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# Firm-Specific Skills, Wage Bargaining, and Efficiency

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## Abstract

We study the bargaining relationship between a firm and its incumbent worker who possesses firm-specific human capital. We show that, in the contract renewal stage, the worker's ability to use his firm-specific skills strategically increases his bargaining power vis-a-vis the firm. The firm can threaten to fire the worker and hire a new inexperienced worker, but this threat is not always credible. Even though the bargaining takes place in an environment with perfect information, the game has inefficient equilibria where delays occur in real time.

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# 1 Introduction

Employment contracts are inherently incomplete. In a typical employment contract the worker agrees to carry out the instructions of the employer, within broad limits, in return of a prespecified wage. In the absence of comprehensive contracts, productive efficiency requires successive adaptations to the changing job and market conditions. In the implementation of these adaptations, parties may find it profitable to bargain ex-post over the terms of the contract within the contract period as well as in the contract renewal stage. If the labor market is competitive, the ex-post bargaining between the firm and its employees results in an efficient allocation, as the firm can replace its employees costlessly without any disruption in production. However, most jobs involve non-trivial firm-specific skills and information which develop during the course of the worker's employment. Employees such as, high level managers, sales representatives, key product engineers, and members of the production teams possess firm-specific human capital, and the firm cannot replace them with new inexperienced workers at the spot labor market. Although the firm's initial hiring decision takes place in a competitive labor market, once the worker's skills are developed as a result of experience, the employment relationship resembles a bilateral monopoly. Therefore, in the ex-post bargaining game the hold-up problem may arise.<sup>1</sup> This, in turn, may create inefficiencies both ex-ante and ex-post.

In this paper, we study the bargaining relationship between a firm and its incumbent worker who possesses firm-specific human capital. We show that, in the contract renewal stage, the worker's ability to strategically disclose his skills increases his bargaining power vis-à-vis the firm. The firm can threaten to fire the worker and hire a new inexperienced worker, but this threat is not always credible. Even though the bargaining game takes place in an environment with perfect information, there exist inefficient equilibria in which delays occur in real time. The wage bargaining between the firm

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<sup>1</sup>There is an extensive literature on the hold-up problem in bilateral relationships and its remedies. Among these, Grossman and Hart [9] studied the incentives to invest in relationship-specific investment when there is contractual incompleteness. Rogerson [17], Chung [5], MacLeod and Malcomson [12] are among those who studied the contractual solutions to ex-ante inefficiency that is created by ex-post hold-up problem.

and its skilled workers results in ex-post inefficiency in the production. This supports the arguments in Williamson et. al. [22] that sequential spot contracting in the labor market is not efficient when firm-specific human capital is important.<sup>2</sup>

The specialized skills and information which we call firm-specific human capital, develop either as a part of on-the-job training or accrue naturally during the course of employment. In most jobs, especially those involving “idiosyncratic tasks”<sup>3</sup> the firm-specific human capital is an important input for the firm. Familiarity with the physical environment (Doeringer and Piore [7]), customer relationships (Anderson and Schmittlein [2]), the ability to communicate and work effectively with the members of a team (Mailath and Postlewaite [13], and Klein [11]) are examples of firm-specific human capital. When the firm-specific skills develop as a result of on-the-job training that is, an investment in human capital, the possibility of ex-post bargaining creates both ex-ante and ex-post inefficiencies. The ex-ante inefficiency arises because the parties’ incentives to invest in specific human capital are distorted.<sup>4</sup> The ex-post inefficiency arises because the worker may strategically disclose his specialized skills during the ex-post bargaining, causing delays in bargaining. In this model we focus on the firm-specific human capital that accrues naturally to the worker during the course of his employment without a significant cost to either him or the firm. In this way, we isolate the effects of the ex-ante investment decisions and study only the ex-post inefficiencies that may arise in the relationship.

It is a well known result in the bargaining literature that if there is an informational asymmetry between the negotiating parties, then in equilibrium delays occur in real time (for example, see Admati and Perry [1]). In these models, the delay serves as a signalling device. Recently, the works of Fernandez and Glazer [8], Haller and Holden [10], and Busch and Wen [4]

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<sup>2</sup>Instead, hierarchical organization of labor such as internal labor markets promotes efficiency by avoiding individual bargaining. The internal labor markets paradigm which is pioneered by Doeringer and Piore [7], argues that there are hierarchical career structure within a firm. The wages are attached to jobs rather than workers which eliminates the inefficient bargaining between the firm and its incumbent workers.

<sup>3</sup>Williamson et. al. [22] discusses the underlying factors that give rise to job idiosyncracies and the efficiency implications of alternative organizational frameworks in which idiosyncratic exchange can be accomodated.

<sup>4</sup>Becker [3] is among the first who considered incentives to invest in specific human capital. For a theoretical model of how ex-post bargaining creates distortions in parties’ incentives to invest, see Grossman and Hart [9] and Mumcu [14]

show that delays can also be observed in equilibrium in bargaining games with perfect information. The alternating offers bargaining game with constant disagreement payoffs has a unique equilibrium. If the disagreement payoffs are endogenous, that is, if the value of disagreement payoffs depend on the actions taken by players in each period, then the players' offers in the bargaining game depend not only on the past rejected offers, but also on the actions taken in the disagreement stage. As in repeated games, multiple equilibria exist because the history-dependent strategies can be used to punish the players for deviations from the proposed equilibrium actions, thus deterring deviations. If the game has multiple equilibria, inefficient equilibrium where delays occur can easily be constructed.

In this model, the firm and the incumbent worker bargain over the total division of surplus. The bargaining game takes place concurrently with the production. If the firm and the worker do not reach an agreement, production takes place and the worker is paid according to the initial contract. The worker can either exert high effort levels and produce the maximum feasible output or shirk, thus, produce less than the maximum. Since the worker does not bear any disutility if he shirks, he receives a higher payoff if he shirks during every period when an agreement is not reached. In fact, by committing to shirk in every period, the worker guarantees himself the highest equilibrium payoff. If, however, the total output is sufficiently large, the firm can support the action "not shirk" in the disagreement game by compensating the worker's loss from choosing this action by offering him a higher wage in the next period. If the worker deviates from his prescribed equilibrium strategy, he is punished in the next period as the firm proposes a smaller wage. By using history-dependent strategies, we show that the game has many equilibria some of which are inefficient. In inefficient equilibria the agreement is delayed and the worker shirks in every period up to agreement.

This paper contributes to the literature on non-Walrasian wage bargaining where the existence of wage differentials in labor market is attributed to the higher bargaining power of insiders compared to outsiders. In these models, however, the way in which the worker's firm-specific skills increases his bargaining power is not explicitly modelled. In Shaked and Sutton [18] this bargaining power is characterized by the firm's inability to replace its current workforce on the spot. The firm's current workforce enjoys a bargaining advantage because it is time-consuming for the firm to replace them. During the wage bargaining, the firm bargains with the incumbent worker for a number of periods before it makes an offer to an outsider. The game has

a unique equilibrium. If the time period during which the firm is forced to bargain with the insider decreases, the equilibrium approaches a Walrasian solution. If the time period increases, then the outsider does not represent a threat to the insider and the equilibrium is similar to the one in bilateral monopoly. Recently, Stole and Zwiebel [19], [20] developed a model of intra-firm bargaining between the firm and its skilled employees in order to explain the firm's input and organizational design decisions. In their model of intra-firm bargaining, the firm has many employees but it bargains with each one individually. The worker's bargaining power stems from his threat to quit. This threat is credible insofar as it deprives the firm from the worker's contribution, thus, weakens its position against the remaining workers. The bargaining game has a unique subgame-perfect equilibrium. An extension of this model is studied in Wollinsky [23] where the firm has the opportunity to replace the existing workers.

All of these models of bargaining between the firm and the incumbent workers assume that the production takes place after a new agreement is reached. In contrast, in our model the intra-firm bargaining game takes place concurrently with production. The worker's decision in the disagreement stage involves how much effort to exert. If the worker chooses to strike in the disagreement stage, hence, produce nothing, both players' disagreement payoffs are zero. In this sense the intra-firm bargaining models described in these papers can be seen as a special case of ours.

The paper is organized as follows. Section 2 presents the model. Section 2.1 solves for the equilibrium of the bargaining game when the firm does not have an outside option. Section 2.2 presents the bargaining game when the firm can exercise its outside option after rejecting an offer and section 3 concludes.

## 2 The Model

In this model, a firm is randomly matched with a worker from a competitive market of identical workers. They sign a contract that specifies the wage that the agent will be paid for a day's work. This wage is equal to the competitive wage which is denoted  $w_0$ . This relationship produces an amount of output that is normalized to 1 in each production period. We assume that initially the worker is unskilled and he does not need to exert effort to perform the job. However, as the worker continues to work in the same firm, his

productivity increases as he acquires firm-specific human capital. He develops these skills without exerting any effort. We assume that, after some time, the worker is able to produce  $A > 1$  units of output when he combines his firm-specific skills with high levels of effort. High effort levels imposes disutility  $c$  to the worker. Although the incumbent worker was drawn from a pool of identical workers before the initial contract was signed, he gradually becomes more productive than the outsiders. Hence the employment relationship resembles a bilateral monopoly. Once the initial contract expires, the worker can negotiate with the firm to raise his wage above the competitive wage.<sup>5</sup>

We characterize the wage negotiation as an alternating offers bargaining game between the firm and the incumbent worker which takes place concurrently with the production. The structure of the game is as follows. In each odd-numbered period the worker proposes a new wage contract  $w_t$ . The firm then responds by either accepting or rejecting the offer. If the firm accepts the offer, the negotiation game ends. In the new wage contract the worker receives the average payoff  $w_t$ , and the firm receives the average payoff  $A - w_t$ , thereafter. If the firm rejects the offer, then the players receive their disagreement payoffs which depend on the actions taken by each player. The firm faces a choice between hiring a new unskilled worker from the competitive market, or continuing to bargain with the incumbent worker. In the former case, the firm obtains the average payoff  $1 - w_0$ . We assume that if the incumbent worker is fired, he earns the competitive wage,  $w_0$ , elsewhere. If the firm chooses not to fire the incumbent worker following a rejection, the worker is paid  $w_0$  during that period. The worker can either work hard and produce the output  $A$ , or shirk and produce  $1 - \varepsilon$ . If the worker works hard he incurs disutility  $c$  in monetary terms. Therefore, his utility when he works is  $w_0 - c$ . If he shirks he does not expend any effort, hence his utility is  $w_0$ .<sup>6</sup> The worker's decision is observed by the firm and time advances one period.

In every even-numbered period, the firm offers a wage contract,  $w_t$ , to the worker. The worker then responds by either accepting or rejecting the offer. The acceptance of the offer implements a binding contract between the firm and the agent that holds forever. If the worker rejects the offer, then

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<sup>5</sup>If there is no breach penalties, the worker could also ask for the raise before the initial contract has expired.

<sup>6</sup>Since the unskilled worker does not choose his effort level, the initial contract does not specify payments contingent on effort. Once the worker becomes skilled, he can choose whether or not to work hard. Regardless of his decision, however he is paid  $w_0$ .

the worker chooses between shirking and not shirking.<sup>7</sup> The same rules as described above govern the consequences of these decisions. We assume that

$$A - c > 1 - \varepsilon \tag{1}$$

This implies that agreement is strictly preferred to disagreement. We also assume that

$$A > w_0 + c. \tag{2}$$

This condition implies that the total output is sufficiently large so that the firm can afford to pay the worker his disutility of work above the competitive wage. If this condition does not hold, then the production is not efficient and an agreement between the incumbent worker and the firm is never reached. In the unique equilibrium of the game, the firm quits the bargaining game and hires a new worker. Both the firm and the worker have the same discount factor  $0 < \delta < 1$ . The worker's objective is to maximize the discounted sum of net earnings,

$$\sum_{t=0}^{\infty} \delta^t (w_t - c)$$

and the firm's objective is to maximize the discounted sum of profits,

$$\sum_{t=0}^{\infty} \delta^t (z_t - w_t)$$

where  $z_t = A, 1$  or  $1 - \varepsilon$  depending on whether the firm continues to bargain or reaches an agreement with the incumbent worker or hires a new worker, and whether the incumbent worker works hard or shirks.

We study the subgame-perfect equilibria of the game described above. Subgame-perfect equilibrium strategies induce a Nash equilibrium in every proper subgame. This game has four typical subgames: at the beginning of each period  $t$  when a player makes an offer, right after a proposal is made, right after a rejection and right after the firm decides whether to stay with the incumbent worker. We assume that each player observes every past action. A strategy for player  $i$ , where  $i$  stands for either the worker,  $w$ , or the firm,

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<sup>7</sup>Note that we only allow the firm to opt out after responding an offer to simplify the analysis. If the firm can opt out in every period then the game has multiple equilibria also when the firm's outside option is binding.

$f$ , is a function  $\sigma_i$ , which assigns an appropriate action to every possible history.

The model has the characteristics of a repeated game in an alternating offers bargaining game. In a simple bargaining model (Rubinstein [16]), the equilibrium strategies are a function of only past proposals and rejections. In this model, the players have a richer set of actions. The strategies are also a function of whether or not the worker has shirked in the past. Therefore, the firm can use strategies, such as punishing the worker if he shirked in any of the previous periods or compensating him in the next period if he has not shirked. When such reward and punishment mechanisms are available to the players, the game, in general, has multiple equilibria and also inefficient equilibria.

## 2.1 Firm has no outside option

We call  $G_0$ , the game where the firm has no outside option. In the  $G_0$  game, the disagreement payoffs are determined solely by the actions of the worker. We consider a subgame following a rejection. In this subgame, shirking yields to the worker a higher payoff in that period. If the worker commits himself to shirking in every period following a rejection, then the game resembles a Rubinstein game with disagreement payoffs  $(w_0, 1 - \varepsilon - w_0)$ . There exists a unique equilibrium where the worker receives  $\bar{w} = w_0 + \frac{A-1+\varepsilon}{1+\delta} + \frac{\delta c}{1+\delta}$ , the firm receives  $A - \bar{w}$ , and the agreement is reached in the first period. The firm immediately accepts the wage proposal  $\bar{w}$ . If she does not accept, she receives  $1 - \varepsilon - w_0$  this period and  $A - \hat{w}$  from the next period onward where  $\hat{w} = w_0 + \frac{c}{1+\delta} + \frac{\delta(A-1+\varepsilon)}{1+\delta}$ . This payoff is equal to receiving an average payoff  $A - \bar{w}$  every period. If an offer is rejected, the worker does not deviate from shirking, since “not shirking” yields a lower payoff in that period, and the continuation strategies are not affected by a deviation.

The wage contract  $\bar{w}$  is not the only equilibrium of the game. Given the strategy profile above, the firm obtains  $A - w_0$  if the worker does not shirk in the disagreement stage. This is not attainable as “not shirk” is a suboptimal action for the worker. If, however, the strategy profile is changed in such a way so that the continuation payoff to the worker depends on the action he chooses in the disagreement stage, the firm can increase her payoff in the disagreement stage. By obtaining a higher payoff in the disagreement stage, the firm can also obtain a higher equilibrium payoff from the game by inducing the worker to choose not to shirk. If in the next period the firm

compensates the worker for the loss generated by not shirking by proposing a higher share so that the worker's discounted payoff remains the same, he is indifferent between shirking and not shirking. In other words, if the firm offers to the worker  $w_{t+1}$  if he shirked in period  $t$ , and  $w_{t+1} + \frac{(1-\delta)c}{\delta}$  if he did not shirk, the worker is indifferent between shirking and not shirking in period  $t$  following rejection. Since he is indifferent, he chooses a suboptimal action, "not shirk", in the disagreement stage. The firm is willing to offer this additional payment because her net average payoff if the worker does not shirk,  $(A - w_0 - c)(1 - \delta) + \delta w_{t+1}$ , is greater than her average payoff if the worker shirks,  $(1 - \varepsilon - w_0)(1 - \delta) + \delta w_{t+1}$ . This is true since  $A - c > 1 - \varepsilon$  by assumption in 1. If we rewrite assumption 1 as

$$A - 1 + \varepsilon > c$$

the gains from "not shirking" exceeds the costs. Therefore, it is feasible for the firm to support the action "not shirk" in the disagreement stage. Given the player's highest and lowest disagreement payoffs, we describe the equilibrium of the game in the following proposition.

**Proposition 1** *Any wage contract  $w$  such that,*

$$w_0 + c \leq w \leq w_0 + \frac{A - 1 + \varepsilon}{1 + \delta} + \frac{\delta c}{1 + \delta}$$

*can be generated as an equilibrium wage contract with agreement reached in the first period.*

**Proof** The formal definition of the equilibrium strategies are presented in the Appendix. We also prove that these strategies are subgame-perfect and generate  $\bar{w} = w_0 + \frac{A-1+\varepsilon}{1+\delta} + \frac{\delta c}{1+\delta}$  as the maximum wage and  $\underline{w} = w_0 + c$  as the minimum wage the worker can obtain in equilibrium.

Note that  $\bar{w}$  and  $\underline{w}$  are the lowest and highest wages the worker can obtain. His lowest utility is  $w_0$ , which is equal to his reservation utility. His highest utility is  $w_0 - \frac{c}{1+\delta} + \frac{A-1+\varepsilon}{1+\delta}$ , which is greater than  $w_0$  under assumption 1.

The subgame-perfect equilibrium strategies that generate  $\bar{w}$  as an equilibrium are the following. The worker's strategy is to shirk after every rejection, offer  $\bar{w}$  in every odd-numbered period, and in every even-numbered period accept an offer  $w_t$  such that,  $w_t \geq \hat{w}$ , where  $\hat{w} = w_0 + \frac{c}{1+\delta} + \frac{\delta(A-1+\varepsilon)}{1+\delta}$ , and reject

otherwise. The firm's corresponding subgame-perfect equilibrium strategy is to propose  $\hat{w}$  in every even-numbered period and accept any offer that pays  $w_t \leq \bar{w}$  in every odd-numbered period.

The minimum wage equilibrium,  $\underline{w}$ , is generated by the following pair of strategies. The firm proposes  $\underline{w} + \frac{(1-\delta)c}{\delta}$  in every even-numbered period if the worker did not shirk in the previous period and proposes  $\underline{w}$  otherwise. She accepts any offer that pays  $w_t \leq \underline{w}$  in every odd-numbered period. If the firm deviates from her strategy, she is punished by the maximum wage equilibrium,  $\bar{w}$ . The worker's strategy is to offer at least  $\underline{w}$  in every odd-numbered periods and accept any offer  $w_t \geq \underline{w}$  in every even-numbered period. In every even-numbered period he shirks if he is not offered at least  $\underline{w}$  or he does not accept an acceptable offer and in every odd-numbered period he shirks if he asks more than  $\underline{w}$  or his proposal of  $\underline{w}$  is rejected.

The equilibrium strategy that we propose calls for the worker to shirk in every even-numbered period and not to shirk in the odd-numbered periods. A strategy that calls for the worker not to shirk in every period generates the same result. If we consider an alternating offers bargaining game with constant disagreement payoffs in every period, a player's equilibrium payoff is increasing in his disagreement payoff only during periods that he responds to an offer. If his disagreement payoff is high, his acceptable offer will be high, hence he can obtain a higher share from the bargaining game. When the player makes a proposal and his offer is accepted, he collects the residual. In this case the size of his payoff depends negatively on the opponent's disagreement payoff. As long as agreement is preferred to disagreement, the residual he obtains exceeds his disagreement payoff. Thus, his disagreement payoff is irrelevant. In the game we analyze, the worker receives the same disagreement payoff regardless of whether or not he shirks. He receives  $w_0$  in even-numbered periods because he shirks. In odd-numbered periods he does not shirk and receives  $w_0 - c$ , but he is compensated in the next period, so that on the average he obtains  $w_0$  in odd-numbered periods as well. From the firm's point of view, the actions taken by the worker during periods when the firm makes an offer do not affect the equilibrium payoff that he receives. However, during periods when the worker responds to an offer, the firm guarantees herself the highest sustainable disagreement payoff and thus receives the highest equilibrium payoff of the game if she supports the "not shirk" action of the worker. (For a more detailed discussion on this see Busch and Wen [4].) Any wage contract  $w$  such that  $\underline{w} < w_0 < \bar{w}$  can be supported by subgame-perfect equilibrium strategies by punishing the worker with the

minimum wage equilibrium if he deviates and the firm with the maximum wage equilibrium if she deviates.

The wage increase the worker can capture from the bargaining game ranges between  $c$  and  $\frac{\delta c}{1+\delta} + \frac{A-1+\varepsilon}{1+\delta}$ . The minimum wage contract equalizes the worker's utility to his reservation utility,  $w_0$ . Thus, the worker is indifferent between working in this firm or elsewhere. The maximum wage contract is increasing in the parameter  $\varepsilon$ .  $\varepsilon$  can be interpreted as a measure of the worker's ability to hold-up the firm in wage negotiation and  $\varepsilon$  takes values between  $[0, 1)$ .

### 2.1.1 Inefficient Equilibria

Besides the efficient subgame-perfect equilibria in which the agreement is reached at the first period, the bargaining game also has inefficient equilibria in which delays occur in real time before an agreement is reached. The following proposition characterizes these inefficient equilibria.

**Proposition 2** *If  $\tilde{w}$  is such that*

$$w_0 + c \leq \tilde{w} \leq \frac{\delta^T - 1}{\delta^T} (A - 1 + \varepsilon + w_0) + \frac{1}{\delta^T} \bar{w}$$

*then there is a subgame-perfect equilibrium in which the worker shirks for  $T$  periods followed by an agreement of  $\tilde{w}$ .*

**Proof** We provide conditions that are sufficient for deviations not to occur. Along the equilibrium path, the player's strategies are as follows. In every odd-numbered period up to period  $T + 1$ , the worker makes a non-serious offer to the firm and the firm rejects his offer. In every period up to the period  $T + 1$ , the worker shirks. In period  $T + 1$ , the worker offers  $\tilde{w}$  if it is an odd-numbered period, and accepts any offer that pays him at least  $\tilde{w}$ , if it is an even-numbered period. The firm makes a non-serious offer to the worker in every even-numbered period up to  $T + 1$ . In  $T + 1$ , the firm offers  $\tilde{w}$ , if it is even numbered period, and accepts any offer that pays at least  $\tilde{w}$ , if it is an odd-numbered period.

The worker can always obtain  $\underline{w}$  in the first period. In order for the worker to be willing to shirk for  $T$  periods and receive  $\tilde{w}$  in period  $T + 1$ , he should prefer to receive  $w_0$  for  $T$  periods and  $\tilde{w}$  thereafter. Hence,

$$\frac{w_0}{1-\delta} \leq \frac{w_0 - \delta^T w_0}{1-\delta} + \frac{\delta^T (\tilde{w} - c)}{1-\delta}$$

or

$$w_0 + c \leq \tilde{w}$$

In the same manner, the firm can obtain her lowest equilibrium payoff,  $A - \bar{w}$  in the first period. In order for the firm not to deviate from the equilibrium strategy, she should prefer to receive  $(1 - \varepsilon - w_0)$  for  $T$  periods and  $\tilde{w}$  thereafter. Hence,

$$\frac{A - \bar{w}}{1 - \delta} \leq (1 - \varepsilon - w_0) + \dots + \delta^{T-1} (1 - \varepsilon - w_0) + \frac{\delta^T (A - \tilde{w})}{1 - \delta}$$

which is equivalent to

$$\tilde{w} \leq \frac{\delta^T - 1}{\delta^T} (A - 1 + \varepsilon + w_0) + \frac{1}{\delta^T} \bar{w}$$

In order for  $\tilde{w}$  to exist,  $w_0 + c$  has to be smaller than  $\frac{\delta^T - 1}{\delta^T} (A - 1 + \varepsilon + w_0) + \frac{1}{\delta^T} \bar{w}$  which holds always given assumption 1. The player's deviations from the strategies described above is eliminated by "equilibrium switching". If the worker deviates, he is punished with the minimum wage contract. If the firm deviates, then she is punished with the maximum wage contract.

## 2.2 Bargaining with outside option

In every odd-numbered period, the rejection of the worker's proposal leaves the firm with the choice of firing the incumbent and hiring a new worker, or continuing to bargain with the incumbent worker. If the new worker is hired, he is paid the competitive wage,  $w_0$ , and produces 1 unit of output. We assume that, once the new unskilled worker is hired, the firm and the worker sign an infinitely-lived contract and the worker remains permanently unskilled. We call this the  $G_1$  game. In an alternating offers bargaining game, the outside option changes the equilibrium of the game if and only if the firm obtains a higher payoff by exercising this option than by continuing to bargain with the incumbent worker.<sup>8</sup> If the firm rejects the worker's offer

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<sup>8</sup>See Shaked and Sutton [18] more on this.

and hires a new worker, her discounted total payoff is  $\frac{1-w_0}{1-\delta}$ . If she stays with the incumbent worker, she obtains at least  $\frac{A-\bar{w}}{1-\delta}$ . If the lowest equilibrium payoff the firm obtains in  $G_0$  is greater than her outside option, then the firm never exercises this option. Since it does not constitute a credible threat, the value of the outside option does not affect the distribution of the surplus in the  $G_1$  game. Thus, the set of equilibria of the  $G_1$  game is the same as the set of equilibria of the  $G_0$  game. If, however, the firm's outside option is binding, then the  $G_1$  game has a unique subgame-perfect equilibrium in which the firm receives her outside option. The following proposition describes the set of equilibria of the bargaining game when the firm can quit the bargaining game only after rejecting an offer.

**Proposition 3** *If  $A - c - \frac{\varepsilon}{\delta} > 1$ , then the firm's outside option is never binding and the set of equilibria of the  $G_1$  game is the same as the set of equilibria of the  $G_0$  game. If  $1 \leq A - c < 1 + \frac{\varepsilon}{\delta}$ , then the firm's outside option is binding for some equilibria of the  $G_0$  game. Hence, the  $G_1$  game has multiple equilibria in which the firm receives at least her outside option,  $1 - w_0$ . If  $A - c \leq 1$ , then the firm's outside option is always binding and the  $G_1$  game has a unique equilibrium in which the firm fires the incumbent worker and hires a new worker and receives  $1 - w_0$ .*

**Proof** A formal proof of this proposition can be found in Osborne and Rubinstein [15].

We now discuss the derivation of the conditions in proposition 3. In any subgame-perfect equilibrium of this game the firm receives, at least,  $A - \bar{w}$ , and at most,  $A - c - w_0$ . The firm's outside option is never binding if the average payoff she receives from the outside option is less than the lowest average equilibrium payoff she obtains from the  $G_0$  game. In other words, if

$$1 - w_0 < A - \bar{w}$$

or, equivalently,

$$A - c - \frac{\varepsilon}{\delta} > 1$$

then the firm never exercises her outside option in any subgame-perfect equilibrium of the game. Thus, the set of equilibria of the game  $G_1$  coincides with the set of equilibria of the game  $G_0$ .

If the average payoff that the firm receives from the outside option is greater than her lowest average equilibrium payoff, but smaller than her highest average equilibrium payoff, then the firm's outside option is binding for some of the equilibria of the  $G_0$  game. This happens if

$$1 < A - c < 1 + \frac{\varepsilon}{\delta}.$$

Then the lowest equilibrium payoff the firm obtains in the  $G_1$  game is  $1 - w_0$  and the highest payoff is, as before,  $A - c - w_0$ .

The firm's outside option is always binding if the average payoff from the outside option is greater than her highest average equilibrium payoff. In this case the firm asks at least  $1 - w_0$ . If the worker accepts this offer, he receives  $A - 1 + w_0$ . However, the wage that the worker receives must satisfy his individual rationality constraint, i.e.  $A - 1 + w_0 > w_0 + c$ . Otherwise, the worker does not accept the contract. This condition implies that  $A - c > 1$ , which contradicts the assumption that the outside option is binding. Therefore, if the outside option is binding, the unique equilibrium of the game is the one where the firm quits the bargaining game in the first period and hires an unskilled worker from the competitive labor market. This occurs if  $c$  is too high. Even though the firm can compensate the worker for exerting high effort, i.e.  $A > c + w_0$ , it is not profitable for her to do so. As her net surplus from hiring an unskilled worker,  $1 - w_0$ , is higher than her net surplus from hiring the skilled worker,  $A - c - w_0$ . The equilibrium of the game is inefficient because 1 unit of output is produced, instead of  $A > 1$ .

It can be easily shown that inefficient equilibria always exist in the second case of the lemma 3 where the firm's outside option is binding only for some equilibria of the  $G_0$  game. Both players can obtain their lowest payoff in a perfect equilibrium where the agreement is reached in the first period. The worker can always obtain  $\underline{w}$  in the first period. In order for the worker to be willing to shirk for  $T$  periods and receive  $w^*$  in period  $T + 1$ , he should prefer to receive  $w_0$  for  $T$  periods and  $w^*$  thereafter. Hence,

$$\frac{w_0}{1 - \delta} \leq \frac{w_0 - \delta^T w_0}{1 - \delta} + \frac{\delta^T (w^* - c)}{1 - \delta}.$$

or

$$w_0 + c \leq w^*$$

In the same manner, the firm can obtain her lowest equilibrium payoff,  $1 - w_0$ , in the first period. In order for the firm not to deviate from the

equilibrium strategy, she should prefer to receive  $(1 - \varepsilon - w_0)$  for  $T$  periods and  $w^*$  thereafter. Hence, we have

$$1 - w_0 \leq (1 - \varepsilon - w_0) + \dots + \delta^{T-1} (1 - \varepsilon - w_0) + \delta^T w^*$$

which is equivalent to

$$w^* \leq A - \varepsilon \left( \frac{1 - \delta^T}{\delta^T} \right) - (1 - w_0).$$

In order for  $w^*$  to exist,  $w_0 + c$  has to be smaller than  $A - \varepsilon \left( \frac{1 - \delta^T}{\delta^T} \right) - (1 - w_0)$  which holds always given assumption 1.

### 3 Concluding Remarks

We study the bargaining relationship between a firm and its incumbent worker who possesses firm-specific human capital. The incumbent worker is more productive than the outsiders because of the special skills and information he acquires during his employment. During the contract renewal stage, the worker can strategically disclose these skills in order to increase his bargaining power. The firm can threaten to fire the worker and hire an unskilled worker in the competitive market, but this threat is not always credible. When the firm's outside option is not binding, the bargaining game has multiple equilibria, some of which are inefficient. In the minimum wage equilibrium, the worker is paid a wage so that he is indifferent between working in this firm or elsewhere at the competitive wage. In the maximum wage equilibrium, the worker is able to capture part of the surplus created by his increased productivity. The worker's rent is increasing in his ability to strategically disclose his skills. In the inefficient equilibria, the agreement is reached in period  $T > 1$  and the worker shirks in every period prior to agreement.

If the firm's outside option is binding for some equilibria of the game, then the lowest equilibrium payoff the firm receives is bounded by the value of her outside option. If the firm's outside option is always binding, then in the unique equilibrium of the game the firm fires the incumbent worker and hires an unskilled worker. In this case, even though the production is efficient, it is not profitable for the firm to compensate the worker because his disutility of exerting effort is very high. Thus, in the equilibrium the amount of output produced is less than the efficient amount.

The existing literature on the wage bargaining between the firm and its skilled workers emphasizes that firm-specific human capital is the source of the worker's increased bargaining power. However, these models fail to capture the ex-post inefficiency that may arise as a result of the bargaining. In our model, the ex-post inefficiency arises because of the workers' opportunistic behavior during the bargaining. By shirking during the periods in which the agreement has not been reached the worker is able to capture a rent by obtaining a higher wage. Our results support the conclusions of Williamson et al [22] who argue that when jobs involve specialized skills and information that can be learned by on-the-job training, the market fails to efficiently carry out the exchange between the firm and its employee.

## 4 Appendix

We define  $H_1(t)$  be the history at the beginning of period  $t$ , which consists of all the rejected offers and the disagreement outcomes up to date,  $H_2(t)$  is the history after an offer has been made in period  $t$ , and  $H_3(t)$  is the history after a rejection in period  $t$ . We denote  $\sigma_i$  to be the player  $i$ 's strategy which assigns an appropriate action to every possible history.

For every period  $t$ , we define  $D_t$  to be the function of all actions taken in that period excluding the worker's decision whether to shirk, such that,

$$D_t = \begin{cases} fd & \text{if } t \text{ is even and } w_t < \sigma_f(h_1(t)) \\ & \text{if } t \text{ is odd, } w_t \leq \sigma_w(h_1(t)) \text{ but the firm rejected.} \\ wd & \text{if } t \text{ is odd and } w_t > \sigma_w(h_1(t)) \\ & \text{if } t \text{ is even, } w_t > \sigma_f(h_1(t)) \text{ but the worker rejected.} \\ nod & \text{otherwise.} \end{cases}$$

$D_t$  indicates whether or not the firm or the worker has deviated in period  $t$  prior to the worker's decision to shirk. If  $D_t = fd$ , the firm has deviated because she either made an incorrect offer if  $t$  is an even-numbered period, or she did not accept an acceptable offer when  $t$  is an odd-numbered period. If  $D_t = wd$ , the worker has deviated because he either made an incorrect offer when  $t$  is an odd-numbered period, or he did not accept an acceptable offer when  $t$  is an even-numbered period. If neither the firm nor the worker has deviated, then  $D_t = nod$ .

For every period  $t$ , let  $FD_t$  be a function of actions taken in period  $t$  such that

$$FD_t = \begin{cases} d & \text{if } D_t = fd \\ nd & \text{otherwise} \end{cases}$$

$FD_t$  indicates whether or not the firm has deviated in period  $t$ . Similarly, let  $WD_t$  be a function of all actions taken in period  $t$  such that

$$WD_t = \begin{cases} d & \text{if } D_t = wd; \text{ or} \\ & \text{if } \tau \text{ is odd, } D_t = nod \text{ for any } \tau \leq t \text{ but} \\ & \text{the worker shirked in that period} \\ nd & \text{otherwise} \end{cases}$$

$WD_t$  indicates whether or not the worker has deviated in period  $t$ . The proposed equilibrium strategy in the odd-numbered periods prescribes that the worker shirks only if either the firm or the worker deviated from their equilibrium strategy profiles in the previous stage of the game. Therefore, the worker has deviated in period  $t$  if he shirks even though neither he nor the firm has deviated in previous stages of the game. We also define  $I_t$  for every period  $t$  and  $\tau, \tau' < t$  as

$$I_t = \begin{cases} f & \text{if } \sup \{ \tau \mid FD_\tau = d \} > \sup \{ \tau' \mid WD_{\tau'} = d \} \\ w & \text{if } \sup \{ \tau \mid FD_\tau = d \} \leq \sup \{ \tau' \mid WD_{\tau'} = d \} \\ nod & \text{if } \sup \{ \tau \mid FD_\tau = d \} = \sup \{ \tau' \mid WD_{\tau'} = d \} = 0 \end{cases}$$

$I_t$  is a function that indicates the identity of the player who last deviated from his/her strategy profile in history up to period  $t$ .  $\tau$  is the last period prior to period  $t$  in which the firm deviated and  $\tau'$  is the last period prior to period  $t$  in which the worker deviated. If  $\tau > \tau'$  then the firm is the last deviant. If  $\tau < \tau'$  then the worker is the last deviant. If  $\tau = \tau'$  then the worker is again the last deviant since he makes the last move within a period, by choosing between shirking and not shirking.<sup>9</sup> Then the following

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<sup>9</sup>If  $\tau = \tau'$  and  $\tau$  is even, the firm deviated by making an incorrect offer. If the worker deviates by accepting the firm's incorrect offer the game is over. Therefore, the only possible deviation for the worker is to make an incorrect shirking decision and he becomes

strategies generate  $w$  as an equilibrium wage, for any  $w \in [\underline{w}, \bar{w}]$ . For period 1

$$\begin{aligned} \sigma_w(h_1(1)) &= w \\ \sigma_f(h_2(1)) &= \begin{cases} N & \text{if } \sigma_w(h_2(1)) > \bar{w} \\ Y & \text{otherwise} \end{cases} \\ \sigma_w(h_3(1)) &= \begin{cases} ns & \text{if } D_1 = nod \\ s & \text{otherwise} \end{cases} \end{aligned}$$

For  $t$  odd and greater than 1,

$$\begin{aligned} \sigma_w(h_1(t)) &= \begin{cases} \bar{w} & \text{if } I_t = f; \text{ or} \\ \underline{w} & \text{if } I_t = w \\ w & \text{otherwise} \end{cases} \\ \sigma_f(h_2(t)) &= \begin{cases} Y & \text{if } \sigma_w(h_2(t)) < \underline{w}; \text{ or} \\ & \text{if } \sigma_w(h_2(t)) \leq \bar{w} \text{ but } I_t = f \\ N & \text{otherwise} \end{cases} \\ \sigma_w(h_3(t)) &= \begin{cases} ns & \text{if } D_t = nod \text{ and } I_t = nod \\ s & \text{otherwise} \end{cases} \end{aligned}$$

For  $t$  even,

$$\begin{aligned} \sigma_f(h_1(t)) &= \begin{cases} \hat{w} & \text{if } I_t = f; \text{ or} \\ \underline{w} & \text{if } I_t = w \\ w + \frac{c(1-\delta)}{\delta} & \text{otherwise} \end{cases} \\ \sigma_w(h_2(t)) &= \begin{cases} Y & \text{if } \sigma_f(h_1(t)) > \hat{w}; \text{ or} \\ & \text{if } w_t \geq \underline{w} \text{ and } I_t = w \\ N & \text{otherwise} \end{cases} \\ \sigma_w(h_3(t)) &= s \end{aligned}$$

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the last deviant. If  $\tau = \tau'$  and  $\tau$  is odd then the only way the firm has deviated is by rejecting a correct offer. The only way the worker can deviate is by making an incorrect shirking decision. Since the worker's shirking decision takes place after the firm rejects the offer, the worker is the last deviant.

where  $\hat{w} = \frac{\delta(A-1+\varepsilon)}{1+\delta} + \frac{c}{1+\delta} + w_0$ .

In order to show that the proposed equilibrium strategies profile generates a subgame-perfect equilibrium, we prove that there is no one-shot profitable deviation from this strategies profile in any proper subgame of the game. First, we show that this is true for the first period. The bargaining game starts with the worker making an offer. We claim that any wage contract  $w$  can be generated as a subgame-perfect equilibrium wage of the game, for any  $w \in [\underline{w}, \bar{w}]$ . If the worker follows the proposed strategy and asks for  $w$  and the firm accepts it, the worker receives the discounted total payoff  $\frac{w-c}{1-\delta}$  and the firm receives  $\frac{A-w}{1-\delta}$ . If the worker deviates and asks for  $x_1$  higher than  $w$ , the firm rejects the offer. Then the worker shirks and receives  $w_0$  this period. Next period, the firm offers  $w$  to the worker. If the worker accepts this offer he obtains  $\frac{w_0}{1-\delta}$ , which is less than or equal to  $\frac{w-c}{1-\delta}$ . Hence, the worker does not gain from asking a higher wage. If the worker asks for  $w$  and the firm rejects, the worker shirks next period and the firm obtains  $1 - \varepsilon - w_0$  this period. Next period the firm proposes  $\hat{w}$  to the worker and the worker accepts. The firm's total discounted payoff from this deviation is  $1 - \varepsilon - w_0 + \frac{\delta}{1-\delta} (A - \hat{w})$  which is less than or equal to  $\frac{A-w}{1-\delta}$ . Hence, the firm does not gain from rejecting the worker's proposal. If the worker asks for  $x_1$ , which is higher than  $w$ , and the firm deviates from the proposed strategy by accepting the offer, then the firm receives  $\frac{A-x_1}{1-\delta}$  which is less than  $\frac{A-w}{1-\delta}$ . Thus, the firm will not accept such an offer. If the worker ask for  $x_1$  which is higher than  $w$  and the firm rejects his offer, the worker obtains  $\frac{w_0}{1-\delta}$  if he shirks following the firm's refusal. If he does not shirk, however, he obtains  $w_0 - c$  this period, he is offered  $\underline{w}$  next period and his total discounted payoff is  $\frac{w_0}{1-\delta} - c$ . Thus, not shirking is not a profitable deviation.

Next we show that there is no profitable one-shot deviation from the proposed equilibrium strategies profile for either of the players in any proper subgame. There are two possible histories for each subgame. The first type is one where the firm is the last deviant and the second type is one where the worker is the last deviant. We consider a subgame in the beginning of period  $t$ . Regardless of the path that led the game to this point, the proposed strategies are prescribed contingent on the identity of the player who last deviated in that history. We now consider two histories,  $h_1(t)$  and  $h'_1(t)$  that lead to the subgame in period  $t$ . As long as the identity of the last deviant is the same in both histories, the strategies, as a function of these histories, will be the same. Thus, it is sufficient to check the subgame

perfection for these two types of histories. We show that for any wage  $w$ , such that,  $\underline{w} \leq w \leq \bar{w}$ , there is no profitable one-shot deviation from the proposed strategies profile for either player in any subgame following the two possible histories.

We consider a subgame that starts in an odd-numbered period with a history where the worker deviated last. The proposed equilibrium strategy prescribes that the worker asks for  $\underline{w}$  and the firm accepts it. The worker obtains  $\frac{w_0}{1-\delta}$  and the firm receives  $\frac{A-c-w_0}{1-\delta}$  by playing this strategy. If the worker asks for  $w_t$  higher than  $\underline{w}$ , the firm rejects the offer. Then the worker shirks and receives  $w_0$  this period. Next period, the firm offers  $\underline{w}$  to the worker. The worker's total discounted payoff from deviating is  $\frac{w_0}{1-\delta}$ . Thus, the worker does not gain by deviating from this strategy. If the worker asks  $\underline{w}$  and the firm rejects the proposed wage, then the worker shirks. The firm receives  $1 - \varepsilon - w_0$  this period and next period she offers  $\hat{w}$  since she deviated by not accepting the offer. The firm's total discounted payoff is  $1 - \varepsilon - w_0 + \frac{\delta}{1-\delta} (A - \hat{w})$  which is less than  $\frac{A-c-w_0}{1-\delta}$ . Thus, rejecting the worker's offer is not a profitable deviation for the firm. If the worker asks for  $w_t$  that is larger than  $\underline{w}$  and the firm deviates from the proposed equilibrium strategy by accepting the offer, the firm receives  $\frac{A-w_t}{1-\delta}$ , which is less than  $\frac{A-c-w_0}{1-\delta}$ . Thus, the firm will not accept such an offer. If the worker asks for  $w_t > \underline{w}$  and the firm rejects, then the worker obtains  $\frac{w_0}{1-\delta}$  if he shirks following the firm's refusal. The worker receives  $w_0$  this period and is offered  $\underline{w}$  thereafter since he deviated by asking a higher wage. If the worker does not shirk, however, he obtains  $w_0 - c$  this period and  $\underline{w}$  from the next period onward. Thus, his total discounted payoff from not shirking is  $\frac{w_0}{1-\delta} - c$ . Therefore, the worker does not deviate.

We now consider a subgame beginning in an odd-numbered period where the firm was the last deviant. The proposed equilibrium strategy calls for the worker to propose  $\bar{w}$  and the firm to accept the offer. Following this strategy, the worker receives  $\frac{\bar{w}-c}{1-\delta}$  and the firm receives  $\frac{A-\bar{w}}{1-\delta}$ . If the worker asks for  $w_t$  that is larger than  $\bar{w}$ , the firm rejects the offer. Then the worker shirks and receives  $w_0$  this period. Next period, the firm offers the worker  $\underline{w}$  because the worker has deviated by asking a higher wage. The worker's total discounted payoff is  $\frac{w_0}{1-\delta} - c$ , which is smaller than  $\frac{\bar{w}-c}{1-\delta}$ . Thus the worker will not deviate. If the worker offers  $\bar{w}$  and the firm rejects, then the worker shirks. The firm receives  $1 - \varepsilon - w_0$  this period and next period the firm offers  $\hat{w}$  since she deviated by not accepting the offer. The firm's total discounted payoff is  $1 - \varepsilon - w_0 + \frac{\delta}{1-\delta} (A - \hat{w})$ , which is less than  $\frac{A-\bar{w}}{1-\delta}$ . Thus, rejecting

the worker's offer is not a profitable deviation for the firm. If the worker asks for  $w_t$  that is larger than  $\bar{w}$  and the firm deviates from the proposed strategy by accepting the offer, the firm receives  $\frac{A-w_t}{1-\delta}$ , which is less than  $\frac{A-\bar{w}}{1-\delta}$ . Thus, the firm will not accept such an offer. If the worker asks for  $w_t > \bar{w}$  and the firm rejects, then the worker obtains  $\frac{w_0}{1-\delta}$  if he shirks following the firm's refusal. If he does not shirk, he obtains  $w_0 - c$  this period and is offered  $\underline{w}$  next period, thus he obtains  $\frac{w_0}{1-\delta} - c$ , which is less than  $\frac{w_0}{1-\delta}$ . Hence, he does not deviate from his proposed equilibrium strategy (shirk) if his offer is not accepted.

Next we consider a subgame beginning in an even-numbered period where the worker is the last deviant. The proposed equilibrium strategy prescribes that the firm offers  $\underline{w}$  and the worker accepts it. The worker obtains  $\frac{w_0}{1-\delta}$  and the firm receives  $\frac{A-c-w_0}{1-\delta}$  by playing this equilibrium strategy. If the firm offers  $w_t$  that is smaller than  $\underline{w}$ , the worker rejects the offer and shirks. The firm receives  $1 - \varepsilon - w_0$  this period. Next period, the worker asks for  $\bar{w}$  because the firm deviated by making an incorrect offer. The firm's total discounted payoff from deviating is  $1 - \varepsilon - w_0 + \frac{\delta}{1-\delta} (A - \bar{w})$ , which is smaller than  $\frac{A-c-w_0}{1-\delta}$ . Thus the firm does not deviate from his proposed strategy. If the firm offers  $\underline{w}$  and the worker rejects it, then the worker shirks. The worker receives  $w_0$  this period and next period the firm offers  $\underline{w}$ . The worker's total discounted payoff is  $\frac{w_0}{1-\delta}$ , which is the same as what he would have received if he accepted the initial offer in the first place. Thus the worker does not deviate. If the firm offers  $w_t$  that is smaller than  $\underline{w}$  and the worker deviates from the proposed strategy by accepting the offer, the worker receives  $\frac{w_t-c}{1-\delta}$ , which is less than  $\frac{w_0}{1-\delta}$ , the payoff he obtains by rejecting the offer. Thus, the worker will not accept such an offer. If the firm offers  $w_t > \underline{w}$  and the worker rejects, then the worker receives  $w_0 - c + \frac{\delta}{1-\delta} (\bar{w} - c)$  if he does not shirk following the firm's refusal. Note that the firm is the last deviant by making an incorrect proposal. Since the worker receives  $w_0 + \frac{\delta}{1-\delta} (\bar{w} - c)$  if he shirks, he does not deviate from his proposed strategy in this subgame.

We now consider a subgame beginning in an even-numbered period where the firm is the last deviant. The proposed equilibrium strategy prescribes that the firm offers  $\hat{w}$  and the worker accepts it. The worker obtains  $\frac{\hat{w}-c}{1-\delta}$  and the firm receives  $\frac{A-\hat{w}}{1-\delta}$  by playing this proposed strategy. If the firm offers wage  $w_t$  that is smaller than  $\underline{w}$ , the worker rejects the offer and shirks. The firm receives  $1 - \varepsilon - w_0$  this period. Next period, the worker asks for  $\bar{w}$  because the firm deviated by making an incorrect offer. The firm's total

discounted payoff from deviating is  $1 - \varepsilon - w_0 + \frac{\delta}{1-\delta} (A - \bar{w})$ , which is smaller than  $\frac{A-\hat{w}}{1-\delta}$ . Thus, the firm does not deviate from his proposed strategy. If the firm offers  $\hat{w}$  and the worker rejects it, then the worker shirks. The worker receives  $w_0$  this period and next period the worker asks for  $\underline{w}$  because the worker has deviated by not accepting the correct offer. The worker's total discounted payoff is  $\frac{w_0}{1-\delta}$  which is less than  $\frac{\hat{w}-c}{1-\delta}$ . Thus rejecting the offer is not a profitable deviation. If the firm offers a wage  $w_t$  which is smaller than  $\hat{w}$  and the worker deviates from the proposed strategy by accepting the offer, the worker receives  $\frac{w_t-c}{1-\delta}$ . If the worker rejects the offer he obtains  $w_0 + \frac{\delta}{1-\delta} (\bar{w} - c)$  which is equal to  $\frac{\hat{w}-c}{1-\delta}$ , hence, greater than  $\frac{w_t-c}{1-\delta}$ . Thus, the worker will not accept such an offer. If the firm offers  $w_t < \hat{w}$  and the worker rejects it, then the worker obtains  $w_0 - c + \frac{\delta}{1-\delta} (\bar{w} - c)$  if he does not shirk following the firm's refusal. Since he receives  $w_0 + \frac{\delta}{1-\delta} (\bar{w} - c)$  if he shirks, the worker will not deviate from the proposed strategy in this subgame and shirk following the firm's refusal.

We have shown that the strategy profile described above generates a subgame-perfect equilibrium wage  $w$ , for any  $w \in [\underline{w}, \bar{w}]$ . Next we show that  $\underline{w}$  and  $\bar{w}$  are indeed the lowest and highest wages the worker can obtain in the equilibrium generated by these strategies. We prove this by contradiction. Suppose that  $\underline{w}$  is not the lowest equilibrium wage and there exist  $w' < \underline{w}$  that can be generated as an equilibrium wage by the same strategies. If the agreement is reached in the first period, the worker receives the total discounted payoff,  $\frac{w'-c}{1-\delta}$  and the firm receives  $\frac{A-w'}{1-\delta}$ . The following deviation is profitable for the worker. If the worker deviates by asking a wage  $w > w'$ , then the firm rejects and the worker shirks. The worker receives  $w_0$  this period and next period the firm proposes  $\underline{w}$  to the worker. If the worker accepts his total discounted utility is  $w_0 + \frac{\delta}{1-\delta} (\underline{w} - c)$ , which is greater than  $\frac{w'-c}{1-\delta}$ . Since the worker gains from deviating,  $w'$  can not be an equilibrium wage. This is true for any  $w' < \underline{w}$ .

Now we consider a wage contract  $w''$  that pays more than  $\bar{w}$ . The following is a profitable deviation for the firm in the first period. The firm deviates by rejecting the worker's offer and the worker shirks. The firm receives  $1 - w_0 - \varepsilon$  this period and offers  $\hat{w}$  next period. The worker accepts this offer and the firm receives a total discounted payoff  $1 - w_0 - \varepsilon + \frac{\delta(A-\hat{w})}{1-\delta}$ , which is greater than  $\frac{A-w''}{1-\delta}$  for any  $w''$  that is greater than  $\bar{w}$ . Therefore any wage contract  $w''$  that pays more than  $\bar{w}$  cannot be generated by the particular

strategy profile we presented.

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