaps through the need to retain the support of its junior members).

5. The second order conditions are assumed to be satisfied. This is not automatic since the labour demand curve will typically be convex. But corner solutions have no economic interest.

6. As we know from the literature on implicit contracts (Hart, 1983), efficiency in general requires payments by the firm to unemployed workers, which are not allowed in the present set up. Such payments are however not usually observed (Oswald, 1986) except in special cases, like redundancy payments, perhaps for moral hazard reasons - how is a firm to identify reliably who is a potential employee?

7. Equation (10) was established by assuming (1). So this is the only point in the argument where the form of the utility function plays a crucial role. Of course, more general utility functions could also lead to (10).

8. According to Rapoport (1974), in experimental situations about 40% of one-shot Prisoner's Dilemma encounters result in cooperation.

9. The possibility of a cooperative outcome in the repeated prisoner's Dilemma was discussed early on by Luce and Raiffa (1957). For a recent survey of approaches to the Prisoner's Dilemma see chapter 9 of Shubik (1983). The
Prisoner's Dilemma has also been the subject of numerous experiments; see Rapoport (1974) and Rapoport et al (1976).

10. In a different framework Tulloch (1985) has argued that cooperation will be the outcome when the one-shot Prisoner's Dilemma is played repeatedly by different players, all of whom know each other's reputations — those with bad reputations will eventually lack for partners. On the other hand, Rubinstein (1986) shows that cooperation will not develop in a repeated Prisoner's Dilemma when played by finite automata. This result, however, depends on his (in our view questionable) assumption that every state of such an automaton must be used infinitely often.

11. An alternative to Tit-for-tat is a "trigger" strategy such as has been studied in the literature on cartels (Friedman, 1977). Fudenberg and Maskin (1986) show that any outcome which Pareto dominates the minimax solution can be sustained as a perfect equilibrium in a two-person repeated game by trigger strategies, provided there is sufficiently little discounting (their Theorem 1). However, trigger strategies are rather unforgiving and did poorly in Axelrod's computer tournament in comparison with Tit-for-tat.

12. We are adopting the convention here that if the firm is indifferent between cooperation and noncooperation, it chooses cooperation.

13. Using (6) and (11),

\[ g = \frac{\partial n^{CN}/\partial w}{\partial n^{CC}/\partial w} = \frac{(\partial n^{CN}/\partial w)}{(\partial n^{CC}/\partial w)} \]

\[ = \frac{L_N(w)}{L_C(w) - (R_L - w)(dL_C(w)/dw)} \]

We already know that \( w > R_L \), \( dL_C(w)/dw \geq 0 \) and that \( L_C(w) \geq L_N(w) \), so the numerator in the expression above does not exceed the denominator, or \( \frac{\partial n^{CN}/\partial n^{CC}}{\partial n^{CC}/\partial w} \leq 1 \).
14. Treating A(ii) and B(ii) as equalities we find

\[ \frac{\partial n^{CN}}{\partial \delta} = \frac{n^{CG} - n^{NN}}{(1 - \delta^2)} > 0 \]

and

\[ \frac{\partial n^{CN}}{\partial \delta} = n^{CG} - n^{NC} > 0. \]

15. This proposition is closely related to Theorem 2 of Axelrod (1981). That theorem holds the payoffs fixed and considers variations in the discount factor, whereas here it is the other way round.

16. We are indebted to Robert Solow for suggesting this comparison to us.

17. Nash (1950) gave an axiomatic foundation for the case \( b = 1/2 \). In Rubinstein's (1982) positive solution of the bargaining problem, where the cake is of a fixed size, the generalised Nash solution emerges in the limit. There is no comparable axiomatisation of the general case \( 0 < b < 1 \), nor up to now any positive analysis yielding the generalised Nash solution in the case where the cake is of varying size.

18. They drew attention to the apparently self-destructive behaviour of some unions when wages are observed to rise particularly rapidly in declining industries. Their explanation runs in terms of the monopoly union model. They argue that a fall in demand for the product may lead to a reduction in the elasticity of demand for labour and so to a higher wage, a result deducible from equation (7).
Table 1  Cooperative and Noncooperative Solutions in the Repeated Prisoner's Dilemma

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Source: own calculations (see sections 5.1 and 5.2).
Figure 1

Figure 2
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* 1 I.G. Sharpe

* 2 I.G. Sharpe
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17. Australian Journal of Management, October 1979
31. AFSI, Commissioned Studies and Selected Papers, AGPS, IV 1982
33. Seventh Australian Transport Research Forum-Papers, Hobart, 1982
34. Economic Record, Vol. 60, No. 166, March 1984
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