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Partially revocable commitments in a negotiation with a deadline

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Abstract

[Fershtman, C., Seidmann, D., 1993. Deadline effects and inefficient delay in bargaining with endogenous commitment. Journal of Economic Theory 60, 306–321] showed that the presence of an irrevocable endogenous commitment with a fixed deadline results in the so called deadline effect. In this paper we analyse the effects of partially revocable endogenous commitments of a seller in an infinite horizon negotiation in which a deadline can arise with positive probability. We obtain that when the commitment possesses a sufficiently large revocable part not only the inefficient delays disappear and an immediate agreement is reached but also the commitment has a value. On the other hand, when the commitment possesses a minimum amount of irrevocability, there exist inefficient delays in equilibrium and the commitment continues to having a value.

Keywords: Bargaining; Endogenous commitment; Delays; Uncertain deadline

JEL classification: C78

1. Introduction

Delayed agreements are a widespread phenomenon in real-life negotiations. Examples of delayed agreements include: wage agreements after lost production due to a long strike, peace settlement after a war. Most research typically focus on asymmetric information to

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explain this issue (Fudenberg and Tirole, 1983; Sobel and Takahashi, 1983, Chatterjee and Samuelson, 1987, 1988; Grossman and Perry, 1986). Nevertheless, delays in bargaining can also be explained in the absence of asymmetric information (See Jehiel and Moldovanu (1995a,b), Haller and Holden (1990), Bush and Wen (1995) among others).

In this paper, we explain delays in a complete information framework by the interaction of two important features of any bargaining process: commitment tactics and the existence of deadlines. More specifically, we analyse a standard infinite horizon seller–buyer bargaining model augmented with a deadline stage which is reached with positive probability after any rejection. Once such a deadline stage is reached, one of the parties is given an opportunity to make a take-it-or-leave-it offer to the other party. Moreover, following Fershtman and Seidmann (1993),[1] we assume that the seller has a type of endogenous commitment in the following sense. The seller may, at no cost, accept any offer more generous than the best offer he has so far rejected. Furthermore, the seller may, at a finite cost, accept an offer less generous than the best offer rejected so far, down to a pre-specific lower bound. Last, accepting an offer below this lower bound is prohibitively expensive.

In this sense, commitment is an essential component in many real-life negotiations because it both clearly affects the bargaining power of the negotiator and it may lead to inefficiencies. An (endogenous) commitment, in which players cannot accept a less generous offer than an offer previously rejected (combined with a deadline), can lead to delay in negotiations as it was first shown by FS. This assumption can be justified by the existence of representatives. In this sense, a representative would have problems in ‘explaining’ to his principal that he had accepted a worse offer than an offer previously rejected.

Another justification for an uncertain deadline appears in this context. If a principal has a fixed deadline, which is private information, he may prefer not to communicate it to his representative until the very last moment since by knowing a priori the exact date when the cake vanishes, he will be in a weaker bargaining position. A result in this direction has been obtained by Sandholm and Vulkan (1999) in a context of automated negotiations where software agents bargain on behalf of their users. These authors even suggest that ‘a user is better off by giving her agent a time discount function instead of a deadline since a deadline puts her agent in a weak bargaining position’. All these arguments imply that from the point of view of a representative the deadline can be an uncertain event.

Although apparently our model resembles a negotiation with probabilistic breakdown, this is not the case. There are two basic differences. First, whereas in the model with a breakdown there is a chance that, after a rejection, the bargaining terminates, in our model after the appearance of the deadline, players remain in the same bargaining relationship, but they face, unexpectedly, the last chance of reaching an agreement in the relationship. Second, the payoffs in the model with breakdown are exogenous to the bargaining process, whereas in our work the players's payoffs depend on the history of offers and counterproposals of the game.

[1] Henceforth, FS.

Our main results are that the seller always benefits from her capacity of endogenous commitment, and that the presence of uncertain deadlines generates delays only when the cost to revoke is sufficiently high. More specifically, we show that the inefficient delays obtained by FS under a fixed deadline persist when the deadline is uncertain as long as the commitment has a minimum degree of irrevocability. In this sense, if the commitment is highly revocable an immediate agreement is reached in equilibrium. On the other hand, we obtain that the commitment has a value regardless of its degree of irrevocability.

2. The model

Consider an infinite horizon bargaining game in which a seller (S) and a buyer (B) bargain over the partition of a cake of unit size. At the beginning of each period, each player gets to be the proposer with probability one half. If an offer is accepted, the game finishes and the players divide the cake according to the accepted offer. By contrast, if an offer is rejected a deadline arises with probability q and players enter in a *deadline stage*. Further, with probability $1-q$ players remain in the *main tree* and the game passes to the next period where again a proposer is chosen randomly.

In the deadline stage it is considered a take-it-or-leave-it procedure in which the proposer is selected with probability one half and in case of rejection neither player receives a positive share of the pie. More rounds of offers could be assumed before the deadline. However, this would not affect qualitatively the results.

On the other hand, we assume that the seller possesses a partially revocable endogenous commitment,[2,3] that is, he cannot accept an offer less generous than those rejected in any previous period without incurring in a cost. This cost is finite if the accepted offer is higher than a specific critical proportion of the commitment and infinite if this offer is lower than this critical proportion. Namely, the seller's commitment is revocable up to a certain extent and with a finite cost. Beyond a given point, it becomes irrevocable.

Periods in the main tree are discounted by the common discount factor $\delta \in (0,1)$. For simplicity, we assume that when the game enters the deadline stage, players do not discount payoffs. Note that this latter assumption is not essential in this model. The results would still hold by assuming a discount factor in the deadline stage $\delta_{\mathrm{D}} \in (0,1)$.

More formally, denote by $x_i^t \in [0, 1]$ any offer made by player i in the main tree in period t, where $(x_i^t, 1-x_i^t)$ is the share of player j and i, respectively. In the same way, we define $d_i^t \in [0, 1]$ as any offer made by player i in the deadline stage at round t whenever it is player i's turn to propose an agreement, where $i \in \{B, S\}$. We index periods by $t = 0,1,2,\ldots$

On the other hand, we define z_t as the seller's commitment in period t, where

$$z_t = \max\{x_B^0, x_B^1, \ldots, x_B^{t-1}\}.$$

Denote as $X_B^t = \{x_B^t\} \cup \{d_B^t\}$ any offer possibly made by the buyer to the seller in period t, that is, X_B^t is either x_B^t or d_B^t or both. Therefore, if the seller accepts any offer X_B^t, he will

[2] This is a simplifying assumption which is not essential for the results.

[3] For a detailed discussion of partially revocable commitments, see Calabuig et al. (2002) and Cunyat (2004).

face a cost for revoking such a commitment, which can be defined by the following function,

Definition 1. Let the cost of revoking function, $C(X_B^t, z_t, \varepsilon, \lambda)$, be defined as

$$C(X_B^t, z_t, \varepsilon, \lambda) = \begin{cases} 0 & \text{if } X_B^t \geq z_t \\ \lambda(z_t - X_B^t) & \text{if } (1-\varepsilon)z_t \leq X_B^t < z_t \\ \infty & \text{if } X_B^t < (1-\varepsilon)z_t \end{cases}$$

where $1 \geq \varepsilon \geq 0$ *and* $0 \leq \lambda \leq 1$.

The parameter ε measures the share of the cake that the seller is ready to give up in relation to the commitment at a finite cost (captured by λ). When ε tends to 0, the commitment becomes completely irrevocable, that is, the seller cannot accept any reduction on the share to which he is committed. By contrast, when ε tends to 1, the commitment becomes completely revocable although at a unitary cost of λ. Notice that this cost of revoking function encompasses as particular cases completely irrevocable and revocable commitments.

If S accepts any offer $z_t(1-\varepsilon) \leq X_B^t < z_t$, he will face a finite cost $\lambda(z_t - X_B^t)$. Therefore, in this case S can obtain a positive utility by accepting such an offer and revoking the commitment z_t. However, if $X_B^t < z_t(1-\varepsilon)$, S must face an infinite cost for accepting such an offer. Hence, in this case S will never accept any $X_B^t < z_t(1-\varepsilon)$.

Let $G(z_t)$ be any subgame in which the seller possesses a commitment z_t. Strategies and subgame perfect equilibria (SPE) for this game are defined in the usual way.

3. Partially revocable commitments with a high revocable component

We show that when the commitment is highly revocable, there exists an equilibrium in which not only an immediate agreement is reached but also the commitment is effective. In this sense, the assumption of completely irrevocable commitments made by FS turns to be pretty restrictive since the inefficient delays obtained by these authors vanish when we consider more general commitment devices.

We first characterise the seller's equilibrium utility in the deadline stage.

Lemma 1. *In the deadline stage of period t and for any* z_t*:*

(a) If $1 \geq \varepsilon \geq (1/1+\lambda)$ *the seller's expected utility in equilibrium is given by:*

$$U_s^*(z_t) = \frac{1}{2}.$$

(b) If $\varepsilon < (1/1+\lambda)$*, the seller's expected utility in equilibrium is given by:*

$$U_s^*(z_t, \varepsilon, \lambda) = \frac{1}{2}(1 + Az_t),$$

where $A = 1 - \varepsilon(1+\lambda)$.

Proof. See Appendix A. □

Therefore, we obtain that if the irrevocable part of the commitment is not large enough (case a), the seller's equilibrium utility in the deadline stage is not affected by the presence of the commitment.

Consequently, it can be easily checked that in this case an immediate agreement can be supported in equilibrium. Note also that in the game without commitments the expected payoff in equilibrium for each player would be (1/2). However, when the seller possesses an endogenous commitment device, the seller can obtain an expected utility greater than (1/2), that is, the commitment is effective, as it is shown in Proposition 1.

Proposition 1. *When $1 \geq \varepsilon \geq (1/1+\lambda)$, there exists a Subgame Perfect Equilibrium which yields an immediate agreement and in which the seller obtains an expected utility greater or equal to (1/2) and the buyer obtains an expected utility below or equal to (1/2).*

Proof. See Appendix B. □

The intuition of this result is the following. When the commitment is highly revocable the seller's utility in the deadline stage does not depend on the current commitment (in contrast with FS) and the buyer can make favourable offers which will be accepted. This avoids the delays but still the commitment is strong enough to yield the seller a better payoff.[4]

4. Partially revocable commitments with a sufficiently irrevocable component

In this section we show that with partially revocable commitments with a sufficiently large irrevocable component ($\varepsilon < (1/1+\lambda)$) there exist delays in any equilibrium. More specifically, there is no agreement in the main tree as long as the buyer gets to be the proposer. Furthermore, the commitment has a value.

We first proceed to characterise the equilibrium path in the main tree of the game. Lemma 2 establishes an upper bound in the buyer's utility in any period t.

Lemma 2. *In any $G(z_t)$ the seller rejects in equilibrium with probability 1 any offer:*

$$x_B^t < \frac{q}{2[1-\delta(1-q)]-qA}.$$

Proof. See Appendix C. □

This result follows from comparing the utility that the seller obtains from accepting an offer and the expected utility he guarantees himself by rejecting such an offer and waiting until the deadline occurs.

In Proposition 2 we obtain that if players are sufficiently patient, there is no agreement in equilibrium in the main tree when the buyer gets to be the proposer.

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[4] In this case, delayed agreements are also possible in equilibrium and, therefore, there exists a multiplicity of equilibria.

Proposition 2. *If $\delta > \hat{\delta}(q,\varepsilon,\lambda)$, where $\hat{\delta}(q,\varepsilon,\lambda) = \frac{1}{4}\,\frac{4-q(2+A)+q\sqrt{4+A^2}}{1-q}$, in any SPE there is no agreement in the main tree whenever the buyer gets to be the proposer.*

Proof. See Appendix D. □

The intuition behind this result is that both players have guaranteed an expected positive utility by disagreeing systematically in the main tree and letting the game to reach the deadline stage. If the buyer wants to have an offer accepted, he must be more generous than in a bargaining game without commitments. This is so because the seller, when possessing partially revocable commitments, can raise the minimum share that he can guarantee himself by rejecting this offer and letting the game reach the deadline stage. Since the offer that would be accepted by the seller is increasing in δ, for a sufficiently high δ, B obtains a worse payoff by making such an offer than by letting the game reach the deadline stage by making non-serious offers which will certainly be rejected. Therefore, the players will only strike a deal either if a deadline arises or the seller becomes the proposer in the main tree.

Corollary 1 establishes the probability of reaching an agreement in any period.

Corollary 1. *If $\delta > \hat{\delta}(q,\varepsilon,\lambda)$, players reach an agreement in equilibrium with probability $(q(1-q)^t)/2)$ in any period t.*

On the other hand, by computing the expected equilibrium payoff of the seller in this case, we obtain that the commitment has a value since he obtains an expected payoff greater than (1/2). The seller's expected payoff has two components. The first one arises when the seller gets to be the proposer. In this case, there is an immediate agreement on the partition $\left(\frac{q}{2(1-\delta(1-q))}, 1-\frac{q}{2(1-\delta(1-q))}\right)$. The second one arises when the buyer gets to be the proposer. In this case, the buyer makes a non-credible offer and there is no agreement until a deadline arises or the seller gets to be the proposer. When players enter the deadline stage both obtain a payoff equal to (1/2).

Summarising, when $\delta > \hat{\delta}(q,\varepsilon,\lambda)$ the seller's equilibrium expected payoff will be

$$\left[\left(1-\frac{q}{2(1-\delta(1-q))}\right)+\frac{q}{2}\right]\left(\frac{1}{2-\delta(1-q)}\right).$$

which is greater than (1/2), for any $\delta > \hat{\delta}(q,\varepsilon,\lambda)$ and $q>0$.

Notice also that $\lim_{q\to 0}\hat{\delta}(q,\varepsilon,\lambda)=1$. Therefore, for any positive probability of the realization of the deadline, as small as we wish, it is possible to find a critical discount factor bounded away from 1 such that for any higher discount factor, there is no agreement in any period in which the buyer is the proposer in the main tree.

Furthermore, if the probability that a deadline arises is above a critical value the previous result holds for any discount factor $\delta \in (0,1)$.

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Appendix A

Proof of Lemma 1. In the deadline stage of any period t, a fair lottery determines the identity of the proposer. First, if the seller makes an offer he obtains the whole pie in equilibrium. Second, when the seller is the responder, in equilibrium he only accepts offers such that $U_s(d_B^t) \geq 0$. This implies that d_B^t has to be higher than or equal to max $\{z_t \cdot (1-\varepsilon), \bar{d}_B^t(z_t)\}$, in order to be accepted in equilibrium. The offer that solves $d_B^t - \lambda(z_t - d_B^t) = 0$ is $\bar{d}_B^t(z_t) = \frac{\lambda}{1+\lambda} z_t$. When $\bar{d}_B^t(z_t) \geq z_t \cdot (1-\varepsilon)$, $U_s(\bar{d}_B^t(z_t)) = 0$ and the seller does not obtain any additional payoff from being committed. This case arises when $\varepsilon \geq (1/1+\lambda)$. Then,

$$U_s^*(z_t) = \left[\frac{1}{2} \cdot 1 + \frac{1}{2} U_s(\bar{d}_B^t(z_t))\right] = \frac{1}{2}.$$

On the other hand, when $\varepsilon < \frac{1}{1+\lambda}$, $\bar{d}_B^t(z_t) < z_t \cdot (1-\varepsilon)$. Then,

$$U_s^*(z_t, \varepsilon, \lambda) = \left[\frac{1}{2} \cdot 1 + \frac{1}{2} U_s(z_t \cdot (1-\varepsilon))\right] = \frac{1}{2}[1 + Az_t].$$

□

Appendix B

Proof of Proposition 1. Consider the following pair of strategies:
B's strategy:

- In the main tree:

  B always offers x_B^* and always accepts an offer x_S:

- iff $x_S \geq x_S^*$ in any subgame in which the buyer has not made any offer previously.
  iff $x_S \geq x_S^{**}$ in any subgame in which the buyer has made an offer previously.
- In the deadline stage, B always offers 0, if he has not made any offer in the main tree and αx_B^*, if he has made an offer in the main tree, where $\alpha = (\lambda/1+\lambda)$. and accepts any seller's offer.

S's strategy:

- In the main tree,
  S always offers:
  x_S^* in any subgame in which the buyer has not made any offer previously.
  x_S^{**} in any subgame in which the buyer has made an offer previously and accepts an offer x_B^* iff $x_B \geq x_B^*$.
- In the deadline stage,
  S always offers 0 and accepts any:

$x_B \geq 0$, if B has not made an offer in the main tree.
$x_B \geq \alpha x_B^*$, if B has made an offer in the main tree.

We show that the former pair of strategies conform a Subgame Perfect Equilibrium.

First, the buyer has to be indifferent between accepting and rejecting seller's equilibrium offer.

In any subgame in which the buyer has not made any offer previously

$$x_S^* = \frac{q}{2} + (1-q)\delta\left[\frac{1}{2}x_S^* + \frac{1}{2}(1-x_B^*)\right]. \tag{B1}$$

In any subgame in which the buyer has made an offer previously

$$x_S^{**} = \frac{q}{2} + (1-\alpha x_B^*) + (1-q)\delta\left[\frac{1}{2}x_S^{**} + \frac{1}{2}(1-x_B^*)\right]. \tag{B2}$$

Second, the seller must be indifferent between accepting and rejecting a buyer's offer.

$$x_B^* = \frac{q}{2} + (1-q)\delta\left[\frac{1}{2}x_B^* + \frac{1}{2}(1-x_S^{**})\right]. \tag{B3}$$

Solving (B1)–(B3) we obtain that there is a unique solution given by

$$x_S^* = -\frac{\begin{array}{c} q\alpha\delta^2 - 4q - 4\delta + 10\delta q + 6\delta^2 - 14\delta^2 q - 6\delta q^2 + 10\delta^2 q^2 + q^2\alpha\delta \\ -2\delta^2 q^3 + 6\delta^3 q - 6\delta^3 q^2 + 2\delta^3 q^3 - 2\delta^3 - q^3\alpha\delta - 2q^2\alpha\delta^2 + \delta^2 q^3 \alpha \end{array}}{\begin{array}{c} 12\delta q + 8 - 12\delta + 4\delta^2 - 8\delta^2 q + 4\delta^2 q^2 - 2q\alpha\delta \\ +2q^2\alpha\delta + q\alpha\delta^2 - 2q^2\alpha\delta^2 + \delta^2 q^3 \alpha \end{array}}$$

$$x_S^{**} = -\frac{2\delta^2 q^2 - 2\delta q^2 + q^2\alpha - q^2\alpha\delta + 4\delta q - 2q - 4\delta^2 q + q\alpha\delta - 2\delta + 2\delta^2}{4 - 4\delta + 4\delta q - q\alpha\delta + q^2\alpha\delta}$$

$$x_B^* = -2\frac{-q - \delta + 2\delta q + \delta^2 - 2\delta^2 q - \delta q^2 + \delta^2 q^2}{4 - 4\delta + 4\delta q - q\alpha\delta + q^2\alpha\delta}$$

The seller's expected utility of this equilibrium is $\frac{1}{2}x_B^* + \frac{1}{2}(1-x_S^*)$, that is

$$\frac{2\delta^2 q^3\alpha - q^3\alpha\delta - 4q^2\alpha\delta^2 + 4\delta^2 q^2 + 3q^2\alpha\delta + 2q\alpha\delta^2 - 8\delta^2 q - 2q\alpha\delta + 12\delta q + 8 - 12\delta + 4\delta^2}{2(12\delta q + 8 - 12\delta + 4\delta^2 - 8\delta^2 q + 4\delta^2 q^2 - 2q\alpha\delta + 2q^2\alpha\delta + q\alpha\delta^2 - 2q^2\alpha\delta^2 + \delta^2 q^3\alpha)}. \tag{B4}$$

(B4) is greater or equal to (1/2), to see that notice that this expression tends to (1/2) when $\delta \to 0$ and tends to $\frac{1}{2}\left(\frac{4(1+q) - q\alpha(1-q)}{4(1+q) - \alpha(1-q^2)}\right) > \frac{1}{2}$ when $\delta \to 1$. Furthermore, it can be easily checked that the derivative of the seller's payoff with respect to δ is positive. The buyer's expected utility of this equilibrium is $\frac{1}{2}(1-x_B^*) + \frac{1}{2}x_S^*$, that is

$$\frac{q^3\alpha\delta + 4\delta^2 q^2 + q^2\alpha\delta - 8\delta^2 q - 2q\alpha\delta + 12\delta q + 8 - 12\delta + 4\delta^2}{2(12\delta q + 8 - 12\delta + 4\delta^2 - 8\delta^2 q + 4\delta^2 q^2 - 2q\alpha\delta + 2q^2\alpha\delta + q\alpha\delta^2 - 2q^2\alpha\delta^2 + \delta^2 q^3\alpha)}.$$

which is below or equal to (1/2). □

Appendix C

Proof of Lemma 2. Let $x_B^t \geq z_t$ be the share that the buyer offers to the seller in period t. Then, S can guarantee himself an expected payoff of

$$\frac{q}{2}(1 + x_B^t A)(1 + \delta(1-q) + \delta^2(1-q)^2 + \ldots) = \frac{q(1 + x_B^t A)}{2(1 - \delta(1-q))}.$$

It follows that the seller rejects in equilibrium such an offer

$$x_B^t < \frac{q(1 + x_B^t A)}{2[1 - \delta(1-q)]}, \text{ that is,}$$

$$x_B^t < \frac{q}{2[1 - \delta(1-q)] - qA}.$$

In the same way, if $x_B^t < z_t$, the result still holds because, on the one hand, the utility of accepting is smaller than in the previous case and, on the other hand, the utility that S can guarantee himself in the case of rejection is greater than in the previous case. □

Appendix D

Proof of Proposition 2. First, we prove that when the buyer becomes the proposer there is no agreement in equilibrium in the main tree. By Lemma 2, the maximum payoff that B can obtain by making an offer that would be accepted in any period t is

$$1 - \frac{q}{2[1 - \delta(1-q)] - qA}.$$

On the other hand, by offering $x_B^t = 0$ in every period, B can guarantee in any period an expected payoff of

$$\frac{q}{2[1 - \delta(1-q)]}.$$

Let $\hat{\delta}(q, \varepsilon, \lambda) = \frac{1}{4}\frac{4 - q(2+A) + q\sqrt{4+A^2}}{1-q}$ be the value of $\delta \in (0,1)$ which satisfies

$$1 - \frac{q}{2[1 - \delta(1-q)] - qA} = \frac{q}{2[1 - \delta(1-q)]}. \tag{D1}$$

To check that $\hat{\delta}(q, \varepsilon, \lambda) > 0$, notice that this condition holds when $q < \frac{4}{2+A-\sqrt{4+A^2}}$. Since $q \in [0, 1]$, $\hat{\delta}(q, \varepsilon, \lambda)$ is always greater than zero if $\frac{4}{2+A-\sqrt{4+A^2}} > 1$, which is true for any $A > 0$.

When $\delta = 1$, the right hand side (RHS) of (D1) is (1/2) and the left hand side (LHS) is less than (1/2). Therefore, since the LHS of (D1) is monotonic decreasing in δ and the right hand side is monotonic decreasing, $\hat{\delta}(q, \varepsilon, \lambda)$ is unique. Furthermore, for all $\delta \in (\hat{\delta}(q, \varepsilon, \lambda), 1)$

$$1 - \frac{q}{2[1 - \delta(1-q)] - qA} < \frac{q}{2[1 - \delta(1-q)]}.$$

Hence, for every $\delta > \hat{\delta}(q, \varepsilon, \lambda)$, B can guarantee a better payoff by offering $x_B^t = 0$ in every period of the main tree than by making an offer that would be accepted.

Finally, we prove that when the seller gets to be the proposer there is an immediate agreement in equilibrium in the main tree. The equilibrium offer will be $(x_S^t)^* = \frac{q}{2[1-\delta(1-q)]}$. It is easy to check that it is optimal for the buyer to accept this offer since by rejecting it $U_B \leq \frac{q}{2[1-\delta(1-q)]} = (x_S^t)^*$. On the other hand, if the seller offers some $x_S^t < (x_S^t)^*$, this offer is rejected by the buyer since he can guarantee an expected payoff of $\frac{q}{2[1-\delta(1-q)]}$. □

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