On the Role of Outside Option in Wage Bargaining

CHEN, Fengjiao

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Abstract

This thesis examines the role of outside option in wage bargaining within a complete information framework. A worker, after obtaining an outside offer higher than his current wage, initiates bargaining with his current firm over a new contract. In each period of bargaining, if an agreement is not reached, the worker must decide whether or not to opt out, and if he decides to stay, whether or not to strike in that period. In this study, it is shown that almost any wage level between the outside option and the entire revenue can be sustained in equilibrium payoffs. Our results provide a game theoretic explanation of phenomena such as preemptive wage increase and contract renegotiation (often initiated by firms).

Keywords: Wage Bargaining, Outside Option, Strike

摘要

本文探讨了外部选择在完全信息框架下对工资谈判的影响。在获得高于他目前工资的外部提供时，一个工人会与他目前的公司开启一个新的合同谈判。如果协议还没有最后达成，工人需要在谈判的每个阶段决定是否要退出；如果他决定留下来，他还要决定是否在此期间罢工。本文研究结果表明：从略高于外部可供选择的工资水平到整个收入之间的任何工资水平几乎都能成为工人的均衡收益。本文的结果可以用来解释（通常是公司发起的）对工人先发制人的工资增长和先发制人的合同重新谈判。

关键词：工资谈判、外部选择、罢工

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Contents

1 Introduction

A professional athlete is often requested by his club to launch the contract renegotiation long before the expiry date of the current contract.[1] What is the underlying force that prompts the early start? More generally, casual observation also shows that employers often give pay raises to their most capable employees without being asked. What is the main motive behind this generosity? One might come up with the following: it would become more costly to keep an employee after he receives outside offers. From such a point of view, the above observations should be considered as the incumbent employers' preemptions. This, however, begs for a better understanding of the role of outside option in wage bargaining.

Outside option principle could be applied to explain the mechanism of the worker's great bargaining power brought by the outside option. The well-known "outside option principle" was first formally analyzed by Binmore, Shaked and Sutton, and it was later tested in a laboratory experiment by the same group (1989). Binmore, Shaked, and Sutton consider the alternating-offers bargaining game originated from Rubinstein (1982), in which one of the parties can opt out after rejecting an offer. They find that the outside option principle predicts the division of the final equilibrium outcome overwhelmingly better than the split-the-difference method. The outcome of the bargaining game highlights the significance of outside option, that is, if the outside option, say, b is lower than the equilibrium share from the game

[1] In the summer of 2009, Lionel Messi, considered one of the best soccer players of his generation, extended his contract with the Spanish club Barcelona to 2016 with a buy-out clause of 250 million euros, whereas his previous contract was to expire in 2014 with a buy-out clause of 150 million euros.

without the outside option, then it has no effect on the bargaining outcome; however, if b is large, then the player with the outside option obtains b in the unique subgame perfect equilibrium. The intuition is that opting out is not a credible threat for a player if he can achieve nothing more from leaving the bargaining table than by staying. By resorting to the outside option principle, we still cannot provide a satisfactory explanation for the preemptive actions because an employer always has the option of waiting until the outside offers arrive, and then outbidding them by a small margin.

An important feature of the Rubinstein bargaining game is that along the bargaining process before any agreement is reached, the parties receive fixed (usually normalized to zero) disagreement payoffs. In the context of wage bargaining, it is equivalent to assuming that the union is committed to strike until the agreement is reached. This gives rise to a unique and efficient subgame perfect equilibrium. However, in reality, wage bargaining is often characterized by lengthy strike and inefficient delay. This motivates the study of Haller and Holden (1990) and Fernandez and Glazer (1991) (HHFG, hereafter). They analyze an extended Rubinstein game in which strike is a strategic choice of the union, and conclude that the bargaining game has multiple subgame perfect equilibria, some of which entail delay and strike.[2]

How would the interaction between inside option (e.g., strike) and outside option affect bargaining outcome? In this thesis, we find that if both strike and outside option are available, the worker's bargaining power would be greatly improved. The worker might succeed in occupying the whole revenue. Thus, by adding an outside

[2] See also a further study along this line by Avery and Zemsky (1994).

option in the HHFG wage bargaining model, we provide a game theoretic explanation for the employers' preemption. The logic is simple: while an outside option may enable the worker to make a credible take-it-or-leave-it offer in bargaining, a preemptive pay raise makes the outside option impossible and significantly reduces the upper bound of the equilibrium wage.

More specifically, we develop a modified version of the HHFG bargaining model. As in the HHFG model, a worker can produce periodic revenue of a fixed size for his firm. The worker and the firm are assumed to bargain sequentially over discrete time and a potentially infinite horizon. The two parties have an pre-existing wage contract W_e. After obtaining an outside offer, the worker initiates a wage bargaining over a new contract. The worker and the firm alternate in making offers of wage contracts, which the responding party is free to accept or reject. Acceptance of a proposed wage concludes bargaining with a new contract. Upon either party's rejection, the worker must decide whether or not to opt out, and if he decides to stay in bargaining, whether or not to strike in that period. If the worker opts out, bargaining is over; from that period onwards, the worker receives his outside option and the firm receives nothing. If the worker stays and strikes, both parties receive nothing in that period, but bargaining continues. Finally, if the worker chooses to stay and not to strike, he receives the pre-existing wage, the firm receives the residual revenue, and bargaining continues. Correspondingly, the outside option exists forever.

We first show that if the outside option is higher than the current wage, and both the worker and the firm are sufficiently patient, then almost any wage level between the outside option and the entire revenue can be sustained in a subgame perfect equilibrium. The multiple equilibria are constructed by forming an expectation cycle. More specifically, if the worker has a credible threat to opt out after his current demand is rejected, he will demand the entire revenue, which will be accepted by the firm. Starting from there, using backward induction, we can establish a decreasing sequence of wage expectations: while expecting that the two parties will agree upon a certain wage greater than the outside option in the next period, the worker will not opt out or strike, which in turn implies that he is willing to settle for a lower wage in the current period. When the wage expectation approaches the outside option, it eventually becomes optimal again to opt out after a rejection, which gives the worker the overwhelming bargaining power to make a take-it-or-leave-it offer. This closes the cycle of wage expectations, and every wage level on the cycle can be sustained in an efficient subgame perfect equilibrium.

Based on the cycle, we get multiple equilibria when the worker makes proposals. The equilibria then extends from discrete ones to continuum ones using the extreme punishment strategies in which the one who deviates will get punished. The worker's equilibria payoffs could range between the wage slightly above the outside option and the entire revenue, when both the worker and the firm are sufficiently patient. Hence, by raising the wage slightly above the possible outside option before its arrival, the upper bound of the equilibrium wage in the forthcoming wage renegotiation is significantly reduced. This provides the incentive for the employers to give preemptive pay raises, which helps avoid competition from other employers. As Schwartz and Wen (2006) prove, the worker always accepts the temporary increase in compensation offered by management. In contract, we do not explictly model the firm's preemptive strategies in this thesis. However, our results indicate the possibility that management unilaterally increases the wage during contract negotiation before the outside option arrives.

The rest of the thesis is organized as follows. Section 2 briefly reviews the most closely related literature. In Section 3, we outline the model. Section 4 characterizes the subgame perfect equilibria of the bargaining game and discusses the implications of our results. Section 5 further compares our model with that of HHFG and Shaked (1994), analyzes the influence of discount factor's different value on the equilibrium of the bargaining game, and considers possible extensions of our analysis. Section 6 concludes.

2 Literature Review

Rubinstein (1982) shows that two bargainers will always reach an immediate agreement in a unique equilibrium under a complete information framework. A large body of literature has evolved to explain the inefficient bargaining delay often observed in real life. Early research mainly focused on the case with information asymmetry between players, where delay serves as a signaling device.

Haller and Holden (1990) and Fernandez and Glazer (1991) analyze wage bargaining within a complete information framework. They show that a large range of wage levels can be sustained in an equilibrium with immediate agreement, and, based on this multiplicity of equilibrium outcomes, they further construct equilibrium with delay and strike.

Strike in reality is regarded as one kind of money burning. Money burning is used as a strategic choice by one player to destroy surplus during bargaining and therefore serves to enhance his bargaining power. Avery and Zemsky (1994) synthesize the multiplicity results from complete information bargaining with money burning, that is, multiple equilibria arise when at least one player can destroy some bargaining value after his own proposal is rejected.

In this thesis, we mainly analyze the wage bargaining with strike (inside option) and outside option within a complete information framework. Our model is most closely related to HHFG and Shaked (1994) models.

2.1 Wage Bargaining and Strike

The phenomenon of striking exists out of the conventional bargaining theory framework. It is regarded as a wasteful mechanism to distribute gains from trade. To explain the existence of strikes, asymmetric information is first introduced. Rubinstein (1985), and Grossman and Perry (1986), among many others, develop the theory of asymmetric information. They regard strikes, or delays in reaching agreement, as a signal device of the firm's lower profits which allows a lower wage agreement to be reached.

However, Haller and Holden (1990) and Fernandez and Glazer (1991) find inefficient equilibria with strikes under complete information for both parties. Haller and Holden (1990) extend the Rubinstein model and show the equilibria with strikes for a length of real time. Fernandez and Glazer (1991) further explain the model, in which a union and a firm carry on wage contract negotiation as a sequential bargaining process. During bargaining, the union could decide, in each period, whether to strike or not for the duration of that period. There exist Pareto-efficient equilibria. However, there also exist several subgame-perfect equilibria in which the union engages in several periods of strikes prior to reaching an agreement, although both parties are completely rational and fully informed. They show that the union could gain more with striking in disrupted periods than in continuous periods. This could be explained by the first mover advantage initiating asymmetric costs to both parties. The basic equilibrium strategy is that any attempt by one of the parties to deviate results in an efficient equilibrium, but one which adversely affects the deviating party. They show that strikes can occur in real time, and discuss extensions of the model, such as lockouts and the possibility of multiple reconstructing opportunities.

2.2 Outside Option

Strike is usually considered as a strategic choice for the worker to improve his bargaining power. Aside from strike as an inside option, outside option is also a method for the worker to improve his bargaining power with the firm.

Binmore, Shaked, and Sutton (1989) carry out an experiment on bargaining with outside option. The players go through the Rubinstein-type game with outside option. In the game, the player can only opt out when he responds to the other. Thus, a unique equilibrium exists. Their conclusion shows that deal-me-out (outside option) predicts the bargaining outcome overwhelmingly better than split-the-difference (half-half split of the remaining part). They also predict that outside option will be irrelevant to the final deal unless the player with outside option would go elsewhere.

Osborne and Rubinstein (1990) classify the bargaining game with outside option into two cases: the player can opt out when responding to an offer and he can opt out when his offer is rejected. They give out the corresponding equilibria.

Shaked (1994) investigates the type of alternating offers bargaining games in which one player could opt out each time his offer is rejected. There exist a continuum of equilibria for this type of bargaining, unlike the one in which a player could opt out when responding to an offer. When the outside option is sufficiently large or sufficiently small, the model has a unique equilibrium; if the outside option is within an intermediate range, there are multiple equilibria. These equilibria do not vanish and shrink to a Walrasion equilibrium when the frictions in the negotiation procedure disappear. Shaked also models a market with bargaining and matching along the so-called "Hi Tech" lines. In this model, outside option is endogenously determined.

Manzini and Snower (2002) identify two sources of bargaining power for the firm: those with its incumbent employees and those with new job seekers. In contrast, we probe the bargaining power on the worker's side. The outsider's influence flows through the outside option.

In the standard Rubinstein model with two-sided outside options, Ponsati and Sakovics (1998) show that there exist a continuum of subgame perfect equilibrium outcomes, including some with significant delay. However, in our model only the worker has both inside and outside options.

3 The Model Setting

We consider the wage bargaining between a worker and his employer, referred to as the firm. There are an infinite number of time periods, and in each period, the worker can produce one unit of revenue for the firm. The two parties have an pre-existing contract that specifies the current wage $W_e \in (0, 1)$. The worker has also obtained an outside option of $b \in (0, 1)$, and hence, initiates a wage renegotiation with the current employer. In the present study, we can simply view the worker's outside option b as a wage offer from another employer who poses no deadline on the offer. We suppose that the firm does not seek a replacement if the worker opts out or strikes.

Bargaining over a new contract follows the alternating-offers procedure. More specifically, at the beginning of each odd-numbered (even-numbered respectively) period t, the worker (the firm respectively) proposes a wage contract x_t. The other party then decides whether to accept or reject the proposal. If the proposal is accepted, bargaining is over and the new wage contract as proposed is enforced right away. If the proposal is rejected, the worker must choose among three options: (i) to opt out, (ii) to stay in bargaining and not strike in the current period, and (iii) to stay in bargaining and not strike. If the worker decides to opt out, bargaining is over, and from that period onward, the worker receives his outside option b while the firm receives nothing. If the worker chooses to stay and strike, both parties receive nothing in the current period and bargaining proceeds to the next period. Finally, if the worker chooses to stay and not strike, he receives the old wage W_e, the firm receives $1 - W_e$, and bargaining continues. Clearly, this is a game of perfect information. The figure below illustrates the first two periods of the game.

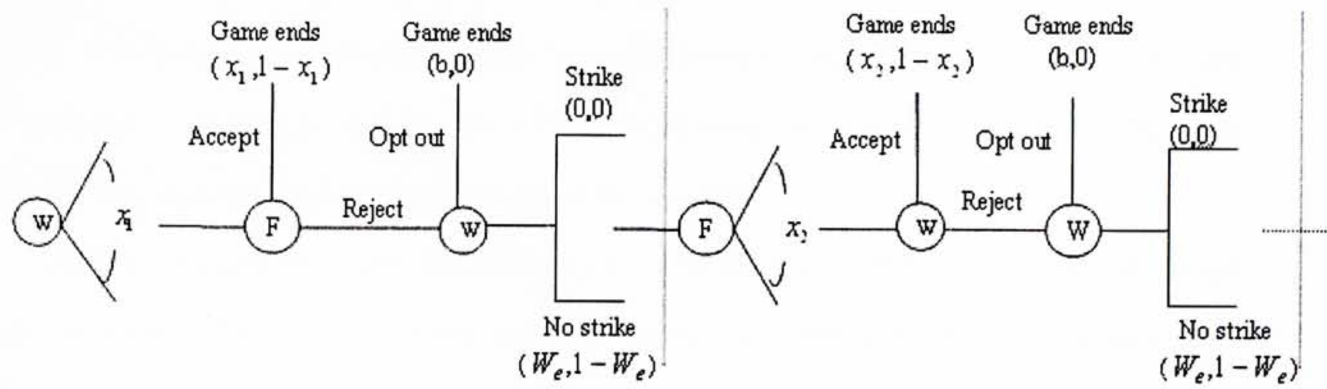

Figure: The First Two Periods of the Game

We assume that both the worker and the firm have linear utility functions, and discount their future payoffs by a common discount factor of $\delta \in (0, 1)$. More precisely, the worker's utility from a bargaining outcome is the discounted sum of his wage bargaining:

$$U = \sum_{t=1}^{\infty} \delta^{s-1} W_s$$

where $W_s = W$ from t to ∞ if an agreement on W has been reached in period t; $W_s = b$ from t to ∞ if the worker has opted out in period t; $W_s = 0$ for t if there is a strike in period t; and $W_s = W_e$ for t if there is no strike, the worker has not opted out, and an agreement has yet to be reached. The firm's utility is then the discounted sum of the residual revenues or profits:

$$V = \sum_{t=1}^{\infty} \delta^{s-1} P_s$$

where $P_s = 1 - W$ from t to ∞ if an agreement on W has been reached in period t; $P_s = 0$ from t to ∞ if the worker has opted out in period t; $P_s = 0$ for t if there is a strike in period t; and $P_s = 1 - W_e$ for t if there is no strike, the worker has not opted out, and an agreement has yet to be reached.

Before proceeding to the equilibrium characterization, a few remarks on the model are in order. First, in our model only the worker has the outside options and there exists a continuum of subgame perfect equilibria. With two-sided outside options, the proposer has the overwhelming bargaining power because he can opt out after a rejection, and his threat of opting out is credible because the next proposer will have the overwhelming bargaining power. In the context of wage bargaining, one-sided outside option seems to be more relevant; after all, one rarely gets fired for asking for a raise.

Another crucial feature of our model is that the worker can opt out both when responding to an offer and after his offer is rejected by the firm. In a Rubinstein bargaining model with outside option, there is a unique subgame perfect equilibrium when one of the parties can opt out only when responding to an offer. However, if this party can also opt out after his own offer is rejected, there exist multiple equilibria when the outside option is within a certain range (strictly between zero and one). Our results rely on the feature that the worker can opt out after his offer is rejected, and the outside option is relevant as long as it is not below the current wage.

Finally, it is assumed that when the worker opts out, the firm receives nothing. This assumption is made to simplify the model. More generally, the firm may receive a profit of d after the worker opts out by hiring a replacement, and it is reasonable to assume that $b + d < 1$.

4 Equilibrium Analysis

This section characterizes the subgame perfect equilibria (henceforth, equilibria) of the bargaining game described above.

We consider three separate cases: bargaining when outside option is smaller ($b < W_e$), equals to ($b = W_e$) and bigger than ($b > W_e$) the pre-existing wage, among which, when $b > W_e$ is the most important case and the center of the analysis. We also construct an equilibrium in which the worker opts out after his proposal is rejected in period 1. Finally, we briefly discuss the implications of our results on preemptive wage increase and contract renegotiation.

4.1 Equilibrium when $b < W_e$

First, if the outside option is lower than the current wage, i.e., $b < W_e$, it cannot affect the bargaining outcomes for all discount factors, and thus, the set of the equilibrium outcomes coincides with that of the HHFG model. This is stated in the following lemma.

Lemma 1 *When $b < W_e$ and $0 < \delta < 1$, the set of equilibria is the same as in the HHFG model.*

Proof. Opting out is a dominated action for the worker because the worker can always choose to accept the pre-existing wage W_e, by which his continuation payoff is strictly higher than that from opting out regardless of the strategy of the firm. Hence, the outside option will not be taken in any equilibrium. Then the set of equilibria coincides with that of the HHFG model. ■

4.2 Equilibrium when $b = W_e$

When $b \geq W_e$, the outside option will influence the bargaining outcome in a significant way. The key reason is that taking the outside option might be a credible threat. Due to several differences on equilibrium characterization, we further separate the analysis into two cases: (i) $b = W_e$ and (ii) $b > W_e$.

When $b = W_e$, the pre-existing wage W_e can be sustained in a stationary equilibrium in bargaining for all discount factors. A stationary subgame perfect equilibrium (henceforth, SSPE) is an equilibrium where, after any history of the bargaining game (independent of the time period t), the worker and the firm always make and accept the same proposals separately, which are optimal for both of them among other strategies (Gul, 1989).

Lemma 2 *When $b = W_e$ and $0 < \delta < 1$, there exists a stationary equilibrium, in which the worker and the firm agree on W_e in the first period of bargaining.*

Proof. When $b = W_e$ and $0 < \delta < 1$, there is one SSPE: the firm always offers W_e, and it is always accepted by the worker; the worker always proposes W_e, and it is always accepted by the firm. This is because, currently, the worker will get the same wage W_e by either opting out or staying in the firm, if he rejects it. Thus, the worker accepts it anyway. Given that the worker and the firm have the same continuation actions, the worker is indifferent between acceptance and rejection. If the worker deviates by asking for more than W_e, the firm will reject it. Thus, it is optimal for the worker not to opt out, because he can get the same by opting out and working under the original wage W_e.[3] ■

An opting out threat can force the firm to give up the whole revenue to the worker. This gives out the maximum value 1 and the minimum value W_e for the bargaining wage when $b = W_e$ and $0 < \delta < 1$. With the boundaries of the bargaining wage, the following proposition can be established.

Proposition 1 *When $b = W_e$ and $0 < \delta < 1$, any $W^* \in [W_e, 1]$ can be sustained in an equilibria with an immediate agreement on W^*.*

Proof. If the outside option $b = W_e$, the worker can make a take-it-or-leave-it offer $W' = 1$, that is, following a rejection, the worker opts out. For all discount factors, the threat of opting out is credible if the worker's deviation leads to the continuation equilibrium with an immediate agreement on W_e.

The worker and the firm will agree on an immediate agreement W^*. If the worker deviates, he will get punished by resorting to an SSPE, in which the worker is always offered W_e and always accepts. If the firm deviates, the worker will work under the pre-existing wage W_e. In the next period, the worker will demand for $W' = 1$ by threating to opt out if rejected. ■

[3] It is the same as in the HHFG model.

An outside offer merely equals to the current wage ($b = W_e$) gives the worker an overwhelming bargaining power. However, opting out is a weakly dominated action. This diminishes the plausibility of the above equilibrium.

4.3 Equilibrium when $b > W_e$

Next we consider the case with $b > W_e$. The value of discount factor δ matters in this case. Lemma 3, Proposition 2, and Proposition 3 establish when δ is sufficiently close to 1, that is, both the worker and the firm are sufficiently patient. It will be discussed in Discussion section that the equilibrium outcomes for the bargaining game depend on different discount factor value, whether both the worker and the firm are patient or not.

As the following lemma shows, no SSPE exists when $b > W_e$ and δ is sufficiently close to 1. Clearly, when the worker can choose to opt out in every period, W_e cannot be sustained in equilibrium. This fact upsets the only stationary equilibrium as described in the previous case.

Lemma 3 *When $b > W_e$ and δ is sufficiently close to 1, no SSPE exists.*

Proof. Suppose there is an SSPE. Then there is either (i) an immediate agreement on $W^* > b$ or (ii) an immediate agreement on $W^* = b$ or (iii) no agreement at all.

(i) If the SSPE is an immediate agreement on $W^* > b$, the worker should accept because the stationary equilibrium requires that the worker gets the same wage offer in the next period. If the firm deviates off the equilibrium path, the worker will reject it. Following the rejection, the worker will neither opt out nor strike because he will get the same offer in the next period in a stationary equilibrium in either way. Opting out is not an optimal choice for the worker when he is pacient. Strike is costly for the worker and it does not affect continuation payoff. Without the threat of opting out and strike, the firm has no incentive to offer greater than b. This contradicts the assumption that $W^* > b$.

(ii) If the SSPE is an immediate agreement on $W^* = b$, the worker will get the same if he works with $W^* = b$ or opt out with outside option b. Thus, the worker has the incentive to threat to opt out asking for an offer greater than b. Then, the stationary equilibrium is not valid.

(iii) If there is no agreement as equilibrium, the worker always opts out. Then if he does so, he will reject any wage less than 1. In this case, no SSPE exists.

Thus, no SSPE exists when $b > W_e$ and δ is sufficiently close to 1. ■

Therefore, we anticipate that this bargaining model's possible equilibrium is non-stationary when $b > W_e$ and δ is sufficiently close to 1. Now, we construct an equilibrium in which the parties take different actions in different bargaining periods and their actions exhibit a cyclic pattern. In the following, we analyze the detailed strategies of the worker and the firm in each period. The worker and the firm alternate to propose W_n as the worker's wage.

First, we suppose that sometime in the future, say, period T, it is the worker's turn to make a proposal and opting out is taken as a credible threat. Before he opts out and ends the game, the worker will demand a take-it-or-leave-it offer, i.e., the whole revenue from the firm, and leave the firm nothing. Considering that the worker threatens to opt out if the firm rejects his offer, it will accept the offer given that it is about to receive zero anyway.

When the firm knows that the worker will ask for the whole revenue 1 in the next period T, it would offer $\delta + (1-\delta)W_e > b$ in period $T-1$, when δ is sufficiently close to 1. The reasons are as follows:

After rearrangement,

$$(1-\delta)W_e + \delta = W_e + \delta(1 - W_e).$$

Since the firm knows that the worker will get 1 in the next period T, it would offer the most it can give to the worker and guarantee the worker would also like to accept such an offer. Additionally, as the worker could get an outside option $b > W_e$, the firm will be left with nothing. Thus, the worker will not strike in equilibrium and get at least W_e in every period during bargaining. As the worker's threat is assumed credible that he will opt out in period T, the worker can get W_e and the discounted value of the remaining part of production. We could also refer to the reasoning in the original Rubistein model: If one player will demand a take-it-or-leave-it offer 1 in the future, the other player will offer $\delta = 1 \cdot \delta$ one period before. However, in our model, the worker can choose to work with pre-existing wage W_e. Thus, if the firm is going to keep the worker, it has to offer $W_e + \delta(1 - W_e) > b$.[4]

At this period $T-1$, if the firm deviates by offering less, the worker will reject it, but will not strike and not opt out, because he would get W_e this period and 1 in

[4]The same reason follows for the subsequent periods (from period $T-2$ backwards).

the next period if he stays and works. The average payoff per period is

$$(1-\delta)W_e + \delta = W_1 > b,$$

which is bigger than the outside option.

Furthermore, we apply the backward induction for the analysis. From period $T-2$ backwards, the offered wage to the worker is decreasing. The reason is the same as in period $T-1$: For the worker, the offered wage is

$$W_e + \delta \cdot \delta^{n-1}(1-W_e),$$

which is the combination of original wage W_e and the remaining part of production with time discounting; or for the firm, it gets

$$(1-\delta^n)(1-W_e) = (1-W_e) - \delta \cdot \delta^{n-1}(1-W_e).$$

Backwardly, the firm decreases its offering to the worker, and the worker vice versa, until the point when the offered wage to the worker is going to be less than the worker's outside option b ($W_n = W_e + \delta^n(1-W_e) < b$). This initiates the worker's opting out one period before the point and asking for the whole revenue as prescribed in the beginning. We assume this point is period 1. Then $n \in \{2, 3, \cdots, T-2\}$ for the above backward induction analysis.

For period $T-2$ to period 2, the worker always gets more than his outside option in the corresponding agreement; thus, he would not opt out in the previous period.

If the firm offers less, he would not opt out and not strike in the current period. Similarly, because

$$(1-\delta)W_e + \delta W_{n-1} = W_n > b,$$

$n \in \{2, 3, \cdots, T-2\}$.

In period 1, if it is the worker's turn to demand $W_n = W_e + \delta^n(1 - W_e) < b$, obviously the worker will not demand such a low wage. Instead, he will come up with the take-it-or-leave-it offer $W_0 = 1$. If it is the firm's turn to offer $W_n = W_e + \delta^n(1 - W_e) < b$, the firm are supposed to offer b to the worker. In the previous period, the worker will demand $W_0 = 1$. If it is the firm's turn to offer $W_n = W_e + \delta^n(1 - W_e) > b$ with the condition that $W_{n+1} = W_e + \delta^{n+1}(1 - W_e) < b$, it will offer W_n. In the previous period, the worker will demand $W_0 = 1$.

Thus, to this point, we complete the cycle. The connection points are that the worker makes the take-it-or-leave-it offer in period T and the firm makes the offer either b or W_n in period 1 (the next cycle). Totally, there are even numbers of periods for one cycle. Then let

$$T = 2k^* = n_{\max} + 1,$$

in which, T is the total period number and n is the index.

In this cycle, W_n is a discrete value which equals to

$$W_n = W_e + \delta^n(1 - W_e) \in [b, 1],$$

$n \in \{0, 1, 2, \cdots, T-1\}$ for one cycle, and $2k^* - 1$ is the critical value, which satisfies the inequality

$$W_{2k^*-2} > b > W_{2k^*}.$$

For the worker and the firm's strategies in period 1, if

$$W_e + \delta^{2k^*-1}(1 - W_e) < b,$$

the worker would not accept the offer $W_e + \delta^{2k^*-1}(1 - W_e)$ from the firm. Obviously, the worker would opt out. Thus, the firm should offer b instead of $W_e + \delta^{2k^*-1}(1 - W_e)$. If the firm deviates by offering less, the worker will reject it and opt out because by opting out, he can get

$$b > W_{2k^*-1} = (1 - \delta)W_e + \delta W_{2k^*-2},$$

for he would receive W_e this period if he works, and W_{2k^*-2} next period.

For another case, if

$$W_e + \delta^{2k^*-1}(1 - W_e) > b,$$

$W_{2k^*-1} = W_e + \delta^{2k^*-1}(1 - W_e)$ is offered by the firm. If the firm deviates, the worker will reject the deviation and not opt out and not strike because he will get

$$W_{2k^*-1} = (1 - \delta)W_e + \delta W_{2k^*-2} > b$$

if he stays and works.

In one period before ($T = 2k^*$ of the previous cycle), the worker's proposal

$W_{2k^*} = W_e + \delta^{2k^*}(1 - W_e)$ for himself is less than outside option b, which is not rational. Then, he would come up with $W_0 = 1$ straight away.

Indeed, it is a credible threat that the worker will opt out immediately if the firm rejects his demand of the whole revenue ($W_0 = 1$) as we assume in the beginning of the analysis of the cyclic equilibria. The reasons are as follows:

In period $T = 2k^*$, if the worker chooses to stay after the rejection of his proposal, he would receive a payoff of at most

$$(1 - \delta)W_e + \delta \max(b, W_{2k^*-1})$$

(he receiving W_e this period, and b or W_{2k^*-1} from next period onwards). However, if $b \geq W_{2k^*-1}$,

$$(1 - \delta)W_e + \delta b < b;$$

if $b < W_{2k^*-1}$, we still have

$$(1 - \delta)W_e + \delta W_{2k^*-1} < b.$$

Therefore, if the firm rejects the worker's demand of $W_0 = 1$, the worker will definitely opt out.

In the above cycle, all equilibria are established simultaneously: the worker's demand of $W_0 = 1$ and the firm's acceptance is well proved as one equilibrium by assuming the worker will opt out if his proposal is rejected. This assumption is valid with the establishment of every other equilibrium in this cycle.

Period numbers do not necessarily mean that bargaining starts from period 1.

With the notation of this cycle, every odd-numbered period can be a starting point when the worker is the proposer. Different equilibria are obtained by letting the game start at various odd-numbered periods of the cycle before continuing with the full cycle permanently.[5] The intuition tells us that different equilibrium periods are selected and realized by the convention.

In the first case, when $W_e + \delta^{2k^*-1}(1 - W_e) < b$, the minimum equilibrium payoff is b. In the second case, when $W_e + \delta^{2k^*-1}(1 - W_e) > b$, the minimum equilibrium payoff is $W_e + \delta^{2k^*-1}(1 - W_e)$, which is offered by the firm.

Remark 1 *The cyclic equilibrium is semi-stationary. The strategies for the worker and the firm do not depend on the history but on different time periods in each cycle. The cycles are the same. In Schwartz and Wen (2007), equilibrium payoffs depend on the state of the subgame. The non-stationary equilibrium characteristic distinguishes our model from most of other model settings which have at least one SSPE among multiple equilibria. For example, there is an SSPE in the original Rubinstein model (1982), Haller and Holden (1990) and Fernandez and Glazer (1991).*

To sum up, we have the following proposition on the discrete multiple equilibria:

Proposition 2 *When $b > W_e$ and δ is sufficiently close to 1, there are multiple equilibria. In particular, for every*

$$W_{2k} = W_e + \delta^{2k}(1 - W_e) \in [b, 1],$$

[5]With the notation of this cycle, they are 2, 4, 6, etc. periods.

$k \in \{0, 1, 2, \cdots, k^* - 1\}$, *there is an equilibrium, in which the worker and the firm agree on* W_{2k} *in the first period of bargaining.*

We illustrate the cyclic equilibria as constructed above with an example ($k^* = 2$).

Table 1. The Cyclic Equilibria

Period	Proposer	Proposed Wage	Acceptance Threshold	Opt Out Decision
1	Worker	$W_0 = 1$	Accept only W_0	Yes
2	Firm	$W_3 = W_e + \delta^3(1 - W_e)$	Reject any $W \geq W_3$	No
3	Worker	$W_2 = W_e + \delta^2(1 - W_e)$	Accept any $W \geq W_2$	No
4	Firm	$W_1 = W_e + \delta(1 - W_e)$	Reject any $W \geq W_1$	No
5	Worker	$W_0 = 1$	Accept only W_0	Yes
6	Firm	$W_3 = W_e + \delta^3(1 - W_e)$	Reject any $W \geq W_3$	No
7	Worker	$W_2 = W_e + \delta^2(1 - W_e)$	Accept any $W \geq W_2$	No
...	...	...	...	...

The third and fourth columns in Table 1 are equilibrium paths. In this example, as $W_3 = W_e + \delta^3(1 - W_e) > b$, the firm proposes W_3, instead of b. In the odd period, the firm accepts any wage below the respective wage in that period. In the even period, the worker accepts any wage no less than the respective wage in that period. If the worker (the firm) deviates by demanding (offering) smaller (greater) wage, it is accepted. If the worker or the firm deviates in favor of himself, it will lead to a rejection, after which the worker executes the corresponding opting out decision. If the worker does not opt out, bargaining proceeds to next period, in which they propose the equilibrium wage.

In this example, the equilibrium path can start from any odd number. There are two different equilibria. The two equilibrium wages are $W_0 = 1$ and $W_2 = W_e + \delta^2(1 - W_e)$.

Proposition 2 finds every discrete equilibrium payoff for the bargaining game. Based on proposition 2, we can extend the discrete equilibrium payoffs to the whole continuum between the maximum and the minimum applying extreme punishment strategy.

From the cyclic equilibrium, we can identify the maximum and the minimum equilibrium wages for the whole game starting with the worker's demand as follows:

$\overline{W}_w = 1$ and

$\underline{W}_w = W_{2k^*-2} = W_e + \delta^{2k^*-2}(1 - W_e)$, slightly above b.

For the subgame starting with the firm's offer,

$\overline{W}_f = W_1 = W_e + \delta(1 - W_e)$,

$\underline{W}_f = b$, if $W_e + \delta^{2k^*-1}(1 - W_e) < b$ and

$\underline{W}_f = W_{2k^*-1} = W_e + \delta^{2k^*-1}(1 - W_e)$, if $W_e + \delta^{2k^*-1}(1 - W_e) \geq b$.

With these maximum and minimum values, we could construct an equilibrium as automata for bargaining when $b > W_e$. Extreme punishment strategies are adopted to realize the proof. The strategy for the worker is, when the firm deviates to offer less to the worker, he can propose the greatest amount to himself, that is, in any case he can propose $(1, 0)$ to the firm as a punishment in the bargaining game.

Proposition 3 *When $b > W_e$ and δ is sufficiently close to 1, any $W^* \in [\underline{W}_w, 1]$ can be sustained in an equilibrium in which the worker and the firm agree on W^* in the first period of bargaining.*[6]

Proof. We use automata to illustrate the equilibrium for the whole bargaining game. Next Table 2 gives out the detailed strategies in different states for each party.

Table 2. The Subgame Perfect Equilibrium in the Proof of Proposition 3

		W^*	EXIT I	EXIT II
Worker	Proposes	W^*	$\underline{W}_w$	1
	Accepts	$W \geq W^*$	$W \geq \underline{W}_w$	$W \geq 1$
Worker	Opts out	No	No	Yes
Firm	Proposes	W^*	$\widehat{W}$	W_1
	Accepts	$W \leq W^*$	$W \leq \widehat{W}$	$W \leq W_1$
Worker	Opts out	No	No	No
Transitions		Go to EXIT I if worker deviates; go to EXIT II if firm deviates.	Go to EXIT II if firm deviates.	Go to EXIT I if worker deviates.

[6] 1. This proposition is for the whole game. For the subgame starting with the firm, the maximum and minimum equlibrium wages are different.

2. The proposition establishes under the condition that δ is sufficiently large and close to 1.

In the above table, $\widehat{W}$ is the solution of $(1-\delta)W_e + \delta\widehat{W} = b$.

The equilibrium strategy is an immediate proposal and acceptance of W^*. These actions are supported by the convention that a deviation will be punished by one of the extreme equilibria, that is, if the worker deviates, the firm will propose $\widehat{W}$ in EXIT I. If the firm deviates, the worker will propose 1 in EXIT II.

Only in state EXIT II will the worker opt out if rejected. In the other state, the worker will not opt out. ■

Proposition 2 gives the discrete equilibrium payoffs in a constructed cycle for bargaining. Proposition 3 asserts that any wage level between the maximum and the minimum in Proposition 2 could be realized in bargaining.

4.4 Opting Out is an Equilibrium

In most of other bargaining models with outside option, opting out is only used as a possible strategy but never carried out in equilibrium. In contrast, we find that in our model for all discount factors, opting out can be realized in equilibium, that is, rejecting an offer and getting an outside option becomes an equilibrium outcome.

Proposition 4 *There is an equilibrium in which the worker and the firm cannot reach an agreement and the worker opts out in the first period.*

Proof. The strategy profile for a worker opting out as an equilibrium are as follows:

At the first period, the worker asks $W = 1$. The firm rejects it if and only if $W \geq b$. Case I: There is no deviation. The worker opts out. Case II: The worker deviates to offer W $(1 > W > b)$. The worker will not strike and not opt out. In the next period, the firm offers $\widehat{W}$ which satisfies $(1-\delta)W_e + \delta\widehat{W} = b$.

For case I, the worker asks $W = 1$, and the firm rejects it because $W = 1 \geq b$. Thus the worker opts out and bargaining ends.

For case II, the worker deviates to demand $W \in (1, b)$. The worker does not strike or opt out in this case, but stays and works, receiving W_e, because in the next period, the firm offers $\widehat{W}$ which satisfies $(1-\delta)W_e + \delta\widehat{W} = b$. The worker can get the an average payoff of $(1-\delta)W_e + \delta\widehat{W}$ in each period. It equals to outside option. Then the worker will not strike and not opt out in the first period. ■

4.5 Implications on Preemption and Renegotiation

Through the analysis, the outside option clearly enhances much of the worker's bargaining power. The firm is supposed to realize the impact on the final bargaining outcome and production efficiency, and takes measures to undermine it. We expect the above results will shed light on the question in the introduction of this thesis.

Bernhardt and Scoones (1993) demonstrate that a firm may offer its employees a wage high enough to discourage competitors from acquiring information and bidding up the wage further or hiring the worker away. However, they mainly examine the strategic promotion and wage decisions of firms when employees may be more valuable to competing firms. Schwartz and Wen (2006) discuss that Sections 8(a)(3) and 8(a)(5) of the National Labor Relations Act (NLRA) prohibit the management of a firm from unilaterally increasing the wage during contract negotiations without the union's approval. While the Supreme Court considers that unilateral wage increases are supposed to undermine the union's authority and the collective bargaining environment, Schwartz and Wen (2006) reason that unilateral wage increases will interfere with the union's incentive to strike. They further show that management can prevent strikes because the union would always approve the temporary increase in compensation offered by management.

Most of the authors above focus more on the firms' ex-ante actions and strategies, e.g., preemption or promotion in fear of outside competition or inside striking. We have illustrated the possible equilibria with employee's rights to freely choose between working, striking, and opting out. Our viewpoint is opposite to the other authors' research we cited in explaining the existence of unilateral wage increases or promotion. The significant extension of equilibrium payoffs has implications on the phenomena of the firm's preemptive wage increase and contract renegotiation. We find that the wage range is extended in the worker's favor in bargaining with an outside option slightly above the pre-existing wage W_e. The upper bound of the equilibrium wage can be greatly reduced after preemptive wage increase and contract renegotiation by the firm.

5 Discussion

5.1 Without Outside Option (HHFG Model)

Outside option extends the set of equilibrium wages in the worker's favor. The HHFG model discusses the bargaining model only with strike and without outside option. There are efficient multiple equilibria or delayed ones (with strikes) in the bargaining model. For the convenience to compare the different models, we unify the notation in different models. In HHFG's analysis, if $W_e < \frac{\delta^2}{1+\delta}$, any wage contract w such that $w \in [W_e, W_e + \frac{(1-W_e)}{1+\delta}]$ can be generated as an equilibrium wage contract with an agreement reached in the first period. After we assume that the worker can opt out during bargaining, the set of equilibrium wage extends. If $b > W_e$, the worker can get any wage contract w such that $w \in [b, 1]$. If $b < W_e$, the set of equilibrium is the same as in the HHFG model. In addition, in our bargaining game, strike is a possible option for the worker to choose, but it is not used in equilibrium.

5.2 Committed to Strike (Shaked 1994)

Usually, strike is considered as a strategic choice for the worker to improve the bargaining power. If the worker is committed to strike, the worker and the firm will get nothing before the final agreement. This is similar to the model in Shaked (1994), in which the players have no fixed division over the pie before they reach an agreement. They mainly analyze the "Hi Tech" model that one player is permitted to opt out as long as one offer is rejected. There is a unique equilibrium if $b < \delta/2$ and $\delta/(2-\delta) < b \leq 1$ and many equilibria if $\delta/2 \leq b \leq \delta/(2-\delta)$. The outside option plays a role when $\delta/2 \leq b$ according to the outside option principle. The number of equilibrium is similar to the case when one player can opt out when his offer is rejected, which is analyzed systematically by Osborne and Rubinstein (1990).

In our model, the worker can choose work besides opting out and strike. When $b < W_e$, the set of equilibria is the same as in the HHFG model, and there are many equilibria. When $b \geq W_e$, multiple equilibria exist and outside option influence the equilibria differently for various discount factor values.

The outcome difference between our model and Shaked (1994) lies in that the turning point value W_e might be less than $\delta/2$ with great possibility in reality. This means much lower outside option in our model than that in Shaked (1994) will help increase the worker's bargaining power.[7] Thus, working under pre-existing wage actually improves the worker's bargaining power more than strike when bargaining with outside option. The worker has a larger bargaining power when his inside option is larger when the outside option influence exists. This forms a paradox compared with the common knowledge that strike can improve the worker's bargaining power in any condition. This also reflects the interaction between strike and opting out in wage bargaining.

5.3 The Influence of discount factor δ

The value of discount factor is quite important during the bargaining process. For different outside option values, we analyze the different discount factor values' influence separately. When $b \leq W_e$, the equilibria do not change if the discount factor varies.

However, when $b > W_e$, the equilibria depend on the value of discount factor. The main difference results from the change of the critical period n when $W_n = b$. Specifically,

$$W_n = W_e + \delta^n(1 - W_e) = b \Longrightarrow \delta = (\frac{b - W_e}{1 - W_e})^{\frac{1}{n}}.$$

(i) If $0 < \delta < \frac{b-W_e}{1-W_e}$, $W_1 < b$. The cycle degenerates to 2 periods. The equilibrium is that the worker will ask for 1 and opt out if rejected, accepting any $W \geq b$; the firm will offer b, accepting any W. If the firm deviates, the worker will opt out and

[7] Suppose the player in Shaked (1994) with outside option is the worker's role.

obtain $b > (1-\delta)W_e + \delta$. This equilibrium is stationary.

(ii) If $\frac{b-W_e}{1-W_e} < \delta < 1$, n increases with the increase of δ. When $\delta < 0.95$, $n < 20$. When $\delta > 0.95$, n increases abruptly with tiny increases of δ and $\underline{W}_w$ converges in probability to b as $\delta \to 1$, that is, the worker is sufficiently patient. The minimum wage for the worker is b even when the worker is the first proposer. Then as $\delta \to 1$, it can be regarded that all range from outside option and the whole revenue can be sustained in equilibrium.

(iii) Suppose it is possible that $\delta = 1$, the cycle collapses. The worker will ask for 1 every period and opt out if rejected, accepting any $W \geq b$. The firm is different between accepting and rejecting, by both of which it obtains nothing. The firm will offer b, accepting any W; if the firm deviates, the worker will work under pre-existing wage W_e. As the worker will still work if the firm deviates, this equilibrium is not stationary.

5.4 Equilibrium Refinement by Good Faith Bargaining Rule

In the US, Section 8(a)(5) of the NLRA (1997) makes it illegal for an firm to refuse to bargain in good faith about wages with a union. In many countries' labor codes, a bargaining in good faith stipulation is also enforced. Wen and Schwartz (2007) study the wage negotiation model of Haller and Holden (1990) and Fernandez and Glazer (1991) under the "Good Faith Bargaining" (GFB) rule. The GFB rule requires that the union and the firm have to (weakly) improve their proposals over time, that is, the offer given to the proposer himself is no more than his offer in the previous period. Specifically, given the worker or the firm offers $(d_i, d_j) \in [0,1]^2$, he will offer

$d_i' \leq d_i$ in the next period under GFB.

They find that the GFB rule significantly restricts feasible strategies and consequently eliminates the union's credibility to strike. The set of SPE payoffs in this game's subgame depend on the state of the subgame, which is non-stationary. Without the ability to initiate strikes, the union fails in its strategic opportunities during disagreement, so that there is a unique equilibrium, compared with multiple equilibria without the GFB rule. In this only equilibrium, the union and the firm will agree on the pre-existing wage contract in the first period.

Consider our bargaining model. First, the equilibria we constructed do not satisfy the GFB rule because the cycle violates it. Second, we conjecture that the GFB rule kills all equilibria in our bargaining game. Generally, we infer that this imposes a paradox on the GFB policy: if no equilibrium exists for the bargaining game under the GFB rule, how could it be possible for the worker and the firm to bargain without violating it? Thus, the existence of the GFB rule might not be good.

6 Conclusion

We study a bargaining model which is a combination of the HHFG model and the Shaked (1994) model settings. The bargaining model with outside option and strike features new results: non-stationary multiple equilibria by constructing a bargaining cycle. The cyclic equilibria are established by backward induction and based on the worker's future take-it-or-leave-it demand of the whole bargaining game. Consequently, the threat from inside and outside options by the worker might make the firm accept any wage level between a wage slightly higher than the outside option and the entire revenue, if both are patient enough. These two options greatly improve the worker's bargaining power. Apart from these equilibria, the worker's opting out immediately could also be realized in equilibrium. To undermine the worker's bargaining power, the firm would apply strategies such as preemptive wage increase and contract renegotiation. Thus, we reinforce the idea in Schwartz and Wen (2006) and Bernhardt and Scoones (1993) that the firm tends to give the worker preemptive wage increase to undermine the worker's strike and opting out incentive. In contrast, however, our basic model setting does not allow the firm to exert special strategies to prevent the worker's strike or opting out.

To discuss furthermore, we compare the model with the other two models: the HHFG model without outside option and the Shaked (1994) model without strike. We also demonstrate how the equilibrium vary with the discount factor, and reveal that the major conclusion in this thesis about the bargaining game depend on the sufficient patience of the worker and the firm. As a possible extension, the GFB rule could also exert an effect to prevent the worker from asking for too much in the revenue.

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