NON-COOPERATIVE WAGE BARGAINING

by

S. Holden
Abstract

The paper argues that the Rubinstein perfect information infinite-horizon alternating-offers model is problematic when applied to wage negotiations. A strike or any other industrial action is not an automatic consequence of a delay in reaching an agreement, because production can continue as normal also when negotiations take place. An infinite-horizon alternating-offers model incorporating the choice of calling a strike is developed. It is shown that in this model there is no longer a unique subgame perfect equilibrium, and that strikes with a length in real time can occur in equilibrium.
NON-COOPERATIVE WAGE BARGAINING

Steinar Holden

Introduction

In recent years non-cooperative wage bargaining has been applied extensively to wage bargaining, either directly or indirectly through the Nash bargaining solution (where non-cooperative bargaining theory has been used as a justification and basis for choosing disagreement points, cf. Binmore et al., 1986). In general, these applications have been based on variants of the Rubinstein (1982) perfect information infinite-horizon alternating-offers model (the "discount rate" case), where the parties bargain over the division of a cake. The parties give offers alternately, and the size of the cake diminishes over time, but the cake cannot be eaten until an agreement on the division is reached.

There is, however, an important problem with this model when it is applied to wage negotiations. While one might readily view the total revenue of the firm over the contract period as the cake to be divided, it is less clear why the parties shouldn't continue "eating the cake" while the bargaining takes place. A natural way to do this would be to prolong the existing wage contract and let production continue as usual when the parties bargain over the new wage level. There could still be costs associated with the bargaining which would motivate the parties to reach an agreement,
but these costs would be considerably smaller than the costs incurred during a strike.

Clearly, this situation would leave the union in a weak position as the firm usually would be only too happy to be able to bargain and pay previous contract's wages. Thus the union would wish to be able to use a strike or another type of industrial action in order to put pressure on the firm to offer a higher wage. An important point of the present paper is that the union's decision on whether to call a strike should be incorporated in the bargaining model. In fact this can be done by a very natural extension of the Rubinstein-model. After each rejection of a proposal, the union is assumed to decide whether or not to strike for one period, until the next proposal is given.

A very similar model is used in Haller (1988). Haller does however conclude that there are only two equilibrium wage levels, not a whole interval. More importantly, Haller does not mention that a strike with a length in real time may be sustained as a subgame perfect equilibrium.

The bargaining model

The setup of the model is the following. In each period of normal production the firm has a value added of one unit of a good which the firm and the union can divide between them. The union's share is \( W \in [0,1] \), the firm's share is \( 1-W \). If the union calls a strike, then both parties get zero in that period, but it is assumed not to affect the value added in later periods. Initially the union's share is \( W_0 > 0 \) (the wage level in the previous contract), and this is assumed to be the prevailing division until a new agreement is reached. For simplicity, both parties are assumed to have linear utility functions, so their payoffs can be represented by the discounted sum of their future shares. For the union this is

\[
U = \sum_{t=1}^{\infty} \delta^t u_t,
\]

where \( u_t = 0 \) if there is a strike in period \( t \), \( u_t = W_0 \) if there is no strike and an agreement has yet to be reached, and \( u_t = W \) if an agreement is reached. \( \delta \) is the discount factor.

For the firm we have correspondingly

\[
V = \sum_{t=1}^{\infty} \delta^t v_t,
\]

where \( v_t = 0 \) if there is a strike in period \( t \), \( v_t = 1-W_0 \) if there is no strike and an agreement has yet to be reached, and \( v_t = 1-W \) if an agreement is reached.

The parties are assumed to give offers alternately, one offer per period, and without loss of generality the firm is assumed to give an offer in period 1. The union can then accept or reject this offer. If the union accepts, the bargaining ends, if it rejects the union will have to decide whether to strike in this period. If the firm's offer is rejected the union gives a new offer in the next period, which the firm accepts or rejects. If the union's offer is
accepted the game ends, if it is rejected the union decide whether to strike in this period, and in the next period it is the firm's turn to give an offer, etc. Both parties are assumed to have perfect information.

The structure of the game is illustrated in Figure 1 below, where the union's and the firm's respective one period payoffs are given in parenthesis.

**Figure 1**

**Period:**

1. **firm:** propose \( W_1 \)
   - **union:** accept/reject
     - game ends, \((W_1, 1-W_1)\)
     - union: strike/no strike
       - \((0,0)\) \((W_1, 1-W_1)\)

2. **union:** propose \( W_2 \)
   - **firm:** accept/reject
     - game ends, \((W_2, 1-W_2)\)
     - union: strike/no strike
       - \((0,0)\) \((W_2, 1-W_2)\)

3. **firm:** propose \( W_3 \)
   - etc.

Per period payoff for the union and the firm, respectively, in parenthesis.

The total payoff of the union (viewed from period 1) if the wage outcome \( W \) is agreed upon in period \( s \), after \( s-1 \) periods of strike, is

\[
\sum_{t=s}^{\infty} \delta^t \frac{W}{(1-\delta)} = \delta^s U(W), \quad \text{for all } s > 0.
\]

For the firm, we have correspondingly

\[
\sum_{t=s}^{\infty} \delta^t (1-W)/(1-\delta) = \delta^s V(W), \quad \text{for all } s > 0.
\]

A (subgame) perfect equilibrium (Selten, 1975) of this bargaining game is a pair of strategies which constitute a Nash equilibrium in every subgame of this game. Our aim is to find a perfect equilibrium in this game.

Before proceeding it is convenient to investigate two different games where the union strike decision is taken as exogenous. One is the original Rubinstein-game, where the union is assumed to strike in every period until an agreement is reached. The unique perfect equilibrium outcome \( w^* \) (cf. Rubinstein, 1982, or Shaked and Sutton, 1984), when the firm gives the first offer, is given by
where \( W^* \) is the unique perfect equilibrium outcome if the union were to give the first offer.

The unique solution to (7) is

\[
(8) \quad W' = \frac{(W_0 + \delta)}{(1 + \delta)}, \quad W'' = \frac{(1 + \delta W_0)}{(1 + \delta)}.
\]

The proof is given in the appendix, where it is also proved that this is the best the union can achieve by any strike strategy. Note that the total payoff to the firm if no agreement is ever reached in this game is \( (1 - W_0)/(1 - \delta^2) \), the payoff from receiving \( (1 - W_0) \) in every other period. This is identical to \( (1 - W')/(1 - \delta) \), i.e. the payoff from reaching an immediate agreement on \( W' \), so the union extracts the whole surplus from reaching an agreement.

An equilibrium where the union is assumed to strike every other period is however not very attractive, particularly when the length of each period is assumed to be small. Thus I shall in the following also comment on the case where such disrupted strikes are not allowed.

In both games above, where the strike decision is taken as exogenous, there is a unique perfect equilibrium. In the richer bargaining model however, where the choice of calling a strike is explicitly modelled, it turns out to be an infinite number of perfect equilibria, and strikes may also occur in equilibrium.
Proposition 1

For all $W \in [W_0, W^*]$, $W$ is a perfect equilibrium partition.²

Proof: The structure of the equilibrium strategies is such that if any of the players deviate from the initial offer or acceptance of $W^*$, then the deviating player is forced down to his minimum payoff in the following subgame. This is done in one of the following two types of equilibria.

No-strike equilibrium (union is forced down to $W^*$):
- Firm: offer $W_0$, reject all $W > W_0$ and accept all $W \leq W_0$.
- Union: offer $W_0$, reject all $W < W_0$, accept all $W \geq W_0$, never strike.

Disrupted strike equilibrium (firm is forced down to $1-W^*$):
- Firm: offer $W^*$, reject all $W > W^*$ and accept all $W \leq W^*$.
- Union: offer $W^*$, reject all $W < W^*$, accept all $W \geq W^*$, strike in all even-numbered periods (i.e. after proposals by the union), no strike in all odd-numbered periods, until agreement is reached.

If the player who is in the advantageous position (the firm in the no-strike equilibrium, the union in the disrupted strike equilibrium) deviates from the equilibrium strategy, one switch to the equilibrium where this player is punished.

Let us first investigate the no-strike equilibrium. The firm's strategy is clearly optimal. As long as the union never strikes, the firm can receive $1 - W_0$ forever, and there is no need to offer more than $W_0$. As for the union, if it strikes in any period $t$, it will receive zero payoff in that period, and $W_0$ in all later periods. This is less than the payoff if it does not strike, as the union then get $W_0$ in all periods, including the current, thus the union will choose not to strike. It is, in fact, arbitrary whether the union accepts or rejects $W_0$, or what wage level the union proposes, as long as it is not less than $W_0$.

In the disrupted strike equilibrium, the union never accepts any wage offer below $W^*$, and it always demand $W^*$. Thus, the firm might as well offer $W^*$ immediately, as it cannot achieve a higher payoff by any later agreement. We then have to show that it is in fact credible for the union to strike after its own proposals, and not after the firm's. If the union strikes in period $t$, $t$ even, following an offer by itself, it will receive zero payoff in the current period and $W^*$ in all later periods, a total payoff of $\delta W^*/(1-\delta)$. This is clearly more than the payoff if the union fails to strike, as it will then be forced down to the no-strike equilibrium and receive a total payoff of $W_0/(1-\delta)$. Thus it will be optimal for the union to strike after own proposals. Similarly, if the union does not strike in period $t$, $t$ odd, after a proposal by the firm, it will receive a total payoff of $W_0 + \delta W^*/(1-\delta)$. This is more than the payoff by calling a strike, $\delta W_0/(1-\delta)$, hence the union will not strike after proposals by the firm. The union will accept $W^*$ immediately, otherwise it will be forced down to $W_0$ in the following subgame.

We now have to show that the firm will offer $W^*$ in the first period, and that this offer will be accepted. If the firm does not
offer \( W' \), the disrupted strike equilibrium follows. Then, the firm's best option is to accept \( W' \) in the next period, which clearly gives the firm a lower payoff than offering \( W' \). In the first period, the union will accept \( W' \) because if it fails to do so the no-strike equilibrium follows and the union receives only \( W_0 \), and it will reject any proposal below \( W' \) because in this case the disrupted strike equilibrium will ensure an agreement on \( W' \) in the next period. QED

Remark 1

Wage levels below \( W_0 \) or above \( W' \) cannot be supported as perfect equilibria. Clearly, it will never be optimal for the union to accept less than \( W_0 \), as it can never be forced below this level. That wage levels above \( W' \) cannot be supported as perfect equilibria (when the firm gives the first offer), is proved in the appendix.

Remark 2

If disrupted strikes are not possible, the union cannot get a higher wage level than \( W' \) in any perfect equilibrium. The proof follows directly from the part of the proof for uniqueness of the original Rubinstein model offered in Shaked and Sutton (1984) which puts an upper bound on player 2's payoff.

In this case one could define a strike equilibrium, where the union strikes in every period until an agreement is reached. The proof that this equilibrium is subgame perfect is similar to the proof for the perfectness of the disrupted strike equilibrium and thus omitted. The strike equilibrium can be substituted for the disrupted strike equilibrium in proposition 1, and the only change would be that the range of wage levels which could be supported as perfect equilibria would shrink to \( [W_0, W'] \).

Remark 3

If \( W_0 \geq W' \), \( W_0 \) is the unique perfect equilibrium as the union will never accept anything less and cannot get more. If \( W_0 \in \{\delta W', W'\} \), the unique perfect equilibrium is also \( W_0 \). To see this, consider the situation if the firm rejects an offer by the union. If the union strikes, it will get at most a total payoff of \( \delta W'/(1-\delta) \), as this is the payoff from a disrupted strike equilibrium from the next period on. However, the union will do better by not calling a strike, because this will give a total payoff of \( \delta W_0/(1-\delta) \). Thus, the disrupted strike equilibrium breaks down and the union is forced down to its minimum level \( W_0 \).

Remark 4

A possible extension of the model is the following. The union is able to commit itself in the sense that if it starts a strike, then this strike will last for at least \( s > 1 \) periods, if no agreement is reached within this time (if an agreement is reached, the strike stops immediately). The union's option of committing itself would capture possible costs to the union of stopping a strike without having reached an agreement. It is trivial to show
that this option would remove the lower part of the range of
perfect equilibria (the firm's threat never to accept or offer more
than \( W_0 \) would no longer be credible, because when the union has
committed itself, the firm would profit from accepting a higher
wage level than \( W_0 \) in order to stop the strike).

**Proposition 2**

For any integer \( N > 0 \) and all \( W' \) \in \( [ W_0/\delta^N, 1 - (1-W')/\delta^N ] \),
there is a discount factor \( \delta < 1 \) such that a perfect equilibrium
exists where the union strikes in \( N \) periods, whereupon an agreement
is reached on \( W' \). These strikes can have a length in real time,
also when the length of each bargaining period goes to zero.

**Proof:** The equilibrium strategies are the following, as long as no
player has deviated.

Firm: Offer \( W_0 \), reject all \( W > W_0 \) and accept all \( W \leq W_0 \) in \( N \)
periods, then offer \( W' \), reject all \( W > W' \) and accept all \( W \leq W' \).

Union: Offer \( W' \), reject all \( W < W' \), accept all \( W \geq W' \), and strike,
in \( N \) periods, then offer \( W' \), reject all \( W < W' \) and accept all \( W \geq W' \), strike in all even-numbered periods, no strike in all odd-
numbered periods.

If any of the players deviates, the subgame described in the
proof above punishing this player follows.

The equilibrium payoff to the firm is \( \delta^N(1-W')/(1-\delta) \). If the
firm deviates in the first period, the disrupted strike equilibrium
follows, giving the firm the total payoff \((1-W_0) + \delta(1-W')/(1-\delta) -
\( (1-W')/(1-\delta) \). Thus the firm will not deviate if \( \delta^N(1-W')/(1-\delta) \geq\)
\( (1-W')/(1-\delta) \), which is equivalent to

\[ (9) \quad W' \leq 1 - (1-W')/\delta^N. \]

Similar but less strict conditions exist for the firm not to
deviate in any later period. Thus (9) determines the upper bound
on \( W' \).

The equilibrium payoff to the union is \( \delta^N W'/(1-\delta) \). If the union
deviates in the first period by accepting \( W_0 \), its payoff will be
\( W_0/(1-\delta) \). Thus the union will not deviate if \( \delta^N W'/(1-\delta) \geq W_0/(1-\delta) \), or

\[ (10) \quad W' \geq W_0/\delta^N. \]

The same condition applies for the union not to strike in the first
period, and similar but less strict conditions exist for the union
not to deviate in any later period. Thus (10) determines the lower
bound on \( W' \).

We now show that the strike can have a length in real
time, also when the length of each bargaining period goes to zero.

Denote the length of each bargaining period \( \Delta \). In the limit when
\( \Delta \) goes to zero, we let \( N \) increase so that the length of the strike
\( \Delta N \) is constant and bounded away from zero. As \( \Delta \) goes to zero and
\( N \) increases, \( \delta \) is adjusted correspondingly, so that the interval
\[ [ W_0/\delta^N, 1 - (1-W')/\delta^N ] \] has a positive length. QED
Remark 5

There is also an infinite number of equilibria where there is delay without strike before the agreement is reached. The structure of this type of equilibria is the following. The parties negotiate for n periods, without any strikes, then the perfect equilibrium in the proposition above starts. Any deviation is punished as above.

Remark 6

Rubinstein (1988) offers the following interpretation of perfect equilibrium strategies. A player's strategy after a deviation describes not only what the player himself would do in the following subgame, but also what the other player expects him to do. This interpretation helps to make the various equilibria more intuitive. For example, if the firm believes that the union will never strike in the future, the firm has no reason to offer more than $w_0$ whatever the union may do. This makes it optimal for the union not to call a strike. Similarly, if the firm believes that the union will strike until an agreement is reached, it will be optimal for the firm to give in immediately. In this case it is in fact profitable for the union to strike until an agreement is reached, to prevent the firm's believes from changing.

The equilibrium where strikes occur can be given the following interpretation. Both parties have to show strength by enduring a strike. If one of the parties shows sign of weakness, this party is forced down to its minimum payoff.

Concluding comments

As there is a multiplicity of equilibria in the model, the actual outcome is left indeterminate. One possible answer to this problem, which has been pursued extensively in the literature (cf. Binmore, 1987), is to develop new equilibrium concepts. One might however argue that this indeterminacy reflects a more basic issue, that an abstract model like the present will not provide enough information to determine whether a union strike threat is credible. Thus, there is need for e.g. a social convention which may act as a signal to the players about what kind of equilibrium can be expected.

One possible interpretation of the equilibrium outcome $w^*$ is that this wage level is considered by one or both players to be fair. Thus, a wage offer below $w^*$ will be considered unfair, and if the union's strike threat is to remain credible it has to be used. Note, however, that this interpretation is at odds with a mechanical application of the Nash bargaining solution where the credibility of strike threats is taken for granted.
Footnotes

1. I wish to thank Ariel Rubinstein for referring me to this paper after having read a first draft of my paper.

2. I assume that $W_0 < \delta W$, the alternative is discussed below.

3. In the absence of any pure negotiation costs.

4. This is not to say that the firm would not prefer a lower wage.

Appendix

We now try to find the perfect equilibrium which gives the highest possible payoff to the union. In order to do this, we use an argument very similar to the one offered in Shaked and Sutton (1984) for uniqueness in the original Rubinstein-game. Note that in this analysis, the strike strategy of the union is taken as exogenous.

In the first part of the proof we derive an upper limit to the payoff of the union. Note that the structures of the subgames starting in period 1 and 3 are identical, thus the infimum of the share the firm can get, in any perfect equilibrium, in period 1 must be equal to the one it can get in period 3. Denote this infimum $\frac{W}{(1-\delta)}$. Now consider the subgame starting in period 2, with an offer by the union. If the firm rejects this offer, and the union strikes, the firm will get at least a payoff of $\delta M/(1-\delta)$, if the union does not strike the firm will get at least $1 - W_0 + \delta M/(1-\delta)$. Hence the firm will certainly reject any offer giving less than the smaller payoff, implying that the supremum of what the union can receive in period 2 is $(1-\delta) M/(1-\delta)$ (recall that the total payoff is $1/(1-\delta)$).

Now consider the firm's offer in period 1. If the union rejects this offer and strikes, it will receive at most $\delta (1-\delta) M/(1-\delta)$, while if it rejects without striking it receives at most $W_0 + \delta (1-\delta) M/(1-\delta)$. Thus the union will certainly accept any offer giving at least this latter payoff, so the infimum of the firm's share is $(1 - W_0 (1-\delta) - \delta (1-\delta) M)/(1-\delta)$, which equals
\(M/(1-\delta)\). Setting

\[(A1) \quad M = 1 - w_0(1-\delta) - \delta(1-\delta M),\]

we obtain

\[(A2) \quad M = (1-w_0)/(1+\delta) \quad \text{and} \quad 1-M = (\delta+w_0)/(1+\delta).\]

Thus \((\delta+w_0)/(1+\delta)\) is the upper limit to the wage level the union can obtain in a perfect equilibrium for any strike strategy. It was derived in the case where the union strikes only after its own proposals.

We now show that the union can indeed get this wage level by the strike strategy described above. The argument is very similar to the one above. \(M/(1-\delta)\) now denotes the supremum of the share the firm can obtain in any perfect equilibrium in the subgames starting in period 1 and 3. In period 2, if the firm rejects the offer by the union and the union strikes, the firm will get at most \(\delta M/(1-\delta)\), so the firm will certainly accept an offer giving this payoff if it expects the union to strike. Thus the union will get at least \((1-\delta M)/(1-\delta)\) in period 2.

We then consider the firm's proposal in period 1. If the union rejects this offer without a strike, the union will receive at least \(w_0 + \delta(1-\delta M)/(1-\delta)\), thus the union will not accept any lower payoff if it plans not to strike. Therefore the firm can get at most \([1 - w_0(1-\delta) - \delta(1-\delta M)]/(1-\delta)\), which equals

\(M/(1-\delta)\). As above, this yields

\[(A3) \quad M = (1-w_0)/(1+\delta) \quad \text{and} \quad 1-M = (\delta+w_0)/(1+\delta).\]

Thus \((\delta+w_0)/(1+\delta)\) is the highest wage level the union can get in any perfect equilibrium, when the firm gives the first offer, and the union can indeed get this wage level if it strikes after its own proposals, but not after the firm's. QED
References


No. 317 C. PISSARIDES AND J. WADSWORTH
On-The-Job Search: Some Empirical Evidence

No. 318 S. ESTRIN AND J. STEJNAR
Estimates of Static and Dynamic Models of Wage Determination in Labor-Managed Firms

No. 319 D. BLANCHFLOWER, A. OSWALD AND M. GARRETT
Insider Power in Wage Determination

No. 320 D. METCALF
Trade Unions and Economic Performance: The British Evidence

No. 321 R. LAYARD AND C. BEAN
Why Does Unemployment Persist?

No. 322 A. NEWELL AND J. SYMONS
Stylised Facts and the Labour Demand Curve

No. 323 M. KEIL AND J. SYMONS
The Canadian Bust of '82

No. 324 D. BLANCHFLOWER AND A. OSWALD
The Economic Effects of Britain's Trade Unions

No. 325 D. ROBERTSON AND J. SYMONS
The Occupational Choice of British Children

No. 326 A. BEN-NER AND S. ESTRIN
Unions and Productivity: Unionized Firms Versus Union Managed Firms

No. 327 C. PISSARIDES
Unemployment Consequences of an Aging Population: An Application of Insider- Outsider Theory

No. 328 R. LAYARD
Review of the Year's Work 1987/88

No. 329 M. MULLINS AND S. WADHWANI
The Effect of the Stock Market on Investment: A Comparative Study

No. 330 G. BRUNELLO
Hysteresis and 'The Japanese Unemployment Problem'

No. 331 C. PISSARIDES AND R. MOGHADAM
Relative Wage Flexibility in Four Countries

No. 332 C. BEAN AND A. GAVOSTO
Outsiders Capacity Shortages and Unemployment in the United Kingdom

No. 333 J. WADSWORTH
Unemployment Benefits and Search Effort in the UK Labour Market

No. 334 S. NICKELL AND S. WADHWANI
Insider Forces and Wage Determination

No. 335 R. JACKMAN
Wage Formation in the Nordic Countries Viewed from an International Perspective

No. 336 W. BENTLEY MACLEOD AND J. MALCOMSON
Labour Turnover and the Natural Rate of Unemployment: Efficiency Wage vs Frictional Unemployment

No. 337 W. BENTLEY MACLEOD AND J. MALCOMSON
Wage Premiums and Profit Maximization in Efficiency Wage Models

No. 338 G. BRUNELLO
Wage Determination in a Simple Hierarchical Model with a Nonzero Probability of Promotion

No. 339 D. BLANCHFLOWER, N. MILLWARD AND A. OSWALD
Unionization and Employment Behaviour

No. 340 D. BLANCHFLOWER AND A. OSWALD
The Wage Curve

No. 341 R. LAYARD
The Real Effects of Tax-Based Incomes Policies

No. 342 A. NEWELL
Three Squeezes: The Demand for Labour During Depressions

No. 343 R. LAYARD AND S. NICKELL
The Thatcher Miracle?

No. 344 D. BLANCHFLOWER
Fear, Unemployment and Pay Flexibility

No. 345 D. BLANCHFLOWER AND A. OSWALD
Wages and House Prices: Cross-section Evidence

No. 346 R. LAYARD
Layoffs by Seniority and Equilibrium Employment

No. 347 J. SYMONS AND A. NEWELL
The Passing of the Golden Age

No. 348 S. HOLDEN
Wage Drift and Bargaining: Evidence from Norway

No. 349 S. HOLDEN
Non-Cooperative Wage Bargaining