

Bargaining with Endogenous Deadlines

Ana Mauleon
LABORES (URA 362, CNRS),
Université catholique de Lille.

Vincent Vannetelbosch^{*†}
FNRS, CORE and IRES,
Université catholique de Louvain.

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Abstract

We develop a two-person negotiation model with complete information that makes endogenous both the deadline and the level of surplus destruction after the deadline. We show that the undominated Nash equilibrium outcome is always unique but might be inefficient. Moreover, as the bargaining period becomes short or as the players become very patient, the unique undominated Nash equilibrium outcome is always inefficient.

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^{*}Vincent Vannetelbosch is Chercheur Qualifié at the Fonds National de la Recherche Scientifique, Brussels.

[†]Corresponding author: CORE, Université catholique de Louvain, Voie du Roman Pays 34, B-1348 Louvain-la-Neuve, Belgium. Tel: 0032-10-474142. Fax: 0032-10-474301. E-mail: vannetelbosch@core.ucl.ac.be

1 Introduction

Negotiations often take place under the pressure of a deadline that may be exogenously imposed, or one of the parties to the negotiation may have chosen the deadline and made a credible commitment to it. Recent work has focused on bargaining models with exogenous deadlines after which there is no surplus to be divided. (See Fershtman and Seidmann (1993), Ma and Manove (1993).) A key feature of our paper is a first attempt to endogenize the deadline in negotiation models. We consider a more general definition of a deadline as a point in time after which the surplus to be shared is permanently reduced.

Moreover, we allow the players to choose the level of surplus destruction after the deadline. Thus, in case an agreement is not reached before the deadline, the value of the underlying relationship will be permanently reduced, and the level of surplus destruction will depend on the actions of the players. Then, the surplus available to the players once an agreement is reached may actually be lower than it is at the beginning.

In one example of bargaining in the face of such endogenous deadlines, wage negotiations between unions and employers, both parties may have the opportunity to set a deadline after which starts either a strike or a lockout. The deadline may be subject to labour laws : it is common that a strike or a lockout requires few days' notice in order to be legal. However, a conflict may reduce permanently the profitability of the relationship itself by affecting, for example, the future demand for the firm's products. Indeed, customers may decide to buy from now on from some competitor. In order to avoid the loss of customers, the firm may decide to move (partially or entirely) the production to another plant or to use replacement workers. However the firm is not alone in having actions at its disposal that directly influence the profitability of the future relationship. For example, the union may jeopardize production equipment by the lack of scheduled maintenance or skilled operators.¹

In this paper, we develop a two-stage negotiation model with complete information between a firm and a union. In the first stage, the deadline in force during the wage bargaining is chosen. That is, the firm and the union choose, respectively, a lockout date (and the intensity of the lockout) and a strike date (and the intensity of the strike). In addition, we allow both parties to choose no deadline. In the second stage, both parties bargain over the division of a surplus that is time dependent. Indeed, before the deadline

¹Cutcher-Gershenfeld *et al.* (1998) have examined, for the U.S., pressure tactics used by unions and employers to influence the process in collective bargaining and its outcomes. In the past, the threats of a strike and the imminent contract expiration deadline have been central features motivating the parties to reach agreements. But in recent years, the observations suggest that management threats regarding replacement workers and plant closings or movings are now also a key part of the collective bargaining landscape.

we have a peaceful bargaining, where in each period until a new agreement is reached, both parties continue to produce and the value added is shared following the old wage contract. After the deadline we have an open-conflict bargaining (a strike or a lockout has occurred), where in each period until a new agreement is reached both parties get nothing and the value added in later periods (once an agreement is reached) will be affected by the intensity of the conflict occurred. The wage bargaining proceeds following Rubinstein's (1982) alternating-offer bargaining procedure with the firm making the first offer.

We show that the undominated Nash equilibrium outcome of our negotiation model is always unique but might be inefficient. The condition to get inefficiency is satisfied whenever the old wage is relatively small, each player has at his disposal both actions that reduce substantially the value added in the future and actions that have only a minor impact on the future value added, and the players are patient. Which is the intuition behind the result? Both players would like the other player to be the last mover at the deadline and preferably facing the threat of a conflict of a strong intensity. A strong conflict simply means that after the deadline, the value added will be reduced substantially. Then, in order to avoid having to accept a very low wage offer facing the threat of a severe lockout, where the firm would grab most of the surplus, it becomes optimal for the union to strike immediately and to destroy part of the future value added, but not too much. So, at equilibrium we observe both players competing to be the one who will make an offer just before the deadline, but also trying to avoid having to move at the deadline due to the threat of a very strong conflict. This can lead to one party launching the conflict immediately and to the conclusion of a Pareto-dominated agreement. Finally, as the bargaining period becomes short or as the players become very patient, the unique undominated Nash equilibrium outcome is always inefficient.

Our two-stage negotiation model is related to papers that derive bargaining inefficiency under complete information², e.g. van Damme et al. (1990), Fernandez and Glazer (1991), Haller and Holden (1990). One important difference is that inefficiency and delay can arise in these other models because there exist multiple efficient equilibria, while the undominated equilibrium is always unique but sometimes inefficient in our model.³

Another strand of related literature includes papers on bargaining models with exogenous deadlines. In fact, any finite horizon bargaining model can be interpreted as such. Fershtman and Seidmann study a complete information bargaining model with a

²Another source for agreements reached with delay is incomplete information (see e.g. Watson, 1998).

³Van Damme *et al.* (1990) have considered an extension of Rubinstein's bargaining game wherein there is a smallest money unit (i.e. the number of feasible agreements is finite). In Vannetelbosch (1999a) it is shown that this discrete bargaining game can have multiple *undominated* subgame perfect equilibrium outcomes. The same holds for Fernandez and Glazer (1991) and Haller and Holden (1990) models.

random proposer and an exogenous deadline beyond which there is no surplus to divide. They assume that a player cannot accept a lower share of the surplus than she has previously rejected during the bargaining session. This endogenous commitment assumption together with the deadline imply that, for patient players, there is a unique equilibrium where agreements are delayed until the deadline. This result depends on the interaction between the existence of a deadline and endogenous commitment. Absent the endogenous commitment, the other assumption cannot explain delay. Ma and Manove construct a bargaining model with complete information, whose unique equilibrium is such that early in the game offers are postponed and late in the game agreements are reached or the deadline is missed with positive probability. To obtain such equilibrium, two assumptions are introduced to the finite-horizon alternating-offer bargaining model. The first one is strategic delay. An alternating-offer model incorporates strategic delay if a player is permitted to postpone the implementation of her move without losing her turn. The second assumption is imperfect player control over the timing of offers during the bargaining session. Offers and counter-offers are exchanged with exogenous random delay.

In these papers just mentioned, the deadline is exogenously determined. Here, we show that once the deadline is endogenous, no other assumptions such as endogenous commitment or strategic delay are needed to get a unique and inefficient equilibrium. Moreover, our result may also justify the existence of Pareto-inferior phenomena other than strikes or lockouts, such as tariff wars, debt moratoria, break-up of cease-fires or wars in general.

The next section presents the basic negotiation model and some preliminary results. In Section 3 we characterize the equilibrium of the deadline stage game and show that the undominated Nash equilibrium outcome is always unique but might be inefficient. In Section 4 we discuss some of the assumptions of the model. Section 5 concludes.

2 The negotiation model

We develop a two-stage negotiation model; its timing is depicted in Figure 1. In the first stage, before the wage bargaining starts at time 0, the firm and the union choose simultaneously a lockout date $d_f \in \{0, 1, 2, 3, \dots, \infty\}$ and its intensity $\gamma_f \in \{\underline{\gamma}, \bar{\gamma}\}$ and a strike date $d_u \in \{0, 1, 2, 3, \dots, \infty\}$ and its intensity $\gamma_u \in \{\underline{\gamma}, \bar{\gamma}\}$, respectively. We allow both parties to choose no deadline: $d_f = \infty$ simply means that the firm decides to not choose a lockout date. Afterwards, the players are committed to the deadline and its intensity they have chosen. A deadline rule that seems reasonable and fits with wage negotiations follows: Let (d, γ) be the deadline and its intensity in force during the wage bargaining

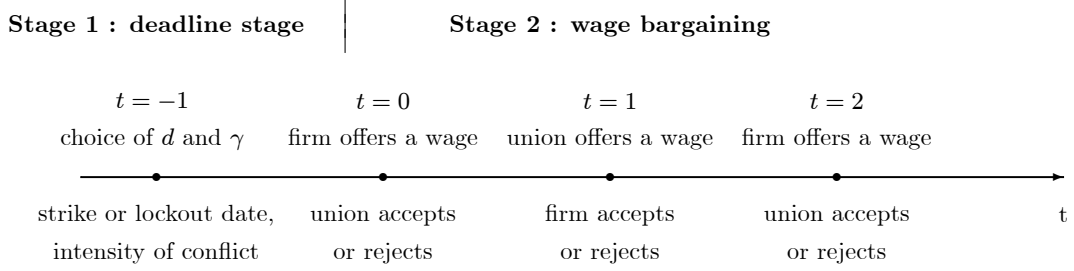


Figure 1: The timing of the negotiation model

stage. It is given by

$$(d, \gamma) = \begin{cases} (d_f, \gamma_f) & \text{if } d_f < d_u, \\ (d_u, \gamma_u) & \text{if } d_u < d_f, \\ (d_u, \min\{\gamma_f, \gamma_u\}) & \text{if } d_u = d_f. \end{cases} \quad (1)$$

That is, the deadline in force and its intensity (d, γ) are determined by the minimum of the deadline choices of the players, and in case of ties, ties are broken in favour of the more intense conflict. This simple deadline rule implies that the wage bargaining will take place facing either the threat of a lockout or the threat of a strike. Finally, $(\infty, \cdot)$ denotes the case where both parties decide to choose neither a strike date nor a lockout date.⁴

In the second stage of the negotiation model, the deadline d and its intensity γ set are common knowledge, and both parties begin to negotiate. There is an infinite number of periods, and in each period of normal production the firm has a value added of one unit of a good that the firm and the union can divide between them. The union's share is $W \in [0, 1]$; the firm's share is $1 - W$. Two bargaining phases are distinguished. Before the deadline we will have a peaceful bargaining, where in each period until a new agreement is reached both parties continue to produce and the value added is shared following the old contract. Initially the wage level in the old contract is $W_0 > 0$. After the deadline we will have an open-conflict bargaining (a strike or a lockout has occurred), where in each period until a new agreement is reached both parties get zero and the value added in later periods (once a new agreement is reached) will be affected by the intensity of the conflict, γ (where γ will be equal to $\underline{\gamma}$ or $\bar{\gamma}$ with $\underline{\gamma} < \bar{\gamma} < 1$).

⁴We can also interpret the commitment assumption to start a conflict at the deadline in terms of negotiators' reputation. Imagine that no agreement has been reached and that the union decides not to go on strike at the chosen deadline. Since the strike date is public knowledge (due to labour laws), the union would lose most of its reputation for the on-going negotiation as well as for future ones. In other words, the results we obtain are robust to the case where the commitment is revocable but the cost of revoking is large enough.

For simplicity, both parties are assumed to have linear utility functions, so their payoffs can be represented by the discounted sum of future shares. For the union this is

$$U = \sum_{t=0}^{\infty} \delta^t \cdot u_t, \quad (2)$$

where $u_t = W_0$ if $t < d$ and an agreement has yet to be reached, $u_t = 0$ if $t \geq d$ and no agreement has been reached, and $u_t = W$ for $t \geq s$ if an agreement is reached at period s on W . The common discount factor is $\delta \in (0, 1)$. For the firm we have correspondingly

$$V = \sum_{t=0}^{\infty} \delta^t \cdot v_t, \quad (3)$$

where $v_t = 1 - W_0$ if $t < d$ and an agreement has yet to be reached, $v_t = 0$ if $t \geq d$ and no agreement has been reached, $v_t = 1 - W$ for $t \geq s$ if an agreement is reached at period $s < d$, and $v_t = \gamma - W$ for $t \geq s$ if an agreement is reached at period $s \geq d$.

The bargaining proceeds following Rubinstein's alternating-offer bargaining procedure. The players are assumed to make offers alternately, one offer per period, and without loss of generality the firm is assumed to make an offer in the beginning of period 0. The union can then accept or reject this offer. If the union accepts, the bargaining ends. If the firm's offer is rejected the union makes a new offer in the next period, which the firm accepts or rejects. If the firm accepts, the bargaining ends. If the union's offer is rejected the firm makes a new offer in the next period, and so on until an agreement is reached. Both parties are assumed to have perfect information in the bargaining stage.

We denote $B(d, \gamma)$ the bargaining stage, in other words the alternating-offer bargaining game where it is common knowledge that the deadline is d and its intensity is γ . As in Rubinstein, one can show that the alternating-offer bargaining game $B(d, \gamma)$ possesses a unique subgame perfect equilibrium (SPE) and that an agreement is reached without delay at period 0. When the deadline in force is an odd period the SPE wage $W^*(d \text{ odd}, \gamma)$ and payoffs are

$$W^*(d \text{ odd}, \gamma) = (1 - \delta^d) \cdot W_0 + \frac{\delta^d \cdot \gamma}{1 + \delta}, \quad (4)$$

$$U^*(d \text{ odd}, \gamma) = \frac{1 - \delta^d}{1 - \delta} \cdot W_0 + \frac{\delta^d \cdot \gamma}{1 - \delta^2}, \quad (5)$$

$$V^*(d \text{ odd}, \gamma) = \frac{1}{1 - \delta} - \frac{1 - \delta^d}{1 - \delta} \cdot W_0 - \frac{\delta^d \cdot \gamma}{1 - \delta^2}. \quad (6)$$

When the deadline in force is an even period the SPE wage $W^*(d \text{ even}, \gamma)$ and payoffs are

$$W^*(d \text{ even}, \gamma) = (1 - \delta^d) \cdot W_0 + \frac{\delta^d \cdot (1 + \delta - \gamma)}{1 + \delta}, \quad (7)$$

$$U^*(d \text{ even}, \gamma) = \frac{1 - \delta^d}{1 - \delta} \cdot W_0 + \frac{\delta^d \cdot (1 + \delta - \gamma)}{1 - \delta^2}, \quad (8)$$

$$V^*(d \text{ even}, \gamma) = \frac{1}{1 - \delta} - \frac{1 - \delta^d}{1 - \delta} \cdot W_0 - \frac{\delta^d \cdot (1 + \delta - \gamma)}{1 - \delta^2}. \quad (9)$$

When the deadline in force is set at period 0, we enter immediately an open-conflict that affects forever the value added to be shared, and the SPE wage $W^*(0, \gamma)$ and payoffs are

$$W^*(0, \gamma) = \frac{\delta \cdot \gamma}{1 + \delta}, U^*(0, \gamma) = \frac{\delta \cdot \gamma}{1 - \delta^2}, V^*(0, \gamma) = \frac{\gamma}{1 - \delta^2}. \quad (10)$$

When no deadline is set, the SPE wage $W^*(\infty, \cdot)$ and payoffs are (see Haller and Holden)

$$W^*(\infty, \cdot) = W_0, U^*(\infty, \cdot) = \frac{W_0}{1 - \delta}, V^*(\infty, \cdot) = \frac{1 - W_0}{1 - \delta}. \quad (11)$$

Comparing the expressions here and above, we obtain the next lemma, giving us some ideas about the preferences of the players over the intensity of the conflict at equilibrium given a deadline d .

Lemma 1 *For any deadline d odd, $W^*(d, \underline{\gamma}) < W^*(d, \bar{\gamma})$, $U^*(d, \underline{\gamma}) < U^*(d, \bar{\gamma})$, and $V^*(d, \underline{\gamma}) > V^*(d, \bar{\gamma})$. For any deadline $d \neq 0$ even, $W^*(d, \underline{\gamma}) > W^*(d, \bar{\gamma})$, $U^*(d, \underline{\gamma}) > U^*(d, \bar{\gamma})$, and $V^*(d, \underline{\gamma}) < V^*(d, \bar{\gamma})$.*

Lemma 1 tells us that, the union prefers the negotiation facing the threat of a conflict of a weak (strong) intensity rather than facing the threat of a conflict of a strong (weak) intensity whenever the deadline is odd (even). A conflict of a strong intensity is simply the case where $\gamma = \underline{\gamma}$, and a conflict of a weak intensity is the case $\gamma = \bar{\gamma}$. On the contrary, the firm prefers the negotiation facing the threat of a conflict of a strong (weak) intensity rather than facing the threat of a conflict of a weak (strong) intensity whenever the deadline is odd (even).

3 Endogenous deadlines

We turn back to stage one of the negotiation model, where the firm and the union choose simultaneously a lockout date $d_f \in \{0, 1, 2, 3, \dots, \infty\}$ and its intensity $\gamma_f \in \{\underline{\gamma}, \bar{\gamma}\}$ and a strike date $d_u \in \{0, 1, 2, 3, \dots, \infty\}$ and its intensity $\gamma_u \in \{\underline{\gamma}, \bar{\gamma}\}$, respectively.⁵ Thus, a strategy for the firm is denoted by (d_f, γ_f) and a strategy for the union is denoted

⁵The results we obtain are not modified if we allow more than two levels of intensity of the conflict.

(d_u, γ_u) in the deadline stage game. Remember that the deadline in force during the wage negotiation is the earliest date among the lockout date and the strike date. In case of a tie we simply assume that the conflict with the strongest intensity will start at the chosen deadline. This assumption to break ties is quite reasonable in case of wage negotiations. Nevertheless, the results we obtain are qualitatively robust to a more general assumption where ties are broken with high probability in favour of the strongest conflict.

Since we allow the firm to choose $(d_f = 0, \gamma_f)$ and the union to choose $(d_u = 0, \gamma_u)$, possible inefficiency is not excluded a-priori. In Table 1 we represent (very partially) the matrix of the deadline stage game, where the firm is the row player and the union is the column player.

	$0, \underline{\gamma}$	$0, \bar{\gamma}$	$1, \bar{\gamma}$	$2, \underline{\gamma}$	$\infty, \cdot$
$0, \underline{\gamma}$	$\underline{\gamma} - W^*(0, \underline{\gamma})$	$\underline{\gamma} - W^*(0, \underline{\gamma})$	$\underline{\gamma} - W^*(0, \underline{\gamma})$	$\underline{\gamma} - W^*(0, \underline{\gamma})$	$\underline{\gamma} - W^*(0, \underline{\gamma})$
$0, \bar{\gamma}$	$\underline{\gamma} - W^*(0, \underline{\gamma})$	$\bar{\gamma} - W^*(0, \bar{\gamma})$	$\bar{\gamma} - W^*(0, \bar{\gamma})$	$\bar{\gamma} - W^*(0, \bar{\gamma})$	$\bar{\gamma} - W^*(0, \bar{\gamma})$
$1, \underline{\gamma}$	$\underline{\gamma} - W^*(0, \underline{\gamma})$	$\bar{\gamma} - W^*(0, \bar{\gamma})$	$1 - W^*(1, \underline{\gamma})$	$1 - W^*(1, \underline{\gamma})$	$1 - W^*(1, \underline{\gamma})$
$2, \bar{\gamma}$	$\underline{\gamma} - W^*(0, \underline{\gamma})$	$\bar{\gamma} - W^*(0, \bar{\gamma})$	$1 - W^*(1, \bar{\gamma})$	$1 - W^*(2, \underline{\gamma})$	$1 - W^*(2, \bar{\gamma})$
$\infty, \cdot$	$\underline{\gamma} - W^*(0, \underline{\gamma})$	$\bar{\gamma} - W^*(0, \bar{\gamma})$	$1 - W^*(1, \bar{\gamma})$	$1 - W^*(2, \underline{\gamma})$	$1 - W_0$

Table 1: The strategic choice of a deadline

In the matrix we only give the per-period SPE payoff for the firm; the per-period SPE payoff for the union is simply the SPE wage. For solving the deadline stage game, a natural concept is the Nash equilibrium (NE). However, this concept fails to exclude strategy profiles that seem implausible such as $\{(0, \underline{\gamma}), (0, \underline{\gamma})\}$.

In most of the equilibrium selection literature it is widely accepted that Nash equilibria involving weakly dominated strategies are not reasonable. Indeed, every perfect, proper, essential, strongly stable or regular equilibrium is undominated (see van Damme, 1991). Moreover, every element of a stable set (Kohlberg and Mertens, 1986) is undominated too. We propose to use the undominated Nash equilibrium concept as a device to select plausible outcomes among the Nash ones. A strategy profile $((d_f, \gamma_f), (d_u, \gamma_u))$ is an undominated NE if and only if it is a NE and neither (d_f, γ_f) nor (d_u, γ_u) is weakly dominated with respect to $\{0, 1, 2, \dots, \infty\} \times \{\underline{\gamma}, \bar{\gamma}\}$. We say that a player's strategy is weakly dominated if the player has another strategy at least as good no matter what the other player does and better for at least some strategy of the other player.⁶

⁶A formal definition of the undominated NE concept for normal-form games can be found in van Damme (1991) or Salonen (1996). In finite normal form games there always exists an undominated NE. Salonen has shown a more general result: an undominated NE exists if (a) strategy sets are convex polytopes in $\mathbb{R}^n$ where n is the number of players and (b) utility functions are affine with respect to each player's own

From Lemma 1 and the weak dominance concept, it is obvious that $(d_f \text{ odd}, \bar{\gamma})$ is weakly dominated by $(d_f \text{ odd}, \underline{\gamma})$. Indeed, (i) against any (d_u, γ_u) such that $d_u > d_f$, the strategy $(d_f \text{ odd}, \underline{\gamma})$ is doing strictly better than $(d_f \text{ odd}, \bar{\gamma})$, (ii) against any (d_u, γ_u) such that $d_u < d_f$, the strategy $(d_f \text{ odd}, \underline{\gamma})$ is doing as well as $(d_f \text{ odd}, \bar{\gamma})$, (iii) against any (d_u, γ_u) such that $d_u = d_f$, the strategy $(d_f \text{ odd}, \underline{\gamma})$ is doing strictly better than $(d_f \text{ odd}, \bar{\gamma})$ if $\gamma_u = \bar{\gamma}$ and is doing equally well if $\gamma_u = \underline{\gamma}$. Similarly, one can show that $(d_f \text{ even}, \underline{\gamma})$ is weakly dominated by $(d_f \text{ even}, \bar{\gamma})$, $(d_u \text{ odd}, \underline{\gamma})$ is weakly dominated by $(d_u \text{ odd}, \bar{\gamma})$, $(d_u \neq 0 \text{ even}, \bar{\gamma})$ is weakly dominated by $(d_u \neq 0 \text{ even}, \underline{\gamma})$, and $(d_u = 0, \underline{\gamma})$ is weakly dominated by $(d_u = 0, \bar{\gamma})$.

Lemma 2 *The strategies $(d_f \text{ odd}, \bar{\gamma})$, $(d_f \text{ even}, \underline{\gamma})$, $(d_u \text{ odd}, \underline{\gamma})$, $(d_u \neq 0 \text{ even}, \bar{\gamma})$ and $(d_u = 0, \underline{\gamma})$ are all weakly dominated.*

Throughout the paper we focus on the case where the players are sufficiently patient (δ large), which can be reinterpreted as though the interval between offers and counteroffers is short.⁷ More precisely, we focus on the case where $\delta > \bar{\gamma} > \underline{\gamma}$.

Assumption 1 $\delta > \bar{\gamma}$.

Lemma 3 *The strategies $(d_f \text{ even}, \bar{\gamma})$, $(d_u \text{ odd}, \bar{\gamma})$ are all weakly dominated.*

Indeed, if $\delta > \bar{\gamma}$ then $(d_f \neq 0 \text{ even}, \bar{\gamma})$ is weakly dominated by $(d_f - 1, \underline{\gamma})$, $(d_f = 0, \bar{\gamma})$ is weakly dominated by $(d_f = 1, \underline{\gamma})$, and $(d_u \text{ odd}, \bar{\gamma})$ is weakly dominated by $(d_u + 1, \underline{\gamma})$. Throughout the paper the proofs related to weak dominance results are similar to the one of Lemma 2 and, henceforth, these proofs are omitted. What will be the equilibrium outcomes?⁸ From Lemma 2 and Lemma 3 we know that the union may choose either $(d_u = 0, \gamma_u = \bar{\gamma})$ or $(d_u \neq 0 \text{ even}, \gamma_u = \underline{\gamma})$, and the firm may choose $(d_f \text{ odd}, \gamma_f = \underline{\gamma})$. So, the "unreasonable" NE strategy profiles $((0, \underline{\gamma}), (0, \underline{\gamma}))$ and $((0, \bar{\gamma}), (0, \bar{\gamma}))$ cannot be undominated NE profiles because $(0, \underline{\gamma})$ is a weakly dominated strategy for both players and $(0, \bar{\gamma})$ is a weakly dominated strategy for the firm. For instance, $(d_f = 0, \gamma_f = \bar{\gamma})$ is weakly dominated by $(d_f = 1, \gamma_f = \underline{\gamma})$. Choosing $(d_f = 0, \gamma_f = \bar{\gamma})$ instead of $(d_f = 1, \gamma_f = \underline{\gamma})$ will give the firm an equally well payoff against $(d_u = 0, \gamma_u)$ but a strictly worst payoff against any $(d_u > 0, \gamma_u)$. The fact that a player does not want to take unnecessary risk is captured by the notion of undominated NE.

strategy.

⁷The discount factor can also be expressed by the formula $\delta = \exp(-r \cdot \Delta)$, where $r > 0$ is discount rate and Δ is the length of a single bargaining period.

⁸It can be shown that, when $\delta > \bar{\gamma} > \underline{\gamma}$, NE outcomes are $(d = 0, \gamma = \underline{\gamma})$, $(d = 0, \gamma = \bar{\gamma})$, and $(d = 1, \gamma = \underline{\gamma})$ iff $W_0 > \frac{\delta(\bar{\gamma}-\underline{\gamma})}{1-\delta^2}$. The concept of undominated NE permits us to say under which conditions NE outcomes are reasonable ones if ever.

Lemma 4 *If $W_0 < \frac{1+\delta-\gamma}{1+\delta}$ then the strategies $(d_u \geq 4 \text{ and even}, \underline{\gamma})$ and $(d_u = \infty, \cdot)$ are weakly dominated.*

Lemma 5 *If $W_0 > \frac{\gamma}{1+\delta}$ then the strategies $(d_f \geq 3 \text{ and odd}, \underline{\gamma})$ and $(d_f = \infty, \cdot)$ are weakly dominated.*

Could it be that the no deadline situation is an undominated NE outcome? No. Indeed, from Lemma 2 to Lemma 5 we already know that, the firm will choose $(1, \underline{\gamma})$ if $W_0 > \frac{\gamma}{1+\delta}$ and the union will choose between $(0, \bar{\gamma})$ and $(2, \underline{\gamma})$ if $W_0 < \frac{1+\delta-\gamma}{1+\delta}$. In order to characterize the undominated NE outcome fully we distinguish three cases.

Case 1 : $\frac{1+\delta-\gamma}{1+\delta} > \frac{\gamma}{1+\delta} \geq W_0$.

It follows from Lemma 2 to Lemma 5 that, at equilibrium, the union could choose either the strategies $(0, \bar{\gamma})$ or $(2, \underline{\gamma})$ and the firm could choose either the strategies $(d_f \geq 1 \text{ odd}, \underline{\gamma})$ or $(\infty, \cdot)$. If the union chooses $(2, \underline{\gamma})$, then the unique best response for the firm is $(1, \underline{\gamma})$. If the union chooses $(0, \bar{\gamma})$, then best responses for the firm are $(d_f \geq 1 \text{ odd}, \underline{\gamma})$ and $(\infty, \cdot)$. If the firm chooses $(d_f \geq 3 \text{ odd}, \underline{\gamma})$ or $(\infty, \cdot)$, then the unique best response for the union is $(2, \underline{\gamma})$. If the firm chooses $(1, \underline{\gamma})$, then the unique best response for the union is $(0, \bar{\gamma})$ if $W_0 < \frac{\delta}{(1+\delta)(1-\delta)}(\bar{\gamma} - \underline{\gamma})$ and otherwise $(2, \underline{\gamma})$. Indeed, $W^*(0, \bar{\gamma}) = \frac{\delta}{1+\delta}\bar{\gamma} > (1-\delta)W_0 + \frac{\delta}{1+\delta}\underline{\gamma} = W^*(1, \underline{\gamma})$ reverts to $W_0 < \frac{\delta}{(1+\delta)(1-\delta)}(\bar{\gamma} - \underline{\gamma})$. As a consequence, the unique undominated NE is $\{(1, \underline{\gamma}), (0, \bar{\gamma})\}$ if $W_0 < \frac{\delta}{(1+\delta)(1-\delta)}(\bar{\gamma} - \underline{\gamma})$ and is $\{(1, \underline{\gamma}), (2, \underline{\gamma})\}$ otherwise.

Case 2 : $\frac{1+\delta-\gamma}{1+\delta} > W_0 > \frac{\gamma}{1+\delta}$.

It follows from Lemma 2 to Lemma 5 that, at equilibrium, the union could choose either the strategies $(0, \bar{\gamma})$ or $(2, \underline{\gamma})$ and the firm will choose the strategy $(1, \underline{\gamma})$. Hence, given that the firm chooses $(1, \underline{\gamma})$, the union will choose $(0, \bar{\gamma})$ if $W^*(0, \bar{\gamma}) = \frac{\delta}{1+\delta}\bar{\gamma} > (1-\delta)W_0 + \frac{\delta}{1+\delta}\underline{\gamma} = W^*(1, \underline{\gamma})$. That is, if $W_0 < \frac{\delta}{(1+\delta)(1-\delta)}(\bar{\gamma} - \underline{\gamma})$. Otherwise, the union will choose $(2, \underline{\gamma})$.

Case 3 : $W_0 \geq \frac{1+\delta-\gamma}{1+\delta} > \frac{\gamma}{1+\delta}$.

It follows from Lemma 2 to Lemma 5 that, at equilibrium, the union could choose either the strategies $(0, \bar{\gamma})$ or $(d_u \geq 2 \text{ even}, \underline{\gamma})$ or $(\infty, \cdot)$ and the firm is going to choose the strategy $(1, \underline{\gamma})$. Hence, given that the firm chooses $(1, \underline{\gamma})$, the union will choose $(0, \bar{\gamma})$ if $W^*(0, \bar{\gamma}) = \frac{\delta}{1+\delta}\bar{\gamma} > (1-\delta)W_0 + \frac{\delta}{1+\delta}\underline{\gamma} = W^*(1, \underline{\gamma})$. That is, if $W_0 < \frac{\delta}{(1+\delta)(1-\delta)}(\bar{\gamma} - \underline{\gamma})$. Otherwise, the union will choose $(d_u \geq 2 \text{ even}, \underline{\gamma})$ or $(\infty, \cdot)$.

Having characterized the equilibrium strategies we can show that the deadline stage

game has a unique undominated NE.⁹ Indeed, if $W_0 > \frac{\delta}{(1+\delta)(1-\delta)}(\bar{\gamma} - \underline{\gamma})$ then the unique undominated NE outcome is $d = 1$ and $\gamma = \underline{\gamma}$. So, at equilibrium, the firm and the union will start the wage bargaining under the threat of a severe lockout at period 1. The firm will make a wage offer $W^*(d = 1, \underline{\gamma}) = (1 - \delta) \cdot W_0 + \frac{\delta \underline{\gamma}}{1+\delta}$ at period 0, and the union will accept this offer immediately.

Proposition 1 *If $W_0 > \frac{\delta}{(1+\delta)(1-\delta)}(\bar{\gamma} - \underline{\gamma})$ then the negotiation model has a unique and efficient undominated Nash equilibrium outcome. The deadline (a lockout threat of a strong intensity) is set at period 1 and an agreement on $W^*(d = 1, \underline{\gamma})$ is reached immediately at period 0.*

However, if $W_0 < \frac{\delta}{(1+\delta)(1-\delta)}(\bar{\gamma} - \underline{\gamma})$ there is a unique undominated NE strategy profile where the firm chooses $(d_f = 1, \underline{\gamma})$ and the union chooses $(d_u = 0, \bar{\gamma})$. So, if $W_0 < \frac{\delta}{(1+\delta)(1-\delta)}(\bar{\gamma} - \underline{\gamma})$ the unique undominated NE outcome is $d = 0$ and $\gamma = \bar{\gamma}$, and it is an inefficient outcome since a strike of a weak intensity occurs immediately at the start of the wage bargaining.

That is, if the equilibrium wage in case of an immediate strike of a weak intensity is greater than the equilibrium wage in case of the union moving at the deadline and facing the threat of a lockout of a strong intensity, then the union will choose at equilibrium to implement immediately a strike of a weak intensity. Since the old wage contract is small enough, the difference between $\bar{\gamma}$ and $\underline{\gamma}$ is large enough and the players are patient enough, it becomes optimal for the union to go immediately on strike and to destroy part of the available surplus. Indeed, such a conflict of a weak intensity allows the union to avoid having to accept a very low wage in the face of a severe lockout that would allow the firm to grab most of the surplus. So, at equilibrium, the union goes into conflict immediately, and a Pareto-dominated agreement follows. In fact, this equilibrium outcome is Pareto-dominated by the equilibrium outcome of $B(d_u = 1, \bar{\gamma})$. At equilibrium, the firm will make a wage offer $W^*(d = 0, \bar{\gamma}) = \frac{\delta \bar{\gamma}}{1+\delta}$ at period 0, and the union will accept this offer immediately.

Proposition 2 *If $W_0 < \frac{\delta}{(1+\delta)(1-\delta)}(\bar{\gamma} - \underline{\gamma})$ then the negotiation model has a unique and inefficient undominated Nash equilibrium outcome. A conflict of a weak intensity starts immediately at time 0 followed by an immediate agreement on $W^*(d = 0, \bar{\gamma})$. The per-period efficiency loss is equal to $1 - \bar{\gamma}$.*

The firm at equilibrium chooses $(d_f = 1, \underline{\gamma})$ either because it is a dominant strategy or because otherwise the firm faces serious repercussions: the union would choose another

⁹Notice that all the results we get throughout the paper can be obtained using rationalizability concepts as defined in Herings and Vannetelbosch (1999, 2000) and Vannetelbosch (1999b).

deadline, leaving the firm with the threat of a severe strike that would allow the union to grab most of the surplus.

The condition $W_0 < \frac{\delta}{(1+\delta)(1-\delta)}(\bar{\gamma} - \underline{\gamma})$ is satisfied whenever the old wage W_0 is relatively small, each player has at his disposal both actions that reduce substantially the value added in the future and actions that have only a minor impact on the future value added¹⁰ (in other words, the difference between $\bar{\gamma}$ and $\underline{\gamma}$ is large enough), and the players are patient (δ is large enough).

Before discussing some of the assumptions, we will also consider the limit case of fully patient players as δ goes to one.

Corollary 1 *As δ goes to one or as the interval between offers and counteroffers vanishes, the negotiation model has a unique and inefficient undominated Nash equilibrium. A conflict of a weak intensity starts at time zero followed by an immediate agreement on $W^*(d=0, \bar{\gamma}) = \frac{1}{2}\bar{\gamma}$.*

Notice that we have taken the limit $\delta \rightarrow 1$, assuming that the players can still reduce permanently the future value added. This assumption may be questionable once we reinterpret the limit as the interval between offers and counteroffers vanishes. An alternative assumption is to suppose that the level of surplus destruction would decline as Δ decreases. Nevertheless, we still obtain the inefficiency result if we assume that the intensities of a conflict are bounded below one. That is, if $\underline{\gamma}(\Delta) < \bar{\gamma}(\Delta) < \delta$ for all Δ and $\lim_{\Delta \rightarrow 0} \underline{\gamma}(\Delta) < \lim_{\Delta \rightarrow 0} \bar{\gamma}(\Delta) < 1$.

4 Discussion

Before concluding we comment upon some of the assumptions of the model. Section 4.1 contains a discussion about the assumption that the players are committed to engage in conflict at the deadline. In Section 4.2 we discuss the assumption that the surplus destruction due to a conflict does not depend on the duration of the conflict. Finally, Section 4.3 is devoted to lockouts.

¹⁰The actions as well as their impact on the future value added may depend on factors such as the competition on both the product market and the labour market (see Cutcher-Gershenfeld *et al.*, 1998). Indeed, if there is a strong competition in the product market, a labour conflict may induce a big loss in market power and future revenues to be generated. However, if there is a strong competition and mobility in the labour market, the impact of a conflict could be reduced since the firm may more easily find temporary replacement workers.

4.1 The commitment assumption

If at least one of the parties has chosen a deadline, the wage bargaining will take place facing either the threat of a lockout or the threat of a strike. It is assumed that if no agreement is reached prior to the deadline, then a conflict will occur with probability one at the deadline. In other words, one of the parties is committed to start a conflict at the deadline. One interpretation for such commitment assumption is in terms of negotiators' reputation. For instance, the union could lose most of its reputation for the on-going negotiation and futures ones if it decides not to go on strike at the chosen deadline. An alternative interpretation for the commitment assumption has to do with certain rules and rituals followed by unions. Labour disputes are often preceded by strike ballots. Goerke and Holler (1999) have analyzed the consequences of strike ballots in a noncooperative model of negotiations between a union and a firm over wage increases. The firm possesses private information about its revenues. The union can only obtain a wage increase if it makes a rejection of a wage demand costly to the firm due to a strike. However, it might be that strike threats are empty because they are not credible. Goerke and Holler have shown that strike ballots can remedy this feature since ballots can provide a commitment to adhere to a strike decision. Thus, ballots can make strike threats credible. For this effect to occur, the timing of voting is crucial: ballot should take place before the first demand can be rejected. They have also derived the minimum level of commitment that a strike ballot must have if a worker is to support a strike in the vote assuming that a strike ballot imposes positive costs on a strike breaker.

As the analysis of Goerke and Holler has made clear, if we allow the union to choose a strike date and make a strike ballot at time zero, then if costs imposed on strike breakers are sufficiently high, the ballot will make credible the threat to strike at the chosen deadline. Thereby we conclude that making strike ballots and deadline notices compulsory can lead to inefficiencies, even in an environment of complete information.

4.2 The severity of labour conflicts

We have allowed the players to choose the deadline after which the surplus to be shared is permanently reduced as well as the level of surplus destruction after the deadline. The union can choose between a "light" strike and a "severe" strike. An interpretation for light strikes are partial strikes or work to rule. One might argue that long lasting damage from labour conflicts (such as a permanent loss of customers or suppliers) is typically caused by prolonged conflicts rather than high intensity of a short conflict whereas duration does not matter in our model. It is assumed that the surplus destruction after the deadline, in case no agreement is reached before the deadline, does not depend on the duration of

the conflict. An alternative would have been both to fix the per-period level of surplus destruction due to strikes and lockouts, and to allow the parties to choose the length or duration of the conflict. Then, both players would like the other player to be the last mover at the deadline and preferably facing the threat of a conflict of a long duration. It might still be optimal for the union to go on strike immediately for a short time, thus not having to accept a very low wage offer or to face the threat of a long lasting lockout where the firm would grab most of the surplus. Thereby, inefficiency losses, but smaller ones, might still occur.

However, in many labour conflicts the main cost of the negotiation appears to be its lasting effects on the profitability of the firm rather than the foregone revenue during the strike or the lockout. For instance, the union could disclose some information about the firm's products that could negatively affect the demand beyond the date of an agreement. Moreover, empirical evidence has suggested that most of the "news" in a strike seems to be incorporated in the Stock Market valuation very early in the strike. Dinardo and Hallock (2002) have examined the Stock Market's responsiveness to strikes by looking at strike actions that labour historians generally view as the major ones occurring in the USA in the years 1925-37. They have found that strikes had large, negative effects on industry stock valuation. In addition, longer strikes, violent strikes, strikes won by the union, strikes leading to union recognition, industry-wide strikes, and strikes that led to wage increases were associated with larger negative share price reactions than other strikes. Industry stock price movements around the start and the end of the strike have also been studied. Their analysis has shown that much of the "news" generated by the typical strikes seems to have been registered by the Stock Market very early in the strike. A negative share price reaction of 3 percent around the start of the strike was observed.¹¹

4.3 Lockouts

Firms have an almost as powerful weapon in their negotiating arsenal through the mechanism of a lockout.¹² Following Fernandez and Glazer, we have treated strikes and lockouts symmetrically. We have assumed that the firm can give the union a deadline notice of the commencement of the lockout, at which time a protected lockout would begin, permitting the firm to lock all workers out of the workplace. In another type of lockout, a lockout in response to a strike, the firm may wish to take the upper hand in seeking a defensive

¹¹Other related studies have suggested a loss of between 1 and 4 percent around the start of the strike; see e.g. Becker and Olson (1986), Nelson, Amoako-Adu and Smith (1994).

¹²Fischer (2001) has developed an asymmetric information model of collective bargaining where the firm has the bargaining power and the union the private information. Results show that the firm may use lockouts to induce the union to reveal its private information.

lockout during a strike; this results in the union and workers being able to bring the strike to an end, but then having to face the lockout. In this case a specification where strikes could be followed by defensive lockouts may be more appropriated. We next incorporate the possibility of defensive lockouts into our model.

In the first stage, before the wage bargaining starts at time 0, the firm and the union still choose simultaneously a lockout date $d_f \in \{0, 1, 2, 3, \dots, \infty\}$ and its intensity $\gamma_f \in \{\underline{\gamma}, \bar{\gamma}\}$ and a strike date $d_u \in \{0, 1, 2, 3, \dots, \infty\}$ and its intensity $\gamma_u \in \{\underline{\gamma}, \bar{\gamma}\}$, respectively. Afterwards, the players are committed to the deadline and the intensity they have chosen. In the second stage of the negotiation model, the deadlines (d_f, γ_f) and (d_u, γ_u) are common knowledge and both parties begin to negotiate with the firm making the first offer. The firm can now use a lockout in two ways: either to preempt the occurrence of a strike (preemptive lockout) or to bring to an end an on-going strike (defensive lockout). The possibility of defensive lockouts is assumed to modify the surplus to be shared each period as follows:

1. $d_u > d_f$. Then, both players will negotiate facing the threat of a lockout. If an agreement is reached before d_f , then the surplus to be shared each period is equal to 1. If an agreement is reached at period $t \geq d_f$, then for $t' < d_f$ the surplus is equal to 1, for $d_f \leq t' < t$ the surplus is equal to 0, and for $t' \geq t$ the surplus is equal to γ_f .
2. $d_u < d_f$. Then, both players will negotiate facing the threat of a strike followed by a defensive lockout. If an agreement is reached before d_u , then the surplus to be shared each period is equal to 1. If an agreement is reached at period $t \in [d_u, d_f)$, then for $t' < d_u$ the surplus is equal to 1, for $d_u \leq t' < t$ the surplus is equal to 0, and for $t' \geq t$ the surplus is equal to γ_u . If an agreement is reached at period $t \geq d_f$, then for $t' < d_u$ the surplus is equal to 1, for $d_u \leq t' < t$ the surplus is equal to 0, and for $t' \geq t$ the surplus is equal to $\min\{\gamma_f, \gamma_u\}$.
3. $d_u = d_f$. Then, if an agreement is reached before d_u , the surplus to be shared each period is equal to 1. If an agreement is reached at period $t \geq d_u$, then for $t' < d_u$ the surplus is equal to 1, for $d_u \leq t' < t$ the surplus is equal to 0, and for $t' \geq t$ the surplus is equal to $\min\{\gamma_f, \gamma_u\}$.

The rest of the model is left unchanged, and we still assume that $\delta > \bar{\gamma} > \underline{\gamma}$. Once the firm has the possibility of using defensive lockouts, it can be shown that the negotiation model has a unique undominated NE outcome that is always efficient. The intuition behind this result is that striking cannot revoke the threat of a severe "defensive" lockout. It is still

optimal for the firm to choose the threat of a severe lockout at period 1, $(d_f = 1, \gamma_f = \underline{\gamma})$. Facing such a threat, the union has no incentive to go on strike at period 0 because an immediate light strike would not preempt the occurrence or the threat of a severe lockout at period 1. The strategy $(d_u = 0, \gamma_u = \bar{\gamma})$ is weakly dominated by $(d_u = 2, \gamma_u = \underline{\gamma})$. Thus, at equilibrium, the firm and the union will start the wage bargaining under the threat of a severe lockout at period 1. The firm will make a wage offer $(1 - \delta) \cdot W_0 + \frac{\delta \gamma}{1 + \delta}$ at period 0, and the union will accept this offer immediately.

However, if the union makes the first offer in the wage bargain, then an inefficient outcome is not excluded. The union has a weakly dominant strategy, which is $(d_u = 1, \gamma_u = \underline{\gamma})$. Facing the threat of a strike at period 1, the firm will choose an immediate preemptive lockout if $V^*((d_f = 0, \gamma_f = \bar{\gamma}), (d_u = 1, \gamma_u = \underline{\gamma})) > V^*((d_f = 2, \gamma_f = \underline{\gamma}), (d_u = 1, \gamma_u = \underline{\gamma}))$, which reverts to $W_0 > 1 - \frac{\delta(\bar{\gamma} - \underline{\gamma})}{1 - \delta^2}$. So, if $W_0 > 1 - \frac{\delta(\bar{\gamma} - \underline{\gamma})}{1 - \delta^2}$, then the negotiation model with defensive lockouts and with the union making the first offer has a unique and inefficient undominated Nash equilibrium outcome. A preemptive lockout of a weak intensity occurs immediately at the start of the wage bargaining followed by an immediate agreement on $\frac{\bar{\gamma}}{1 + \delta}$. The per-period efficiency loss is equal to $1 - \bar{\gamma}$. Intuitively, when the old wage contract is not too low, it becomes optimal for the firm immediately to start a lockout and to destroy part of the available surplus. Such a conflict of a weak intensity allows the firm to avoid having to accept a higher wage offer facing the threat of a severe strike, where the union would grab most of the surplus. Thus, at equilibrium, the firm goes into conflict immediately and a Pareto-dominated agreement follows.

Labour conflicts, strikes, and lockouts have not been uncommon in professional sports in the USA (see Leeds and von Allmen, 2002). Major sports have experienced lockouts over the last decades.¹³ For instance, the National Hockey League (NHL) prepared to enter the 1994-95 season without having signed a new collective bargaining agreement with the NHL Players Association. Fearful of another stoppage at playoff time, the league staged a preemptive lockout, the NHL's owners choosing to lock out the players at the beginning of the season because the timing of a lockout can be crucial. In professional sports, players have incentive to strike near the end of the season when fan interest is high and network coverage is most intense. Because any stoppage of play at this time would have a significant impact on both gate revenue and media revenue, the owners are highly vulnerable to a strike. In addition, the players are best able to withstand a strike at the end of the season because they have already received most of their salaries. Owners understand

¹³Major League Baseball owners have locked players out of training camps over a 32-day period in 1989. National Hockey League has experienced an interruption of the season 94-95, when 468 games were lost over a 103-day lockout. The 1998-99 National Basketball Association season was truncated by a 202-day lockout.

this, and they have the incentive to lock players out early in the season, minimizing the costs to them and maximizing the costs to the players. Thus, if we invert the bargaining protocol (the union makes the first offer instead of the firm), the NHL lockout story is consistent with our model predictions.

5 Conclusion

We have developed a two-person negotiation model with complete information that is a first attempt to make endogenous both the deadline and the level of surplus destruction after the deadline. We have shown that the undominated Nash equilibrium outcome is always unique but might be inefficient. Moreover, as the bargaining period becomes short or as the players become very patient, this unique outcome is always inefficient. Our model may also justify the existence of Pareto-inferior phenomena other than labour conflicts, such as tariff wars, debt moratoria, break-up of cease-fires or wars in general.¹⁴

One very interesting extension would be to consider a more general bargaining procedure as in Perry and Reny (1993) that allows the players to choose when and whether to make an offer.

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¹⁴Garfinkel and Skaperdas (2000) have obtained similar conclusions but in a totally different framework. They have demonstrated that conflict can ensue even without misperceptions or incomplete information when the antagonists take a long-run view. Despite the short-run incentives to settle disputes peacefully, there can be long term, compounding rewards to going to war when doing better relative to one's opponent today implies doing better tomorrow. Peaceful settlement involves not only sharing the pie available today, but also foregoing the possibility, brought about by war, of gaining a permanent advantage over one's opponent into the future. Garfinkel and Skaperdas have shown how war emerges as an equilibrium outcome in a model that takes these considerations into account. War is more likely to occur, the more important is the future.

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