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Bargaining under a deadline: evidence from the reverse ultimatum game ☆

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Abstract

We study a “reverse” ultimatum game, in which proposers have multiple chances to offer responders a division of some fixed pie. The game ends if the responder accepts an offer, or if, following a rejection, the proposer decides not to make a better offer. The unique subgame perfect equilibrium gives the proposer the minimum possible payoff. Nevertheless, the experimental results are not too different from those of the standard ultimatum game, although proposers generally receive slightly *less* than half of the surplus.

We use the reverse ultimatum game to study deadlines experimentally. With a deadline, the subgame perfect equilibrium prediction is that the proposer gets the entire surplus.

Deadlines are used strategically to influence the outcome, and agreements are reached near the deadline. Strategic considerations are evident in the differences in observed behavior between the deadline and no deadline conditions, even though agreements are substantially less extreme than predicted by perfect equilibrium.

JEL classification: C7; C9

☆ Accompanying materials to be found at http://www.utdallas.edu/~eharuvy/deadline/.

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Prologue: In memory of Bob Rosenthal

One of Bob's many contributions was the centipede game (Rosenthal, 1981), which captured the attention of the profession as a model for exploring the kind of perplexing backward induction questions that arise, e.g., in the finitely repeated prisoner's dilemma. Both of those games, and also the ultimatum game, have received a lot of attention from experimenters interested in the tension between backwards induction and psychological and other strategic considerations. (Bob himself became an experimenter in recent years.) The present paper, dedicated to Bob's memory, proposes another such game, the "reverse ultimatum game." It is useful here for studying deadline effects in bargaining because its backward induction equilibrium properties are sensitive to the presence or absence of a deadline. Like many game theory papers, this one would have been better if we could have run it by Bob's critical eye. We miss him.

1. Introduction

Eleventh hour agreements are often reported in negotiation settings. Labor agreements tend to be reached just before contracts expire and court settlements tend to be reached just before or at the deadline. Williams (1983), for example, found that 70% of all civil cases in one sample were settled in the last 30 days before the trial and 13% were settled on the day of the trial (see also Spier, 1992). In experimental settings, the concentration of agreements near the end of the allotted time appears to be far more robust to bargaining parameters than are other aspects of the bargaining outcome (Roth et al., 1988).

In some settings, a possible explanation of the deadline effect appears to be straightforward: Consider a finite-horizon negotiation without discounting, and suppose players have the option of delaying. Then the player who moves at the last possible time might hope to capture the lion's share of the surplus by making an ultimatum offer (Ma and Manove, 1993).[1] A one-step backward induction argument reveals that the subgame perfect equilibrium of an ultimatum game gives all or virtually all the surplus to the proposer, so under this argument, the deadline effect is the result of strategic behavior aimed at creating the conditions to issue an ultimatum.

However, when ultimatum bargaining is examined in the laboratory, the large advantages to the proposer predicted by subgame perfect equilibrium are most often notable by their absence. A typical experiment of this sort uses the ultimatum game first stud-

[1] In other settings, incomplete information is often used to explain delays in bargaining agreements (Fudenberg and Tirole, 1983; Fudenberg et al., 1985; Hart, 1989; and Rubinstein, 1985), where typically an informed bargainer in a "strong" position can signal his position by delaying agreement as the probability that an agreement can be reached before the deadline diminishes. Fershtman and Seidmann (1993) showed that in a sequential bargaining model, negotiators delay agreements until the deadline if a player who rejects an offer is committed not to accept any poorer proposal in the future. In general, strategic uses of time can have multiple causes, since a single dimension (time) is being manipulated in response to complicated strategic considerations. For example, see Roth and Ockenfels (2002) for a discussion of the multiple causes of last minute bidding on eBay. (There is also an Organizational Behavior literature that considers the perception of deadlines; see, e.g., Moore, 2000.)

ied by Güth et al. (1982), in which one player makes a proposal over how to divide a fixed sum, and a second has only the options of accepting the proposal—in which case the proposed division takes effect—or rejecting it, in which case both the proposer and the responder receive zero. If players care only about their own payoffs, the subgame perfect equilibrium prediction for such a game is that the proposer will receive virtually all of the pie to be divided, while the responder will get at most the smallest monetary unit in which proposals can be made. However, the experimental results (see, e.g., the survey in Roth, 1995) are that responders receive much closer to half of the pie. This result is robust (see, e.g., Roth et al., 1991), which seems to involve strong initial preferences involving fairness (see, e.g., Ochs and Roth, 1989; Bolton and Ockenfels, 2000; Fehr and Schmidt, 1999), and it is persistent, which seems to involve the different speeds of learning that the game induces in proposers and responders (Roth and Erev, 1995; Slonim and Roth, 1998; Cooper et al., 2003).

The goal of the present study was to design and explore an environment in which the subgame perfect equilibrium predictions are as clear, and extreme, as in the ultimatum game, but in which time can be used strategically in a way that will let deadlines become potentially important.[2] To this end, we examine the role of deadlines in a novel bargaining environment, which we call the *reverse ultimatum game* (RUG). In the RUG, the addition of a deadline can drastically shift the subgame perfect equilibrium prediction from one extreme to the other in terms of which bargainer is predicted to gain all but a fraction of the available wealth.

In its simplest form, the RUG involves two players. Player 1 proposes a division of a fixed amount (in our case 25 tokens) to player 2 in the form of an integer offer of x tokens. If player 2 accepts the x tokens, then the game ends with this division as the outcome. If player 2 rejects the offer, player 1 is then allowed to make another offer, as long as that offer is *strictly higher* by a minimum increment (1 token), and as long as both players' shares remain strictly positive. In addition, player 1 may end the bargaining at any point, in which case both players receive 0 tokens. That is, the game ends either when player 2 accepts a proposal, or when, following a rejection, player 1 declines to make a better offer. The game would also end if player 2 rejects the highest feasible offer player 1 is able to make.

We call the game a "reverse" ultimatum game because player 2's rejection of an offer is a form of "reverse" ultimatum, which may be interpreted as meaning "give me more, or we will each get nothing," and because the subgame perfect equilibrium division between proposer and responder is the reverse of that in the ultimatum game.

The proof that the unique subgame perfect equilibrium gives one token to the proposer and the remainder ($N - 1$ tokens) to the responder is as follows. At a subgame following

[2] This is not to say that imposing a deadline in a conventional ultimatum game could not in some circumstances have an effect on observed behavior, but it does not enter into the strategic calculations that determine the subgame perfect equilibrium, which in the conventional ultimatum game is invariant to the presence of a deadline. See also Güth et al., 2001, which studies deadline effects in an ultimatum game in which the proposer may make (and repeat) a demand over several periods. When the pie size is constant, the ability to issue an ultimatum over several periods does not change the perfect equilibrium prediction, and Güth et al. find that it does not make a big difference in the observed distribution between proposer and responder.

a proposal that gives the proposer only a single token, the responder will accept, because the requirement that both players' shares must be positive implies that the proposer cannot make another offer if this proposal is rejected, so a rejection will lead to both players receiving zero. At a subgame following a rejection of any other proposal, the proposer is therefore faced with a choice of stopping the bargaining and receiving zero, or making a new proposal and eventually receiving a payoff of (at least) one token. At any subgame following a proposal that gives the proposer $k > 1$ tokens, the responder is therefore faced with a choice of accepting it and receiving $N - k$ tokens, or rejecting it and eventually receiving $N - 1$ tokens.[3]

That is, in the reverse ultimatum game, the proposer is potentially faced with a series of small ultimata, in contrast to the ultimatum game in which it is the responder who is faced with one ultimatum. In both kinds of ultimatum games there are many imperfect equilibria supported by "non-credible" threats, but in the reverse ultimatum game it is the proposer whose threat (to end the negotiations) is not credible, when players are taken to be concerned solely with their own monetary payoffs.[4]

Adding a deadline to the RUG reverses the subgame perfect equilibrium prediction. The proposer is able to wait to the last second to make an offer, thereby resulting in a conventional "take it or leave it" ultimatum.[5]

In addition to studying the RUG with one responder, we also study it with *two* responders, with and without a deadline. In the two responder games, the proposer first bargains with the first responder, with whom he may reach agreement. But if he decides, following a rejection, to make no more offers to the first responder, then he may begin to make offers to the second responder. The subgame following a disagreement with the first responder is a reverse ultimatum game of the sort described above. (In order to have a unique perfect equilibrium, we require that the offer to the first responder may be no larger than 23 tokens, while it is still feasible to offer the second responder up to 24 tokens.[6])

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[3] We initially studied a relaxed form of the game in which it was feasible for the proposer to offer the entire pie to the responder. In the relaxed form of the RUG, there is a multiplicity of subgame perfect equilibria. But only the one discussed above, at which the proposer gets a single token, is robust to introducing arbitrarily small costs of making an offer. A control condition was run comparing the basic RUG (in which a maximum of 24 tokens may be offered to player 2) to the relaxed version (in which the rules allow him to be offered all 25 tokens). As expected, no difference was detected.

[4] Not credible in theory, as it is not sequentially rational in the subgame in which players are assumed to care only for their own payoffs. In experiments, we will see that proposers sometimes carry out this implied threat, and it is credible enough to affect responder behavior.

[5] We avoid here a detailed model of the last moments of the game, in which offers take a fixed amount of time, or in which there may be a time near the end in which there is some probability between zero and one that another offer can be made (see, e.g., Ockenfels and Roth, 2002). For our present purpose it is enough to note that the proposer can certainly make an offer late enough so that it would be very risky for the responder to reject it in the hope of a better offer. And such a subsequent offer, if it arrived in time to be accepted, would itself be an ultimatum that need only be one token greater than the rejected offer.

[6] We also initially studied a relaxed form of the two person RUG, in which it was feasible for the proposer to offer the entire pie to either responder. Although this game has multiple subgame perfect equilibria, observed behavior in the lab was indistinguishable from the game with unique equilibrium that we report.

2. Experimental procedure for the one-responder RUG

The one responder study involved three experimental conditions: a *no-deadline* condition, a *one-minute deadline* condition, and a *three-minute deadline* condition. In each condition subjects divided a pie of size 25 tokens, each worth $0.05. We chose an odd number of tokens to avoid the focal point issues associated with precisely equal splits (see, e.g., Güth et al., 2001).

In each condition, experimental sessions involved groups of six subjects seated at networked computers. Within each group, three subjects were randomly assigned to the proposer role and three to the responder role. These roles stayed fixed for the duration of the experiment, which lasted 25 repetitions (games). Proposers and responders were randomly rematched each game. Dividers separated the subjects and they could not see each other, or communicate except via the play of the game. Once seated, participants received written instructions (see Appendix A), which were also read aloud by the experiment administrator.

In each game, there is one proposer and one responder, who must reach an agreement to get a positive payoff. The proposer makes integer offers to the responder, which must be between 0 and 25 tokens and must be strictly increasing. An onscreen clock shows the time from the start of the bargaining.

The responder faces two buttons, "accept" and "reject." Pressing the accept button results in an agreement and ends the bargaining. Pressing the reject button rules out the rejected offer or any offer below it, forcing the proposer to choose between making a strictly higher offer or ending the game. If the proposer ends the game, both bargainers receive zero payment for that game. Following a proposal, the responder may choose to press one of the buttons, or wait for the proposer to make a better offer without pressing the reject button (thereby implicitly rejecting the offer but reserving the right to accept at a later point).

In the no-deadline treatment (ND), a bargaining game could stop for one of three reasons:

(1) the responder accepts the proposal,
(2) the proposer decides not to increase the proposal and to end the bargaining, or
(3) the responder rejects the maximum offer of 24 points, in which case the proposer cannot increase the proposal any more.

In the one-minute deadline treatment and three-minute deadline treatment, the rules were the same as in the ND, except that once the clock reached the deadline, the bargaining would be over, and unless an agreement had been reached, both proposer and responder would receive 0 tokens.

To make the deadline and no-deadline conditions fully comparable, a clock was visible in all conditions. In the no-deadline condition, however, it did not play any role in causing the game to end.

The experiment was conducted in the experimental computer laboratory at Harvard Business School, using z-tree software (Fischbacher, 1999). In all, 96 people participated in the experiment: four sessions of ND, and six of each of the two deadline conditions.

Subjects were Greater Boston residents. The vast majority were undergraduate students from Boston University, Harvard, and MIT.

3. Experimental results

Before discussing each condition in detail, we set the stage by reporting the average offer accepted in each of the five conditions. Table 1 reports the average accepted offer in each condition over all 25 games and over the last five games. Figure 1 shows the average accepted offer in each of the 25 games in each condition.

Table 1
Average accepted offer in bargaining agreements

Average over games	One responder no deadline (1RND)	One responder 3 minute deadline (1R3minD)	One responder 1 minute deadline (1R1minD)	Two responders no deadline (2RND)	Two responders 3 minute deadline (2RD)
Games 1–25	13.34 (1.43) $N = 262$	11.48 (3.30) $N = 359$	10.52 (2.57) $N = 351$	10.60 (2.18) $N = 298$	8.45 (2.62) $N = 224$
Games 21–25	12.92 (1.00) $N = 59$	11.44 (3.08) $N = 79$	10.74 (1.76) $N = 70$	10.08 (2.29) $N = 60$	7.07 (2.62) $N = 45$

Note. Standard deviation is shown in parentheses and N is the number of agreements.

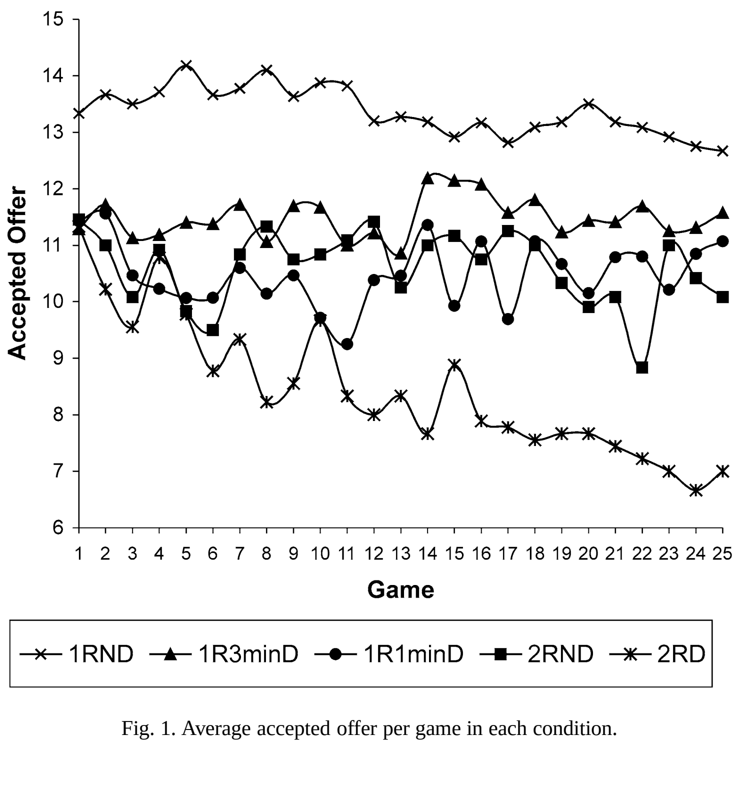


Fig. 1. Average accepted offer per game in each condition.

The graph makes clear that the experimental treatments have a substantial effect: the one-responder-no-deadline treatment yields the highest offers, the two-responder-deadline treatment the lowest, with the other conditions in between those two and clearly separated from both of them once the players have gained experience (e.g., in the last five games).

Recall that, in the no-deadline conditions, the subgame perfect equilibrium offer is 24 in the one-responder games and 23 in the two-responder games, and in the deadline conditions it is 1. Since there are 25 tokens to divide, the "equal split" divisions are 13 or 12.

Thus the basic reverse ultimatum game, in the one-responder-no-deadline condition, yields results much like the conventional ultimatum game, in that the mean agreement is near an equal split, although unlike in the conventional ultimatum game, the responders receive slightly more than the proposers.[7] The addition of a deadline moves the mean agreement in the proposers' direction, more so with a shorter deadline. Similarly, addition of a second responder moves the mean agreement in the proposers' favor, and, with two responders, the addition of a deadline has a pronounced effect, with responders now accepting, on average, only a third of the pie. This effect is particularly pronounced when the bargainers are experienced; in the last five games of the two-responder deadline condition, the mean accepted offer is only 7.07 tokens.

3.1. RUG with no deadline (ND)

The full distribution of agreements (i.e., final offers that were accepted) in the one-responder-no-deadline (1RND) condition is given in Fig. 2. The modal accepted offer is 13. As indicated in Table 1, the average agreement gave 13.34 tokens to the responder,

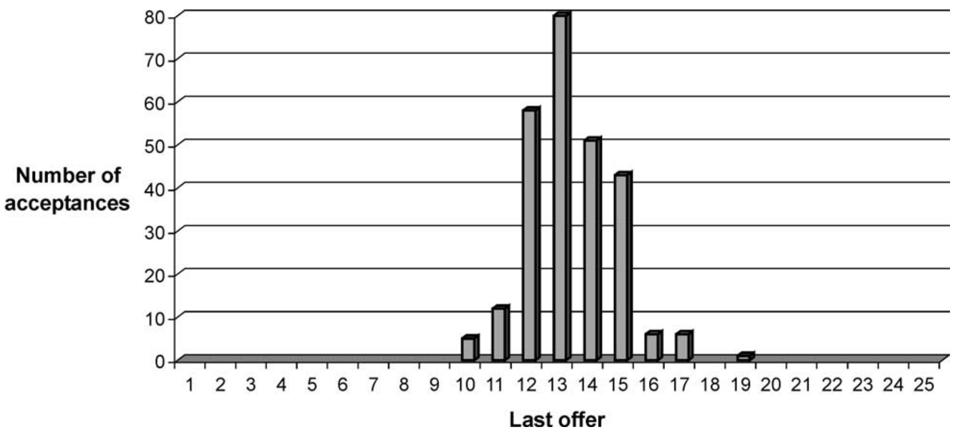


Fig. 2. Bargaining agreements: 1RND.

[7] Recall that the subgame perfect prediction in the conventional ultimatum game is for the proposer to get the entire surplus. In contrast, in the one-responder RUG with no deadline, the subgame perfect prediction is for the responder to get all the surplus. So we should not be surprised that the observed split is tilted in favor of the proposer in the conventional ultimatum game and in favor of the responder in the one-responder RUG with no deadline.

giving the responder a small (surprisingly small relative to the SPE prediction) advantage. Testing the significance of the difference in payoff, conditional on a successful bargain, between proposer and responder, the t-value is 9.49, which with 261 degrees of freedom has a p-value smaller than 0.0001.

To understand the distribution of agreements, Fig. 3 presents the decision of the proposers to terminate the bargaining process after a proposal they make is rejected. That is, it is often the case that when a responder rejects an offer, the proposer chooses not to come back with a new offer. This results in both bargainers getting zero for that game. This stopping of the bargaining by the proposer in the reverse ultimatum game resembles rejection by the responder in the ultimatum game. Proposers ended bargaining early without reaching an agreement in 38 (13%) out of 300 observations (12 proposers $\times$ 25 games). Figure 3 presents the number of times the proposer ended the bargaining plotted against the last offer rejected by the responder prior to the proposer ending the bargaining.

It appears from Fig. 3 that responders are safe in rejecting any offer less than 12. Once the responder rejects 12, she enters uncertain territory with a positive probability of 0.024 (4 rejections of an offer of 12 that ended in bargaining failure out of 166 total rejections of 12) of bargaining failure. That is, if the responder rejects 12, intending to accept 13, she will in expectation earn 12.69, and will be better off rejecting 12 than accepting it (if she is not too risk-averse). However, if the responder were to reject 13, she would face a probability of the proposer declining to make another offer of 0.195 (25 rejections of a 13 offer that ended in bargaining failure out of 128 total rejections of 13). That is, if the responder rejects 13, intending to accept 14, she will in expectation earn 11.27, and will be better off accepting 13 than rejecting it. Hence, the risk-neutral money-maximizing responder would not reject an offer of 13. The modal accepted offer was 13. There were 208 offers of 13 overall. Of these, 128 were rejected, and 80 were accepted. Of the rejected offers, 25 resulted in bargaining failure and 113 resulted in a higher offer.

Of the 25 rejections of 13 that resulted in a failure, 14 were preceded by an offer of 12 (of these, 12 were preceded by an offer of 11 and 2 were preceded by an offer of 10), but 11 of the offers of 13 that resulted in failure were the first and only offers by the proposer. This

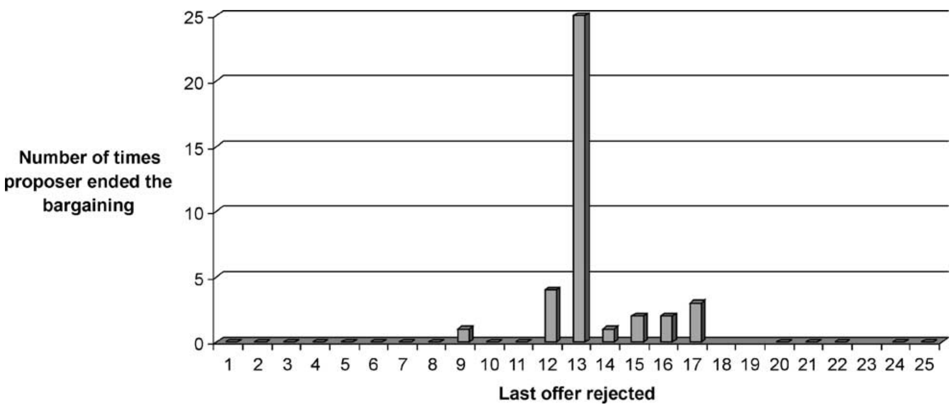


Fig. 3. A histogram of rejections leading to proposer ending the bargaining: 1RND.

indicates that most proposers were making incremental offers, yet a significant portion of proposers began by proposing what they considered to be a “fair” proposal.

3.2. RUG with deadlines

As noted above, in the no-deadline condition, an examination of the data reveals that responders were safe in rejecting any offer less than 12. Not so in the deadline conditions. Figure 4 shows that, in the three-minute deadline condition, rejecting offers as low as 5 had a positive probability of resulting in the proposer ending the bargaining. In both the one-minute and the three-minute deadline conditions, rejecting an offer of 11 could result in a bargaining failure (with probability of 3/117 in the one-minute condition and 4/149 in the three-minute condition). Though these probabilities are small, in the no-deadline condition rejection of an offer of 11 never resulted in bargaining failure. Similar comparisons emerge for bargaining failures following offers of less than 11. Note that incidents of proposers

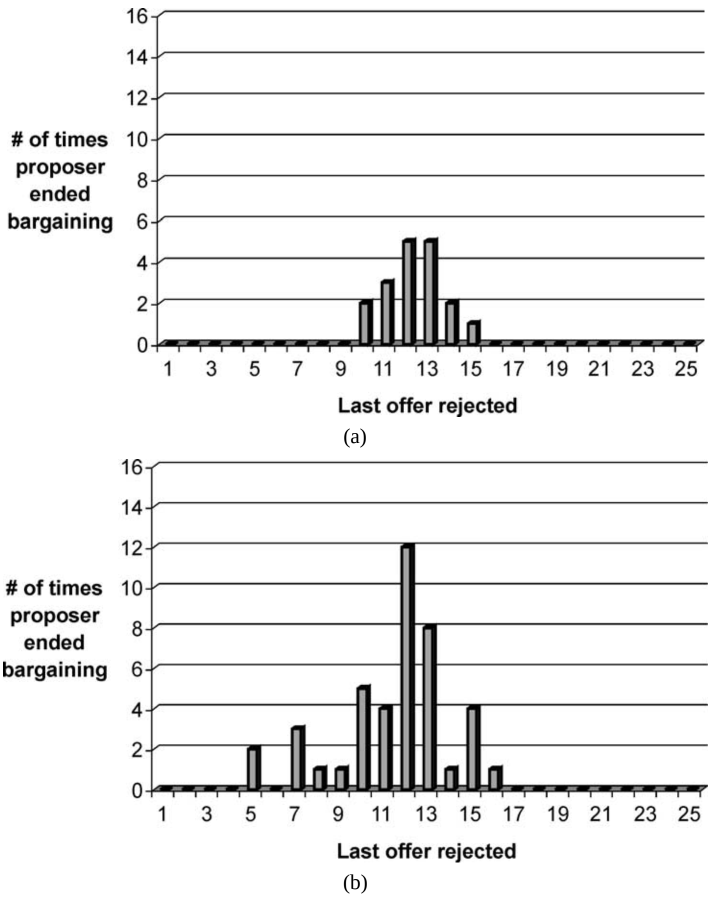


Fig. 4. Rejections leading to the proposer ending the bargaining: 1RD. (a) One-minute deadline. (b) Three-minute deadline.

ending the bargaining in the one-minute condition were rare relative to both the three-minute deadline and no-deadline condition. This is complicated by the fact that proposers have two ways of ending the bargaining: explicitly, by pressing the button, or implicitly, by letting the time run out. However, the two causes of bargaining failure cannot be aggregated since the first is clearly due to the proposer's choice, whereas the second can be due to choices by proposer, responder, or failure to respond quickly enough by either proposer or responder. Figure 5 nevertheless shows that incidents of time running out are far more common in the one-minute deadline condition than in the three-minute deadline condition.

Figure 6 demonstrates that in the deadline conditions, the modal agreement is at 12 in the one-minute deadline condition and 11 in the three-minute condition. Furthermore, the tails to the left of the mode are wider in the deadline conditions, benefiting the proposer relative to the no-deadline condition, which has a mode at 13 and almost no tails. Though the mode in the one-minute deadline condition appears to favor the responder relative to the three-minute deadline condition, this is more than offset by the thinner

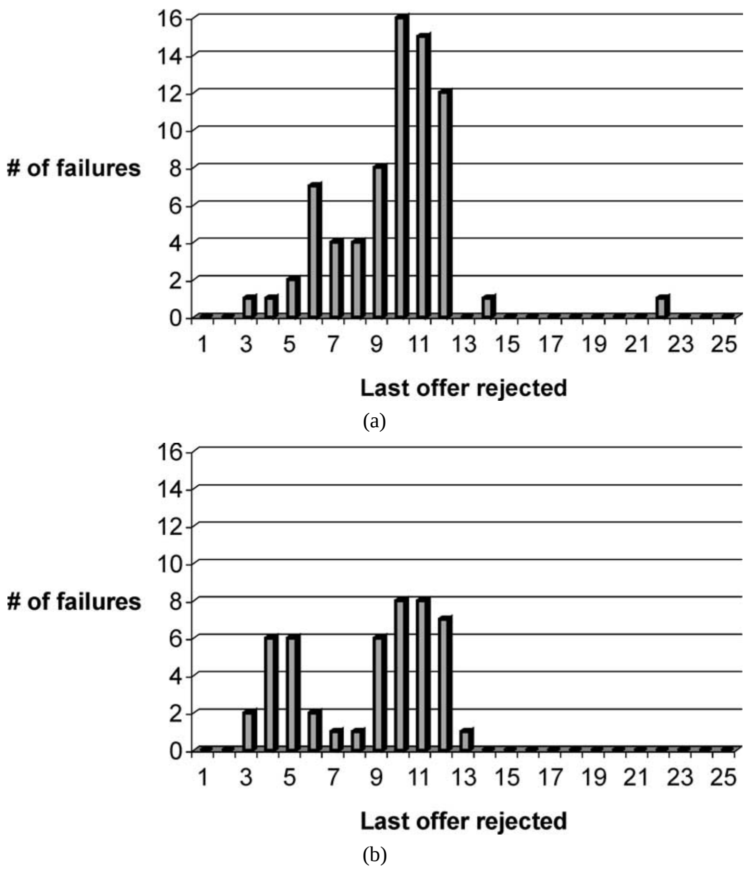
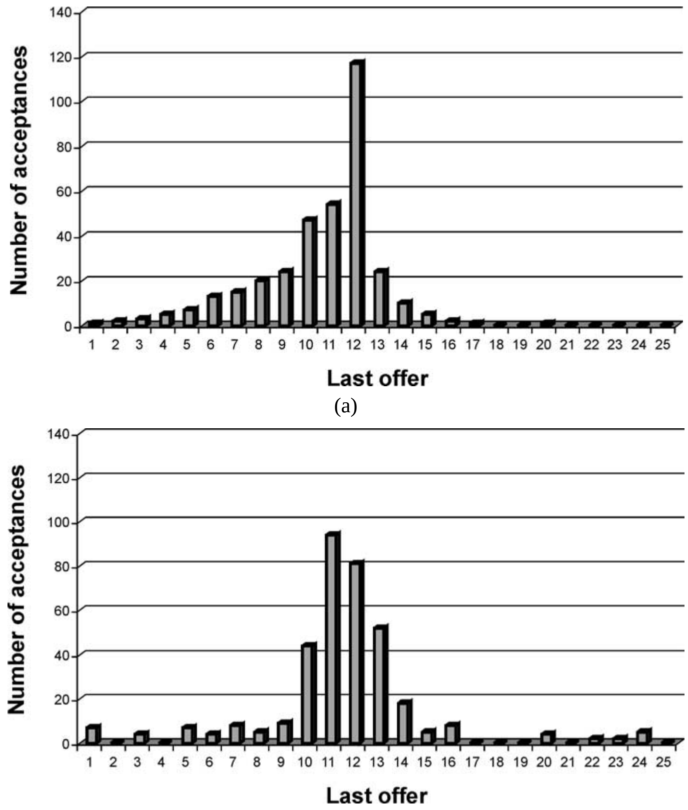


Fig. 5. Bargaining failures due to the deadline being reached: 1RD. (a) One-minute deadline. (b) Three-minute deadline.



(b)

Fig. 6. Bargaining agreements: 1RD. (a) One-minute deadline. (b) Three-minute deadline.

right tail and the wider left tail in the one-minute deadline condition. In fact, the average responder share, conditional on agreement, in the one-minute deadline condition (10.52) is significantly smaller than the corresponding average of 11.48 in the three-minute deadline condition (p-value < 0.0001). These average responder shares in each deadline condition are also significantly different from the average responder share of 13.34 in the no-deadline condition (p-value < 0.0001 in both comparisons). Furthermore, as Fig. 1 suggests, the difference between the three conditions is persistent over time and no significant changes are observed between early and late stages.

3.3. Evidence for strategic use of time

The addition of a deadline benefited the proposer. Our conjecture is that this benefit to the proposer arises out of her ability to wait and propose in the last second, thereby transforming the bargaining into an ultimatum game. Perfect equilibrium and selfish maximization predict that, with the addition of a deadline, we should observe the proposer *always* waiting until the deadline to make her offer. This is because, given the rule that

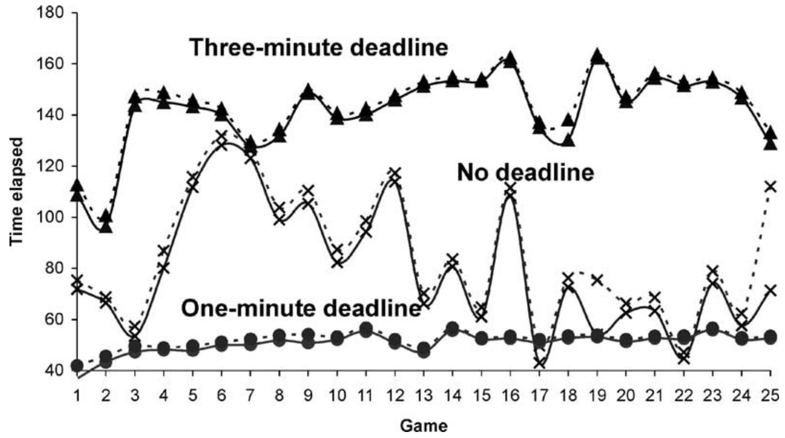


Fig. 7. Time elapsed by last proposal and acceptance: one responder. Solid lines represent last proposals; dashed lines represent acceptances.

specifies that a proposer must strictly increase an offer once it is rejected, the responder's best response is to reject any offer that is given before the deadline.

We do observe that proposers indeed delay. Figure 7 shows average time elapsed by final proposal and final acceptance. It appears that the last proposal occurs on average far later (on average, 61 seconds difference) in the three-minute deadline condition than in the no-deadline condition. In fact, acceptance in the three-minute deadline treatment occurs on average with only 39 seconds remaining to the deadline. This suggests that the agreements take place near the deadline not because of a need for time to reach an agreement, but rather due to the strategic use of time to force a concession. It also appears from Fig. 7 that final bargaining delays in both treatments are proposer-induced rather than responder-induced, since the last acceptance (represented by the dashed lines) generally follows the last proposal with no more than a few seconds delay.

Figure 8 provides the distribution of agreements over time. Whereas close to half of all agreements (42%) take place within the first 40 seconds in the no deadline condition, 7.1% of agreements take place in the first 40 seconds in the one-minute deadline condition and 15.3% of agreements take place in the first 40 seconds in the three-minute deadline condition. In contrast, 87.5% of agreements take place with less than 10 seconds remaining in the one-minute deadline condition and 75.6% of agreements take place with less than 20 seconds remaining in the three-minute deadline condition. That is, Fig. 8 shows a clear "deadline effect," comparable to that observed for bargaining in Roth et al. (1988), and for bidding in Roth and Ockenfels (2002).

4. A RUG with two responders

There is a growing body of evidence showing that the UG outcome is closer to the SPE when the proposer faces multiple responders, who compete with each other for the pie (Güth et al., 1997; Grosskopf, 2003). One rough intuition is that the presence of multiple

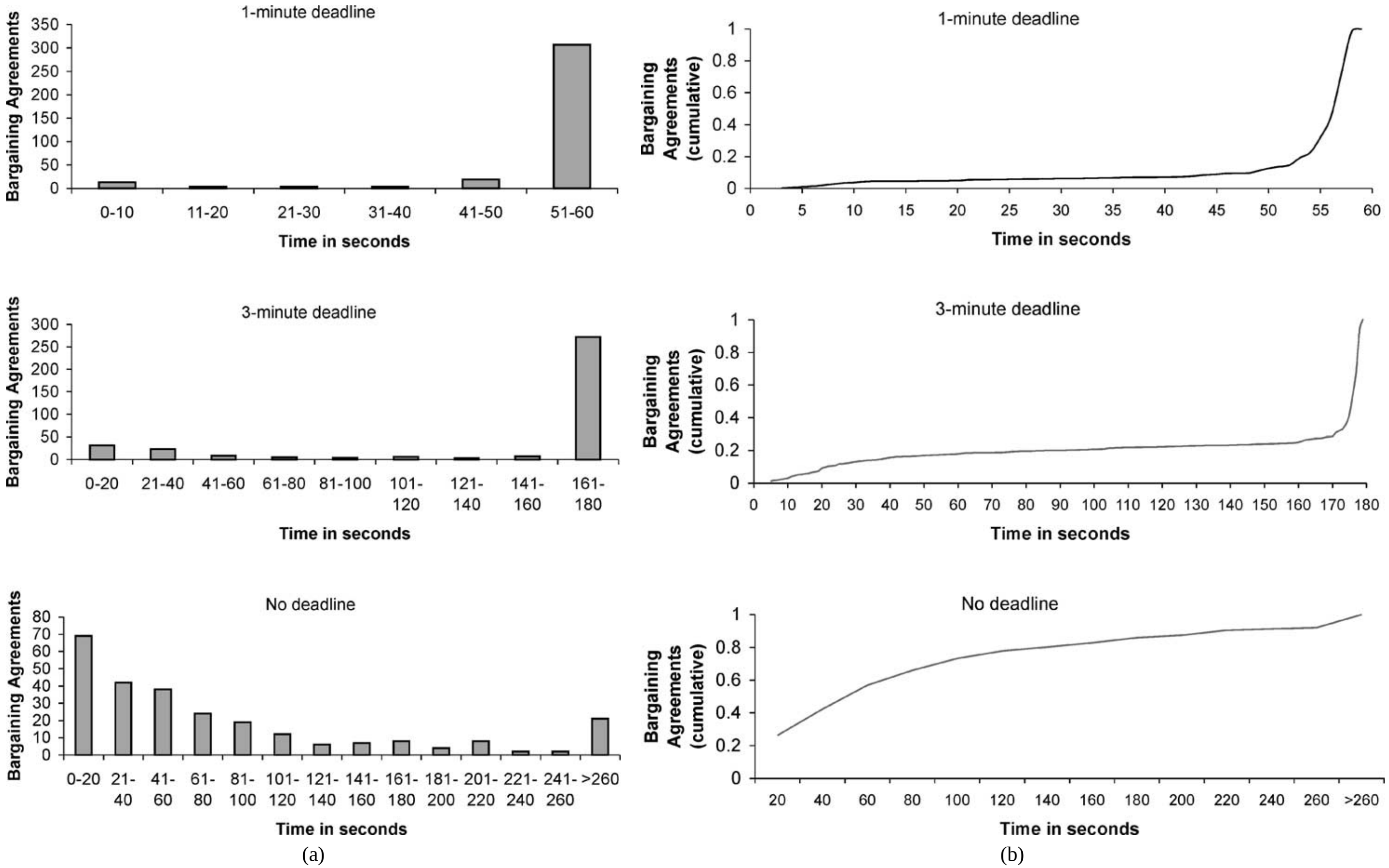


Fig. 8. (a) Distributions of bargaining agreements over time in the one-responder conditions. (b) Cumulative distributions of the same agreements.

responders drives out or dilutes notions of altruism and equity. This would be good for a proposer in the UG, but bad for a proposer in the RUG, since if notions of equity modify the perfect equilibrium predictions in the RUG it is in the direction of allowing the proposer to share some of the surplus. Another intuition is that competition between responders simply strengthens the bargaining position of the proposer. If this is the case, then it would also be good for the proposer in the no deadline RUG. So it is interesting to investigate RUGs with two responders.

Recall that in a two-responder RUG, following a rejection by the first responder, the proposer may decide to terminate bargaining with the first responder, and begin making proposals to the second responder, with a minimum feasible proposal of one token. The subgame at which bargaining commences with the second responder is a basic RUG, with an SPE division of $(1, 24)$. To ensure a unique subgame perfect outcome in the whole game, the maximum share allowed to the *first* responder is 23 tokens. If the first responder rejects 23, the proposer cannot offer any higher amount and must end the bargaining with the first responder. Hence, the unique SPE for the entire game is for the proposer to offer the first responder 23, and for the first responder to accept.[8]

We examine two-responder RUGs with and without a deadline (treatments 2RD and 2RND, respectively). Groups of nine subjects were randomly divided into roles, such that three subjects were assigned to the proposer role, three to the "first responder" role, and three to the "second responder" role.

In these two-responder treatments, a proposer would face a first responder, to whom he or she would make strictly increasing integer offers between 1 and 23. If the first responder accepted some offer, the 25-token pie would be divided according to the agreement reached. In that case, the second, unreached, responder would get a payment of zero. In the proposer-to-first-responder bargaining, at any point in the bargaining, the proposer could choose to end the bargaining with the first responder. This would result in an irreversible switch for that game from bargaining with the first responder to bargaining with the second responder. The first responder in that case would earn zero payment for that game. Though the minimum offer would revert to 0, the clock would not be reset and would continue counting from the beginning of the proposer-to-first-responder bargaining. (As in the one responder games, to make the deadline and no-deadline conditions fully comparable, a clock was visible in both conditions. In the no-deadline condition, however, it did not play any role in causing the game to end.)

In the two-responder-no-deadline (2RND) treatment, each game was played until an agreement was reached or the proposer exited. Bargaining groups were reshuffled after each game. In the two-responder-with-deadline (2RD) treatment, each of 25 bargaining games was played until an agreement was reached, or the proposer exited, or until the 3-minute deadline expired. Bargaining groups were similarly reshuffled after each game.

A total of 63 people participated in this part of the experiment: four sessions of 2RND, and three of the 2RD. Subjects were Greater Boston residents. The vast majority were undergraduate students from Boston University, Harvard, and MIT.

[8] If the proposer could offer 24 to the first responder, multiple SPEs could be supported by the proposer's indifference between receiving 1 in agreements with either of the two responders.

4.1. Two-responder no-deadline (2RND)

There were almost no bargaining failures in this condition: of the 300 games played, 64 included the second responder, and of these only two resulted in early exits by the proposer.

Figure 9 shows that the modal offer accepted (in terms of responder share) in the no-deadline setting with two responders is 10 tokens for the responder who ended up reaching the agreement. The average offer accepted is 10.60 (std. dev. 2.18), pooling the two responders. We see a substantial shift down relative to the corresponding one-responder (1RND) average agreement of 13.34. The 10.60 average accepted offer consisted of 236 agreements with first responders, with an average accepted offer of 10.39 (std. dev. 1.58), and 62 (out of 64 bargaining opportunities) agreements with second responders, with an average accepted offer of 11.40 (std. dev. 3.55). Note that one would need to divide the average accepted offer by two to get average responder share, as one responder always ends up with nothing. Given the much lower offers accepted, the proposer, without deadline, would prefer facing two responders to facing only one responder.

Recall our two conjectures. One was that the presence of multiple responders would reduce considerations of equity, moving the outcome in the direction of the SPE. The

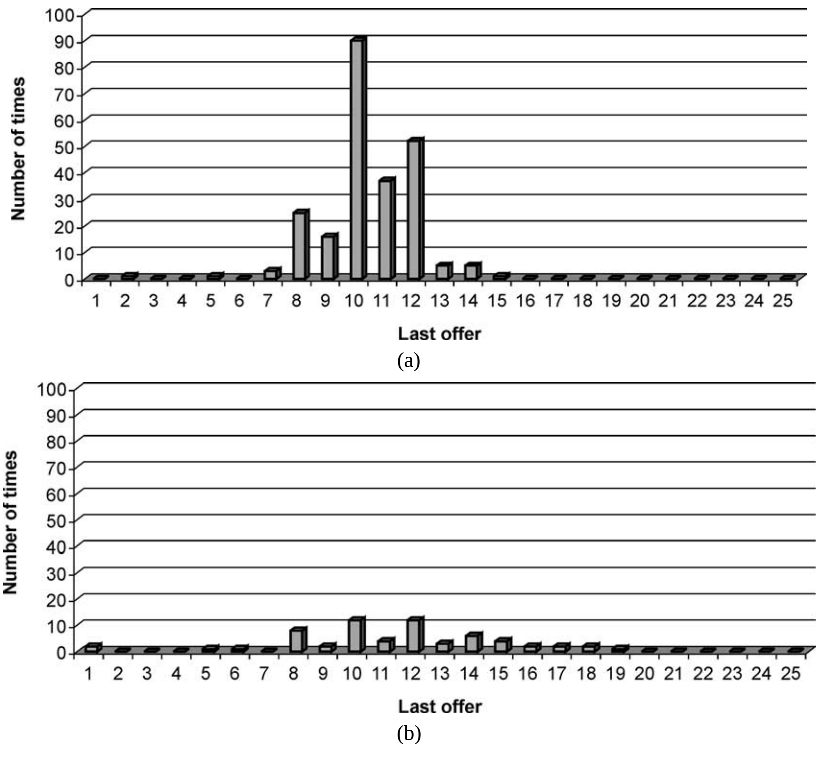


Fig. 9. Acceptance histogram for two-responders-no-deadline; (a) acceptances by first responder, (b) acceptances by second responder.

other was that responder competition would strengthen the proposer's bargaining position, moving the outcome away from the SPE. It appears that the effect of competition dominates in this case.

4.2. Two-responder bargaining with a deadline (2RD)

Of the 225 games played in this condition, 87 involved the second responder, and none resulted in early exits by the proposer. One bargain with a first responder ended with time running out.

Figure 10 shows that the distribution of offers accepted (in terms of responder share) when a deadline is imposed with two responders shifts the agreement further in the proposer's favor. The average offer accepted is 8.45 (std. dev. of 2.62), pooling the two responders. We see a further shift down relative to the two-responder-no-deadline (2RND) average agreement of 10.60. The 8.45 average accepted offer consisted of 137 agreements with first responders, with an average accepted offer of 8.41 (std. dev. of 2.61), and 87

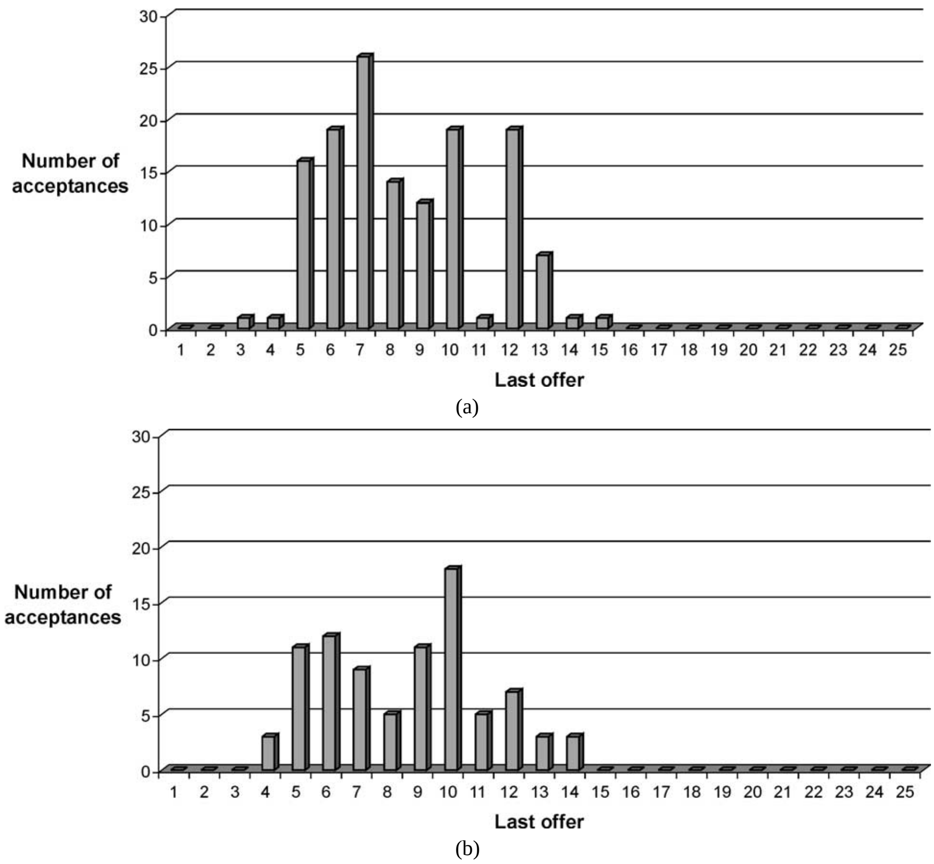


Fig. 10. Acceptance histogram for two responders with a deadline. (a) First responder. (b) Second responder.

agreements with second responders, with an average accepted offer of 8.52 (std. dev. of 2.65).

Given the low average of offers accepted, the proposer would clearly prefer facing two responders with a deadline to facing two responders without a deadline or one responder with or without a deadline.

The results indicate that the deadline, even in the presence of responders' competition, clearly affects the outcome in the proposer's favor, as in the one responder case. But does the proposer exploit the deadline, and if so, is it against the first responder or the second? What does theory prescribe? The theory has unclear predictions in the deadline case since the proposer could wait out the bargaining with either first or second responder.

As in the one-responder-3-minute-deadline condition, imposing a deadline makes the bargaining last *longer*. Whereas subjects did not appear to exhibit any discernible learning pattern in the one responder case (recall Fig. 1), in the two-responder treatment, they exhibit a clear movement towards both longer elapsed time before acceptance (Fig. 11), coupled with lower responder share over time (Fig. 12).

5. Conclusions

The goal of this study was to shed some light on how and why deadlines matter, i.e., on why negotiations in a large variety of settings are settled only at the last minute. To this end, we designed an experiment around a new bargaining game, the Reverse Ultimatum Game, intended to allow us to examine the interplay between psychological and strategic factors that influence bargaining behavior.

This interplay is interesting because one plausible reason that deadlines might matter is captured by theoretical models like those of Ma and Manove (1993). They argue that, at least in some circumstances, a deadline beyond which bargaining may not continue allows a bargainer to try to gain an advantage by delaying an offer. This would turn an unstructured bargaining game[9] into an ultimatum bargaining game, in which the perfect equilibrium prediction is that the bargainer who made the late proposal will receive all the surplus.

But there are two considerable obstacles to testing this hypothesis directly. The first is that, when ultimatum games are examined in the laboratory, the observed outcomes tend to be much closer to equal divisions than to the extreme divisions predicted by perfect equilibrium. The second is that the addition of a deadline to an ultimatum game does not change the perfect equilibrium prediction (which already gives all the surplus to the proposer). But the fact that the perfect equilibrium is not a good point predictor does not imply that the strategic incentives to delay might not exist, and influence the outcome of bargaining, in the manner, if not in the magnitude, predicted by perfect equilibrium.

The reverse ultimatum game permits us to test this latter, modified hypothesis. The addition of a deadline to a reverse ultimatum game does change the perfect equilibrium predictions, for reasons like those that Ma and Manove (1993) proposed. In a reverse

[9] Like those reported in Roth et al. (1988), which had big concentrations of agreements very near the deadline.

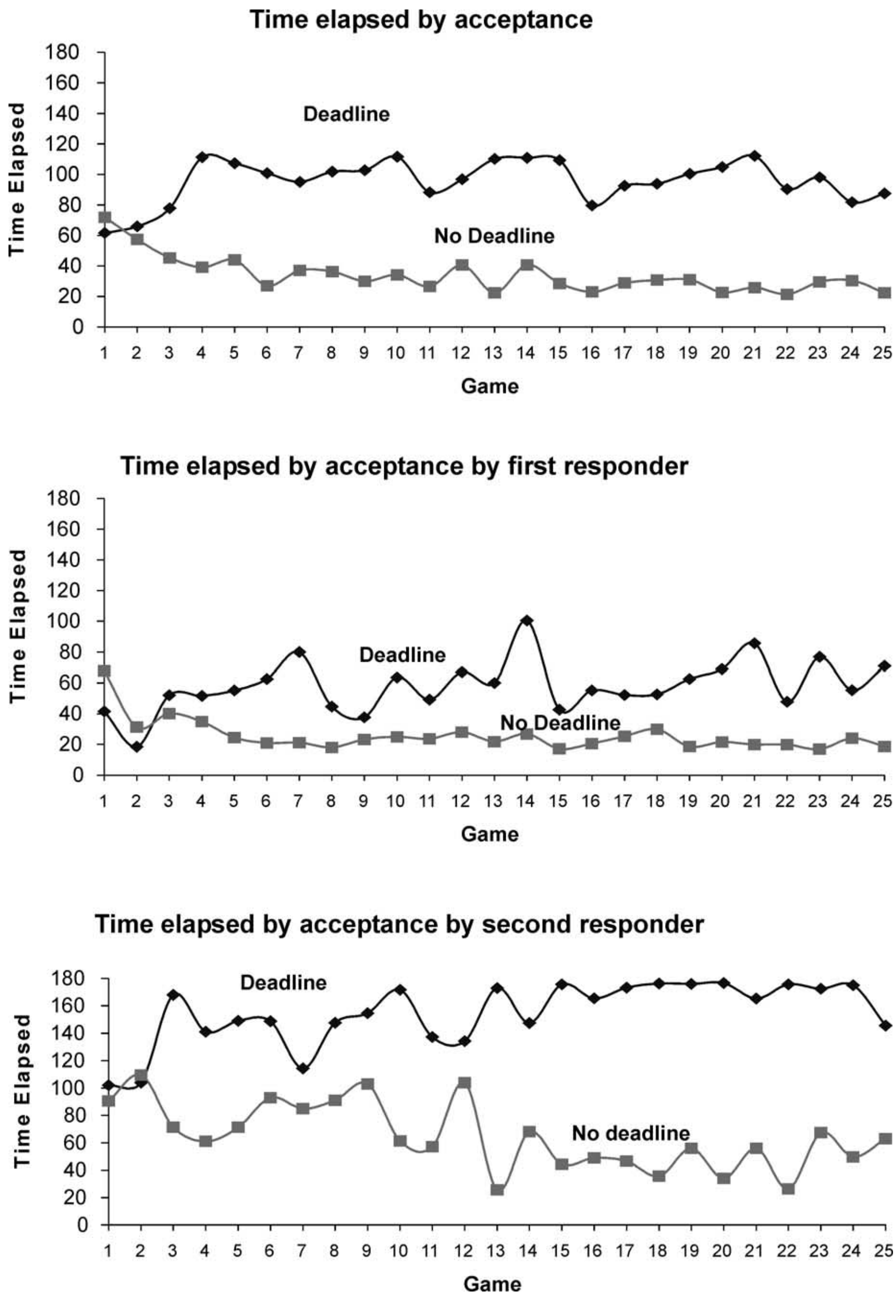


Fig. 11. Time elapsed by acceptance in the two-responder conditions. The first graph pools over the two responders. The bottom two graphs separately depict first and second responders.

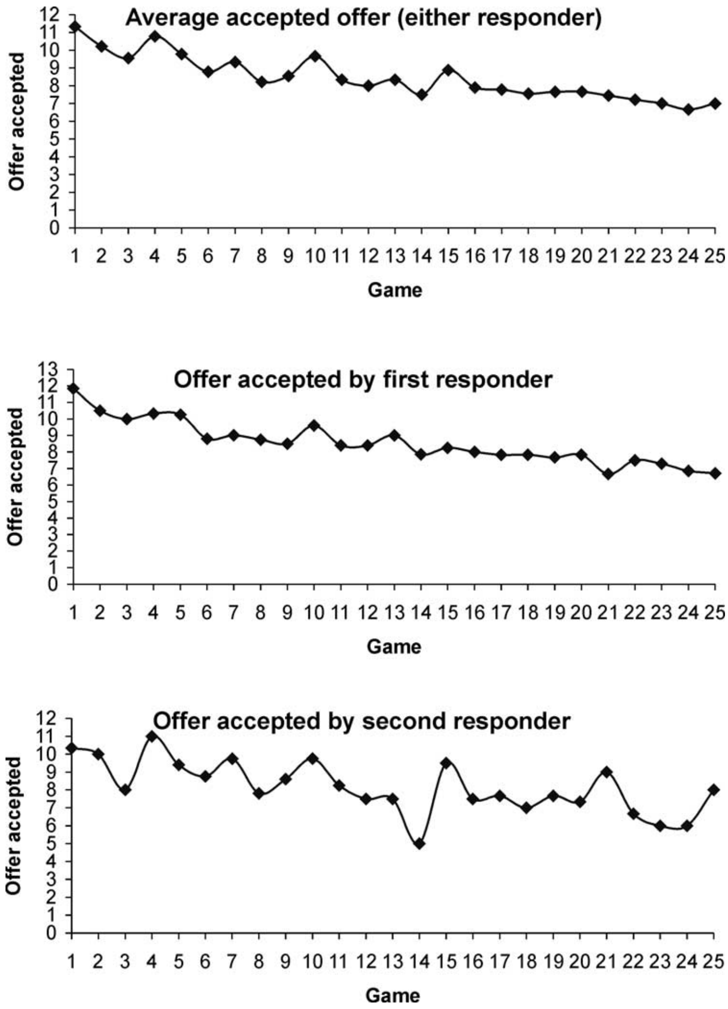


Fig. 12. Offers accepted over time in the two-responder-deadline condition.

ultimatum game with no deadline, the proposer is predicted to gain only the smallest feasible part of the surplus. But when a deadline is imposed, the perfect equilibrium prediction is that the proposer will delay making offers, and by doing so gain almost the full surplus.

Our main finding is that, when a deadline is added to the reverse ultimatum game, proposers do delay proposals until close to the deadline. (Indeed, when a relatively long deadline is imposed, agreements are reached later on average than when there is no deadline.) By delaying agreements, proposers alter the surplus distribution between the negotiating parties significantly to their advantage, though not to the extent theory would predict for pure money-maximizers.

As expected, the experimental results for the reverse ultimatum game are closer to equal division than to the extreme perfect equilibrium predictions, both when there is and when there is no deadline. This conforms to the results of many previous bargaining experiments. In addition, proposers earn more in reverse ultimatum games with two responders than with one, even though the perfect equilibrium prediction is not affected by the addition of a second responder, either when a deadline is in effect, or when there is no deadline.

Aside from these distributive issues, we also find significant deviations from the theoretical predictions regarding the timing of agreements, on the parts of both proposers and responders. In contrast to the prediction of perfect equilibrium, proposers make quite a few offers long before the deadline. And although perfect equilibrium predicts that responders will never accept an offer before the deadline, we observe many agreements long before the deadline. That is, the theoretical prediction that agreements will be reached close to the deadline is supported by our data, but in a much less extreme way. As is the case with the distribution of the surplus, perfect equilibrium predicts the direction of a deadline's effect, but not the magnitude.

To summarize, the reverse ultimatum game allows us to experimentally investigate the tradeoffs between the still poorly understood psychological factors that cause bargaining agreements to be more equal than predicted, and the strategic considerations captured by game theoretic notions like perfect equilibrium (when employed with the auxiliary assumption that players are concerned with maximizing their own income). Concerning the effect of deadlines, this allows us to test the perfect equilibrium prediction that the imposition of a deadline will cause proposals to be delayed until near the deadline, to the advantage of the proposers. Our results confirm this qualitative prediction. Aside from the implications this has for the study of deadlines, these results also suggest that the strategic considerations reflected by perfect equilibrium may have force even in environments in which the point predictions of perfect equilibrium are imperfect.

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Appendix A. Instructions for the one-responder-no-deadline treatment welcome

This is an experiment about economic decision making. If you follow the instructions carefully you might earn a considerable amount of money. This money will be paid at the end of the experiment in private and in cash.

It is important that during the experiment you remain SILENT. If you have any questions, or need assistance of any kind, RAISE YOUR HAND but DO NOT SPEAK. One of the experiment administrators will come to you and you may whisper your question to him. If you talk, laugh, or exclaim out loud, you will be asked to leave and will be paid only the show up fee. We expect and appreciate your cooperation.

In this experiment you will be assigned one of two roles: (1) *PROPOSER*, or (2) *RESPONDER*. Your role will stay fixed throughout your experiment. The experiment will consist of 25 rounds. In each round, your relevant bargaining group consists of two people, including yourself, one in each of the two possible roles. The groups will be reshuffled each round.

In each round, there are 25 tokens (25 tokens = $1.25). The *PROPOSER*'s task is to divide the 25 tokens between himself and the responder. The proposer has unlimited time to reach an agreement with one of the responders.

The proposer can make as many offers to the responder as he wishes. Offers can never decrease and must rise in increments of at least 1 token per offer. Offers must be between 0 and 24 tokens.

Bargaining with the responder will end when one of two things happen: (1) the responder accepts an offer, or (2) the proposer ends the bargaining.

In the case that the responder accepts a proposal, the task ends. Payment for the proposer and responder is determined according to the agreed upon division of the 25 tokens.

If the proposer ends the bargaining, both proposer and responder get no payment for that round. Otherwise, payment is determined according to the agreed upon division of the 25 tokens.

Remember: OFFERS MUST BE BETWEEN 0 and 24 tokens.

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