Reference points in sequential bargaining: Theory and experiment*

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Abstract

We introduce loss aversion in the infinite horizon, alternating offers model. When outside options serve as reference points, the equilibrium of our model follows that of the standard Rubinstein bargaining model. However, when reference points are given by the resources players contribute to the pie, the bargaining outcome changes such that a player's share increases in her contribution. We test our model predictions in the laboratory. As predicted, only binding outside options impact on the division of the pie. Data also show that contributions matter for bargaining outcomes in the way predicted by our theory when they are activated as reference points.

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Keywords*: Bargaining, Reference points, Loss aversion, Outside options, Laboratory experiment*

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1. Introduction

In negotiations a match-specific surplus is created by parties that contribute resources. These contributed resources may have little or no value outside of the match. According to conventional economic theory, the distribution of contributions with zero outside value is irrelevant for the final distribution of the surplus. In contrast to this, a mounting body of experimental evidence suggests that such contributions can impact forcefully on bargaining behavior. In particular, the bargainer contributing relatively more to the surplus tends to capture more of it in the final agreement (Meta et al. 1992, Hackett 1993, Gächter & Riedl 2005, Birkeland 2013, and Karagözoğlu & Riedl 2014).[1]

Conventional theory also predicts that what a bargainer obtains if she terminates bargaining may impact on the distribution of the surplus in an agreement. In particular, sufficiently valuable outside options are predicted to strengthen a bargainer's position and allocate more of the surplus to her. Experimental evidence lends support to this outside-option principle (Binmore et al. 1989, 1991).

We introduce loss aversion in the infinite horizon, alternating offers model. This allows us to rationalize the two sets of observations from the experimental bargaining literature within a single coherent framework. The impact of two kinds of reference points is explored: valuable outside options and contributions with zero outside value. We show that when contributions serve as reference points, the share of the pie is increasing in the players' relative contribution. However, in our equilibrium players with low (high) contributions get more (less) than their contribution. Furthermore, when outside options serve as reference points, the equilibrium of our model is no different from the standard alternating offers equilibrium.

We set up an experiment designed to test the model predictions. In contrast to many other models used in bargaining experiments the equilibrium of our model is unique. Thus, we obtain a benchmark to evaluate behavior against. Our approach to the activation of reference points is in the spirit of Fehr et al. (2011).[2] Outside options and contributions are only activated as reference points when players become entitled to them under competitive conditions.[3] In the experiment competitive conditions are induced by a real-effort tournament in which contributions and outside options are earned. We contrast this with randomly allocated contributions and outside options.

We find that the outside-option principle is strongly present in the data under both conditions. In line with our model, both earned and randomly allocated outside options impact on bargaining outcomes in the same way.[4] Furthermore, data lend support to the prediction that

[1] Relatedly, a growing experimental literature on hold-up problems finds that bargainers generally over-invest relative to equilibrium levels, and are compensated for these investments in the final agreement, despite investments being sunk costs (e.g. Sloof et al. 2004, Ellingsen & Johannesson 2001, 2004, Sonnemanns et al. 2001).

[2] See also Hart & Moore (2008) and Fehr et al. (2009).

[3] It is well known from the experimental literature that subjective entitlements are generated by effort rather than luck. See e.g. Gächter & Reidel (2005); Karagözoğlu & Reidl (2014); and Birkeland (2013). More generally, earned endowments are often used to reinforce self-regard in the study of fairness norms (e.g., Forsythe et al. 1994, Cherry et al. 2002, Oxoby & Spraggon 2008).

[4] In this we replicate the results in Binmore et al. (1989), but also stress test these results by (i) introducing more extreme outside options, and (ii) investigating the effect of earned outside-options in addition to the randomly allocated outside-options of the original experiment.

relative contributions matter for bargaining outcomes only when they are earned. In particular we find a functional relationship between earned contributions and bargaining outcomes that closely corresponds to the one predicted by our theory. Also, we estimate a loss aversion parameter that is within the range typically found in non-strategic decision experiments.

Why focus on outside options and contributions as candidates for reference points? An outside option is a players' maximin payoff in the bargaining game. Since a subject can guarantee itself the maximin payoff, we believe that only payoffs exceeding this level are evaluated as gains. Further, the irrelevance of match-specific contributions in conventional theory may be counter intuitive for subjects. We believe that a subject that has contributed more than its match is likely to feel entitled to a larger share of the pie, and to consider it a loss if not compensated for its contribution.

A growing body of research models agents with reference dependent preferences. Empirical evidence from the field and the lab indicates that such dependencies can be powerful determinants of economic outcomes.[5] To the best of our knowledge, however, only two other papers model alternating offer bargaining with loss averse preferences. In contrast to us, these papers build on a forced breakdown protocol, and reference points are either formed on the basis of offers in the present game (Driesen et al. 2012) or in the preceding game (Compte & Jehiel 2003). In our model, the focus is on reference points formed on the basis of what players bring into the bargaining situation.[6,7] We are not aware of other papers exploring loss aversion in alternating bargaining empirically.

In our model reference points define the regions of loss and gain. Reference points are activated by entitlements obtained under competitive conditions. We do not assume that entitlements give rise to moral obligations, as is the case in, for instance, Cappelen et al. (2007) and Hoffman & Spitzer (1985). Neither do we assume that entitlements generate social comparisons and shape behavior through the need for dissonance avoidance, as is common in social psychology (Adams 1963, 1965, and Huseman et al. 1987). In our model we simply assume that players have a purely self-regarding motivation, and that their utility kinks around a reference point.[8] Our design is not meant to test alternative theories of social, psychological or moral motivation. Nevertheless, it is natural to wonder how other theories of motivation relate to our data. We discuss this briefly at the end of the paper.

[5] Examples include the cutoff between perceived losses and gains (Kahneman & Tversky 1979, Camerer 2000, Köszegei & Rabin 2006); fairness norms (Kahneman et al 1986; Fehr & Schmidt 1999, Bolton & Ockenfels 2000); perceived kindness of the acts of others (Rabin 1993, Charness & Levine 2007, Falk et al. 2008); contractual obligations entered into under competitive conditions (Hart & More 2008; Fehr et al. 2011; Hoppe & Schmitz 2011); fixed individual income targets (Camerer et al. 1997, Faber 2005); and relationship-specific investments in bargaining (Ellingsen & Johannesson 2005).

[6] Shalev (2002) also formulates a model of loss aversion in alternating offer bargaining. In his model loss aversion is equivalent to higher impatience.

[7] The focus is thus on reference points that arise because of what players bring to the bargaining table and not on reference points that arise endogenously like in Köszegi & Rabin (2006). Also, since our model assumes complete and perfect information, and has a unique equilibrium, there is no room for expectations based reference points of the Köszegi & Rabin (2006) kind.

[8] Loss averse preferences are well documented in the field (Camerer 2000) as well as in the lab (Abdellaoui et al. 2007). Furthermore, such preferences seem to have deep roots. Chen et al. (2006)—using capuchin monkeys as experimental subjects—provide evidence indicating that loss averse preferences are innate rather than learned, and are likely to have evolved at an early stage. Tom et al. (2007) present neural correlates of loss aversion in humans, indicating that we are hard-wired to evaluate gains and losses asymmetrically, relative to a reference point.

The paper proceeds as follows. The next section lays out the alternating offer model with and without reference dependent preferences. Section 3 presents the experimental design, while the results from the lab and tests of model predictions are given in section 4. Section 5 provides a discussion, while section 6 concludes.

2. Model

In this section we set up and solve the subgame perfect equilibrium of an infinite-horizon alternating-offers models with loss averse bargainers.

There are two players $i \in \{1, 2\}$ that bargain over a perfectly divisible pie of size π. Denote s_i player i's share of the pie, where the bargaining outcome satisfies $s_i \geq 0$ and $s_1 + s_2 = 1$. The alternating-offers protocol is as follows: player 1 is the proposer in even periods, and player 2 is the proposer in odd periods. The player that is not the proposer can accept the offer, reject the offer, or take her outside option. Bargaining continues until an agreement is reached, or a player uses her outside option. Time is infinite and payoffs in future periods are discounted by a common factor $\delta \in (0, 1)$.

Denote ψ_i the outside option of player i, where ψ_i is measured as a share of the pie. We assume $\psi_2 \geq 0$ and $\psi_1 = 0$. If a player terminates bargaining by taking his outside option the opponent gets nothing. Let u_i be player i's utility function over outcomes s_i. The shape of the utility function will be the only difference between the standard model (Rubinstein 1982, and Binmore 1986) and our model with loss aversion.

The standard bargaining model

To facilitate a comparison with the loss aversion model below we briefly outline the equilibrium of the standard model. Let player i's utility be given by

$$u_i(s_i) = s_i\pi.$$

Consider first the game without outside options. Player 1 makes an offer x, where x is the share of the pie that goes to player 1 with the complement $1 - x$ going to player 2. If player 2 rejects, the pie shrinks and player 2 makes a counteroffer y, where y again is the share of the pie that goes to player 1. In the subgame perfect equilibrium of the game, player 1 proposes x and player 2 proposes y such that

$$\begin{aligned} u_1(y) &= \delta u_1(x) \\ u_2((1-x)) &= \delta u_2((1-y)). \end{aligned} \tag{1}$$

The equilibrium condition with linear utility is then

$$\begin{aligned} y\pi &= \delta x\pi \\ (1-x)\pi &= \delta(1-y)\pi. \end{aligned} \tag{2}$$

Notice that utility is proportional to π so we can eliminate the pie size from equations (2). Solving these equations, we get the equilibrium solution

$$x^* = 1 - y^* = \frac{1}{1+\delta} > 0.5.$$

The fact that both players propose to take more than half of the pie is the first-mover advantage. It is well known that the equilibrium is unique and in stationary strategies.

Outside options only matter if they are binding. That is, if the equilibrium offer in the game without outside options provides a player with more than her outside option, the outside option does not impact on the player's equilibrium share. On the other hand, if the equilibrium offer in the game without outside options provides a player with less than her outside option, the outside option is binding and will be offered to the player in equilibrium. Given our assumptions, player 1's outside option is never binding.[9]

Bargaining with loss aversion

In what follows we focus on the effect of two different reference points: valuable outside options and contributions with no outside value. A contribution is defined as the share of the pie a player brings to the bargaining table. The idea of a reference point in the form of a cut off between perceived gains and losses is central to Prospect Theory, introduced by Kahneman and Tversky (1979). In line with much of the subsequent literature we focus only on the loss aversion element of Kahneman and Tversky's utility function—or value function in their terminology—and assume except for a kink at the reference point that the utility function is linear.[10]

Let r_i denote player i's reference point measured as a share of the pie. In addition to the linear payoff $s_i\pi$, a player suffers a loss if her outcome is below the reference point, i.e. when $s_i < r_i$. We assume that the utility function is given by $U_i = u_i(s_i)\pi$ with

$$u_i(s_i) = \begin{cases} s_i & \text{for} \quad s_i \geq r_i \\ s_i - \mu(r_i - s_i) & \text{for} \quad s_i < r_i \end{cases}, \tag{3}$$

where $\mu > 0$ reflects loss aversion and outcomes $s_i < r_i$ are in the loss zone. Notice that the slope of the utility function in the loss zone is $\lambda = 1 + \mu$. This slope is specified as the key parameter of loss averse preferences. Empirically, the critical test of the effect of a reference point is whether μ is significantly larger than 0. Note that the utility function is calibrated such that it is identical to the utility in the standard bargaining model when players are in the gain zone. As a result, utility departs from the standard formulation only if a player's share is below its reference point.

The reference points are exogenous to the bargain game and can either stem from outside options or contributions in our model. Since we satisfy the axioms of the Rubinstein bargaining model, the equilibrium of the model with reference points is still given by (1), is unique, and

[9] With outside options, uniqueness of the equilibrium is conditioned on the specifics of our protocol; i.e. that only player 2 can opt out. More generally, other protocols with outside options can generate multiplicity (see Shaked (1994))

[10] Empirical investigation of the value function frequently returns estimates close to linearity on each side of the reference point (see for instance Abdellaoui et al. 2007).

in stationary strategies. In particular introducing a reference point is compatible with the requirement of a continuous utility function that is increasing in the pie-share and decreasing in the discount factor.[11]

We now analyze the equilibrium for the two different reference points separately. Consider first the case in which the reference points are given by outside options. Recall that only player 2 may have a positive outside option.

As with standard preferences, the outside option of player 2 only matters when it is binding. Further, when it is binding the player is offered her outside option in equilibrium. The following theorem is then straightforward to establish.

Theorem 1 *With outside options as reference points, loss aversion does not impact on equilibrium behavior.*

Proof. See Appendix ■

Theorem 1 follows from the fact that a player never gets less than her outside option in equilibrium, and thus is never in her loss zone. We conclude that if bargainers are loss averse and use their outside option as a reference point, the predictions of the standard model and the model with loss averse preferences are identical.

Now consider the case in which the reference points are given by the players' relative contributions to the pie. To simplify the exposition we set outside options to zero for both players. The pie size is given by the sum of contributions. We denote $\bar{s}$ the relative contribution of player 1, with $1-\bar{s}$ the relative contribution of player 2. Note that for a given proposal, at most one player will be in the loss zone. We prove the following theorem.

Theorem 2 *Assume that the reference points of the players are $r_1 = \bar{s}$ and $r_2 = 1-\bar{s}$. Then the equilibrium share of the pie is increasing in the player's contribution. In particular, the subgame perfect equilibrium solution can be written as the proposal from player 1 as a function of $\bar{s}$:*

$$x(\bar{s}) = \begin{cases} \frac{1}{1+\delta} + \frac{\delta\mu}{(1+\delta)(1+\mu)}\bar{s} & \text{if} \quad \frac{1+\mu}{1+\delta+\mu} < \bar{s} \leq 1 \\ \frac{(1-\delta)(1+\mu)}{(1+\mu-\delta)(1+\mu+\delta)} + \frac{\mu}{1+\mu-\delta}\bar{s} & \text{if} \quad \frac{\delta}{1+\delta+\mu} < \bar{s} \leq \frac{1+\mu}{1+\delta+\mu} \\ \frac{1}{(1+\delta)(1+\mu)} + \frac{\mu}{(1+\delta)(1+\mu)}\bar{s} & \text{if} \quad 0 \leq \bar{s} \leq \frac{\delta}{1+\delta+\mu} \end{cases},$$

where $x(\bar{s})$ is player 1's share.

Proof. See Appendix ■

Theorem 2 states that if the players' relative contributions form reference points, a player receives more of the pie in equilibrium the higher her contribution is. The intuition is that offers too far into the loss zone will be rejected. A player facing such an offer prefers to wait and make a counteroffer with reduced loss—there is always less loss in the counteroffer—rather than accepting now. This is anticipated by the proposer and in equilibrium proposals are not

[11] For a discussion of the axioms see Osborne & Rubinstein (1990): section 3.3.

too far from the reference points. As in the standard model, the first-round offer is accepted in equilibrium, and thus $x(\bar{s})$ is the share of π that goes to player 1 with $1 - x(\bar{s})$ to player 2. Also, the first mover has an advantage.

The equilibrium share is piecewise linear in the relative contributions. To develop insights about the impact of loss aversion, consider first the equilibrium in the mid range of $\bar{s}$ ($\frac{\delta}{1+\delta+\mu} < \bar{s} \leq \frac{1+\mu}{1+\delta+\mu}$). In this range a player is in the loss zone only if she is a responder. Consider player 2's choice between accepting an offer $1 - x < 1 - \bar{s}$ or rejecting and claiming $1 - y$ in the next round. Recall that in the absence of loss aversion the equilibrium condition for player 2 would be $(1 - x)\pi = \delta(1 - y)\pi$. By waiting she can claim a larger share of a pie that is worth less due to discounting. With loss aversion, there is an additional gain from waiting, as rejecting the offer will remove the loss given by $\mu\left[(1 - \bar{s}) - (1 - x)\right]\pi$. This places a cap on how much player 1 can claim without provoking a rejection. The same mechanism limits the amount player 2 can claim in the subgame following a rejection. In equilibrium then, the shares offered are close to the players' contributions.

Next, in the high range of $\bar{s}$ ($0.5 < \frac{1+\mu}{1+\delta+\mu} < \bar{s} \leq 1$) player 1's contribution is substantially higher than that of player 2. Since player 2's contribution is too small for her to accept an offer at or below her reference point, player 1's equilibrium claim is forced into his loss zone. In effect, the equilibrium shares are further away from the reference points than in the mid range, and the slope of $x(\bar{s})$ is less steep. Still, player 1—when responding—can reduce his loss by rejecting and make a counteroffer. Thus player 2 will offer more in the presence of loss aversion than she would have done if player 1 did not have such preferences. Finally, behavior in the low range of $\bar{s}$ ($0 \leq \bar{s} \leq \frac{\delta}{1+\delta+\mu}$) mirrors that in the high range.

Notice that the mid range—where equilibrium shares are close to contributions—expands with loss aversion, while it shrinks with a higher discount factor. As loss aversion increases, the players can credibly hold out for a share close to their reference points. On the other hand, the effect of loss aversion is diluted as players become more patient, since the player with the smaller contribution now can credibly hold out for a larger share.

In the next section, we discuss model predictions and show some comparative statics on the equilibrium when varying the loss aversion parameter, given the other parameters of experiment.

3. Design and procedures

The predictions of the infinite horizon, alternating bargaining model are summarized in Table 1 for standard preferences and for loss averse preferences, given outside options $\psi_1 = 0$ and $\psi_2 \geq 0$ and a common discount factor $\delta = .9$ used in all sessions of our experiment. The table highlights the centerpiece of our design: loss aversion *only* impacts on equilibrium behavior when contributions form reference points. By assumption, reference points are only activated when they are earned under competitive conditions. Thus, by Theorem 1, we conjecture that behavior under T1 and T2 is identical and follows the standard Rubinstein model. Since contributions are randomly allocated under T3 while they are earned under T4 we expect behavior to differ. In particular we expect behavior to follow the standard Rubinstein model in T3 while in T4 we expect behavior to conform to Theorem 2.

	STANDARD PREFERENCES	LOSS AVERSION
OUTSIDE OPTION	$x^* = .53, 1 - x^* = .47$ if $\psi_2 \leq .47$	$x^* = .53, 1 - x^* = .47$ if $\psi_2 \leq .47$
(T1 and T2)	$x^* = 1 - \psi_2, 1 - x^* = \psi_2$ if $\psi_2 > .47$	$x^* = 1 - \psi_2, 1 - x^* = \psi_2$ if $\psi_2 > .47$
		(Theorem 1)
CONTRIBUTION	$x^* = .53, 1 - x^* = .47$	$x^* = x(\bar{s}), 1 - x^* = 1 - x(\bar{s})$
(T3 and T4)		(Theorem 2)

Table 1: *Theoretical predictions; ψ_2 is the outside option of the second mover*

The predicted relationship between contribution and equilibrium demand of the first mover in our experiment is plotted in Figure 1. Detailed calculations are provided in the Appendix. The figure displays $x(\bar{s})$ for $\delta = .9$, and for four values on the loss aversion parameter $\lambda = 1 + \mu$. The typical finding in the literature is that λ is in the range $(1.0, 2.5]$ (see e.g. Abdellaoui et al. 2007 with references). Note, however, that we only consider relative losses, thus the effect may be somewhat smaller. A reasonable conjecture is that λ should be in the range simulated in Figure 1.

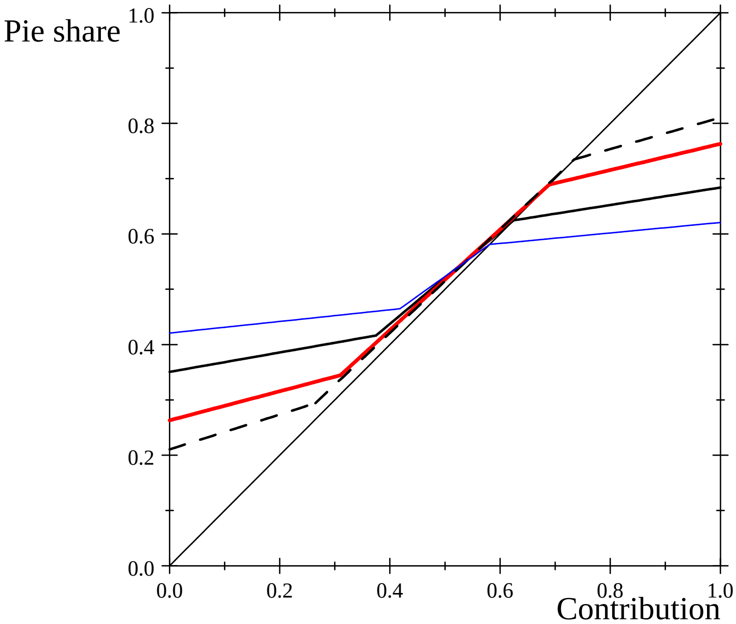


Figure 1: *Equilibrium payoff (x) to player 1 as a function of its contribution $(\bar{s})$; for $1 + \mu = \lambda = 1.25$ (blue); 1.5 (black); 2 (red); 2.5 (dashed black).*

From Figure 1 we appreciate that the equilibrium demand of the first mover is increasing in his or her contribution, and that the increase is steeper for contributions in a mid range. Furthermore, the support of the mid range is wider the more loss averse players are. Lastly, increasing loss aversion imposes a higher ceiling and a lower floor on the players' equilibrium demands.

Our design has four treatments. In the first two treatments (T1 and T2) the pie size was held constant at $Z = 70$ Experimental Currency Units (ECU), and an outside option worth $w_i = \{0, 20, 40, 60\}$ ECU was allocated to the second mover. Thus, $\frac{w_i}{Z} \equiv \psi_i = \left\{0, \frac{2}{7}, \frac{4}{7}, \frac{6}{7}\right\}$. In T1 the allocation of w_i was random, while in T2 it was based on the ranking of subjects in a costly effort task performed prior to bargaining. Note that while $\psi_i \in \left\{0, \frac{2}{7}\right\} < 1 - x^*$ and therefore non-binding, $\psi_i \in \left\{\frac{4}{7}, \frac{6}{7}\right\} > 1 - x^*$ and therefore binding. Following Binmore et al. (1989), instead of providing the first mover with an outside option of value zero, the first mover was not provided with the opportunity to opt out at all. The equilibrium remains the same whether the first mover is given an outside option of value zero, or no outside option at all.

In the last two treatments (T3 and T4) all second movers had a non-binding outside option $\psi_i = 0$. In these treatments the pie size (Z) in a match was the sum of ECU's brought to the table by each of the bargainers in the match; $z_1 + z_2 = Z$, with $z_i = \{0, 20, 40, 60\}$ ECU. As a result $Z = \{0, 20, 40, 60, 80, 100, 120\}$ ECU with contributions $\frac{z_i}{Z} \equiv s_i = \left\{0, \frac{1}{4}, \frac{1}{3}, \frac{2}{5}, \frac{1}{2}, \frac{3}{5}, \frac{2}{3}, \frac{3}{4}, 1\right\}$.[12] In T3 the allocation of z_i on subjects was random, while in T4 it was based on the ranking of subjects in a costly effort task performed prior to bargaining.

The costly effort task used in T2 and T4 was identical, and based on Erkal et al. (2011). Subjects were given a string of five random letters and a "key" assigning a number to each letter in the alphabet. The task was to translate the letters of a string of corresponding numbers. Performance was measured as the number of correctly coded strings over the 10 minutes allocated to the task. w_i and z_i respectively, were allocated according to performance scores in the following manner: the quartile with the highest score was allocated 60 ECU as their w_i or z_i, the second to highest quartile was allocated 40 ECU as their w_i or z_i, and so on.

In the bargaining part of the experiment, half of the subjects started in the role of first mover while the remainder of the subjects started in the role of second mover. Role allocation in game one was random. After half of the bargaining games had been concluded, roles were switched. Subjects kept their allocated w_i or z_i respectively for all games in their session. Subjects were matched using an absolute stranger matching, in which no subject was matched with the same subject more than once in a session. This matching protocol helps control for dynamic session effects produced by reciprocity and strategic teaching.[13]

Discounting was implemented by shrinking the pie by 10 percent in each new period. An infinite horizon was implemented as in Binmore et al. (1989). That is, after explaining moves and payoffs of period one, the instructions stated that "[T]he game continues in this way, with the pie shrinking by 10 percent following each rejection, until an agreement is reached or the second mover opts out".[14,15]

Prior to each bargaining game in T3 and T4, subjects were informed about the contribution

[12] If a matched pair had $s_1 = s_2 = 0$, bargaining was aborted and subjects received a payoff of 0 ECU.

[13] See the discussion in Frechette (2012).

[14] We acknowledge that the implementation of an infinite horizon in Binmore et al. (1989) might be considered in the grey zone of deception by the standards of today. Nonetheless, in the interest of replication we decided to follow the original implementation.

[15] While behavior in the alternating offer game is in general consistent with equilibrium play under infinite horizon, publicly announcing a final period seems to create substantial deviations from equilibrium. At least this holds for games of 3 to 5 stages (Ochs & Roth 1989). There seems to be a consensus that subjects are in general not very good at performing backwards induction, at least not when they are unfamiliar with this principle (Binmore et al. 2002, Camerer *et al.* 1993).

of their match in that game. Prior to each bargaining game in T1 and T2, the first mover was informed about the outside option of its match in that bargaining game. Information about the outside options and contributions respectively, also appeared in every decision screen as a reminder.

We ran one session with 30 subjects in both T1 and T2, and two sessions of 30 subjects in both T3 and T4. Thus the experiment used a total of 180 subjects. Due to time constraints—subjects were told that the experiment would not last more than an hour and a half—we ended up with a varying number of games in the four treatments.[16] Subjects in T1 played a total of 10 games, while subjects in T2 played a total of 8 games. Subjects in the first session of T3 played a total of 4 games, while subjects in the second session of T3 played a total of 6 games. In T4 subjects played a total of 4 games in both sessions. Subjects were recruited from the general student populations of the University of Oslo and BI Norwegian Business School using the ORSEE system (Greiner 2015). All sessions were conducted in the BI Research Lab in Oslo.

The experiment was programmed in z-Tree (Fischbacher 2007), using neutral language. Subjects were randomly allocated to numbered cubicles on entering the lab (to break up social groups). After being seated, each subject was issued written instructions and these were read aloud by the administrator of the experiment (to achieve public knowledge of the rules).[17] After the last game of a session had been concluded, accumulated ECUs were converted to NOK at the pre-announced exchange rate, and subjects were paid privately on leaving the lab. Data were collected between January 2013 and February 2014. On average a session lasted 90 minutes, and average earnings were 350 NOK (around 48 US dollars at the time of the experiment).

4. Results

In what follows we focus on the outcome of bargaining, while briefly commenting on players' offers. A detailed analysis of offers is contained in the supplementary materials. We perform a number of regressions in what follows. The regressions in the main text use the match as the unit of observation, and are performed using robust standard errors. We acknowledge that strictly speaking observations at the match level are not independent. To control for dependencies we run additional regressions in the supplementary materials, clustering standard errors on sessions if more than one session was conducted, and using random effects for individuals to control for unobserved heterogeneity. The supplementary material shows that our results are robust to such corrections. We also perform non-parametric tests of behavior in the first game of each session.

Outside options

Figures 2a and 2b show the payoff of the second mover as a share of the pie at the moment of agreement, given the second mover's outside option, and by treatment, i.e. whether outside options were allocated randomly T1 (Figure 2a) or earned T2 (Figure 2b). As is evident from

[16] The experiments was programed such that all pairs had to finish before the next game could start. Variation in the number of games is largely due to i) the presence of an effort stage in T2 and T4, and ii) some pairs of bargainers using many periods to reach agreement.

[17] A full set of instructions with screenshots is provided in the supplementary materials.

the light grey bars in the figures, behavior is far from equilibrium in the first game.[18] However, as the experiment progresses, the splitting of the pie approaches equilibrium.

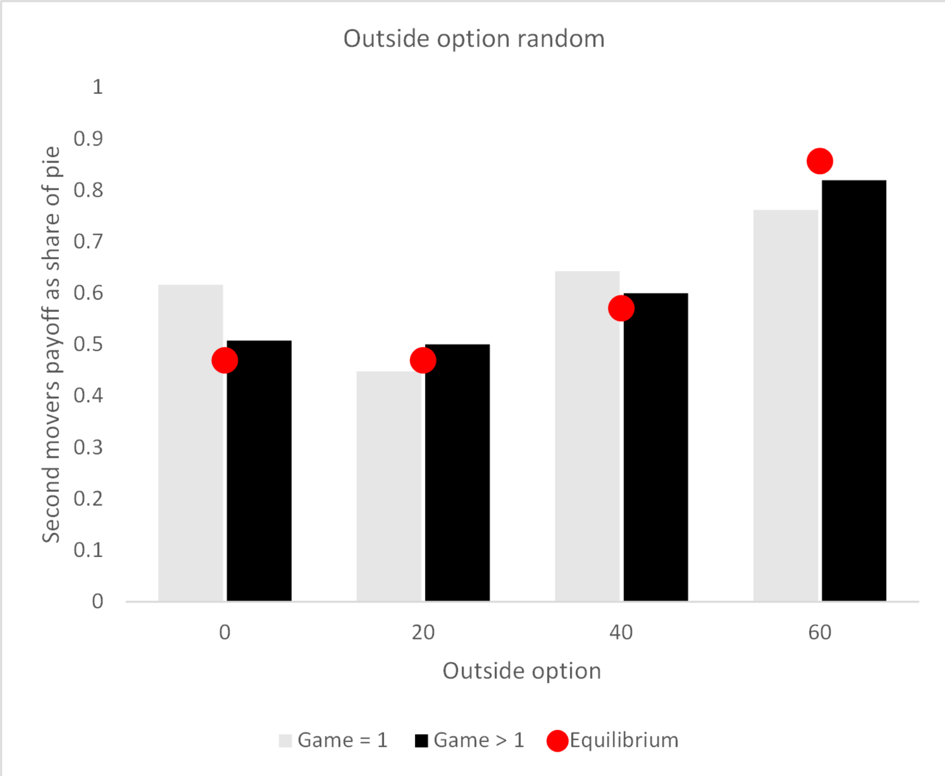
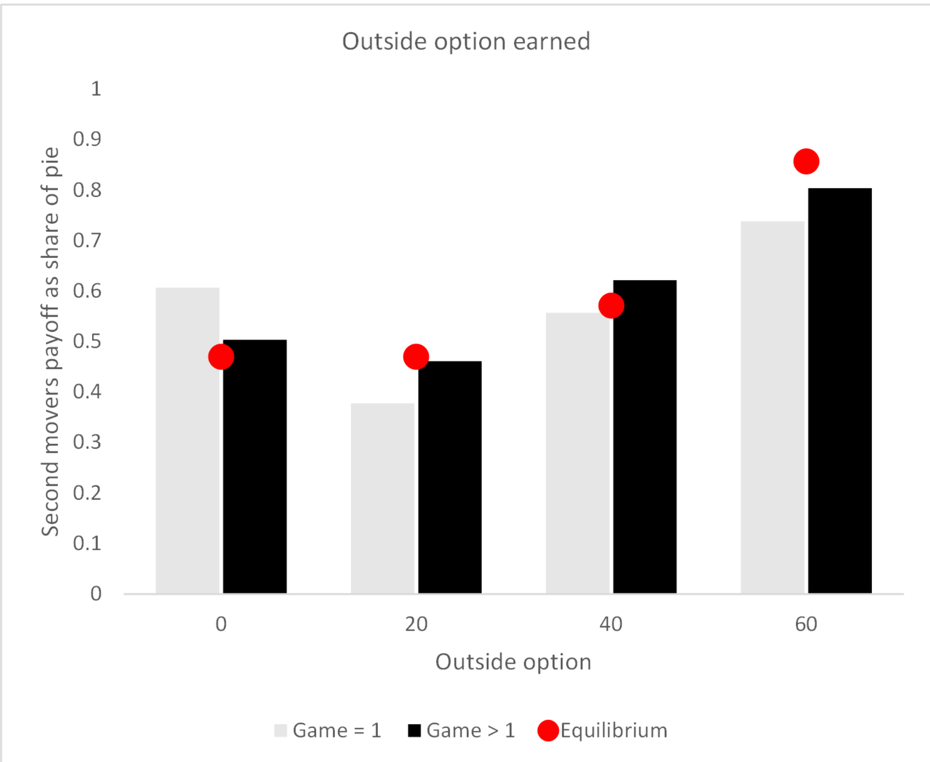


Figure 2a: *Share of the pie received by the second mover: randomly allocated outside options.*



[18] Out of equilibrium behavior in the first game is significant, and is confirmed by Wilcoxon rank sum (WRS) tests for differences in pie share over outside options provided in the supplementary material Table S1.

Figure 2b: *Share of the pie received by the second mover: earned outside options.*

Tables 2a and 2b show the average payoffs for randomly allocated (T1) and earned outside options (T2) respectively, using all games. The numbers show a pattern broadly consistent with theory. In particular, players with outside options equal to zero or twenty get on average about 50% of the pie. T-tests reveal that there is no significant difference between the payoffs of players with 0 and 20 outside options. In contrast, players earn a higher average payoff when holding outside options. We conclude that in both treatments only binding outside options impact on the division of the pie. Moreover, the result in the randomly allocated outside option treatment (T1) replicates Binmore et al. (1989) findings for $w_i = \{0, 20, 40\}$, which were studied in their experiment.

An additional result is that whether outside options are randomly allocated or earned have little impact on the splitting of the pie. In fact, T-tests reported in Table S10, in the supplementary material, reveal no significant difference in share of the pie received by the second movers between the two treatments.

T1: Average payoff		Option=20	Option=40	Option=60
Option=0	.519	.462‡	.002†	.000†
	(.024)			
Option=20	.495		.000†	.000†
	(.022)			
Option=40	.604			.000†
	(.016)			
Option=60	.814			
	(.022)			
N	150			
# of games	10			
# subjects	30			

Table 2a: *Second movers' payoff as share of the pie when outside options are allocated randomly.*
Mean (robust standard errors) in column 2.
P-values from the T-tests are reported in columns 3-5. †One sided test; ‡Two sided test

T2: Average payoff		Option=20	Option=40	Option=60
Option=0	.520	.057‡	.001†	.000†
	(.027)			
Option=20	.451		.000†	.000†
	(.023)			
Option=40	.616			.000†
	(.016)			
Option=60	.796			
	(.027)			
N	120			
# of games	8			
# subjects	30			

Table 2b: *Second movers' payoff as share of the pie when outside options are earned.*
Mean (robust standard errors) in column 2.
P-values from the T-tests are reported in columns 3-5. †One sided test; ‡Two sided test

Moreover, the supplementary materials document that the model predicts average offers less well. This is mainly due to two issues. First, offers are often too meagre and get rejected.[19] Figures S1a and S1b in the supplementary materials show the average offers in the first game and in the following games compared to the theory predictions. In general, offers fall below the predictions. This is especially so in early games and when the second mover has an outside option of 60.[20] Second, when offers are below the binding outside option, the second mover takes its outside option.[21] In fact, when offered less than the outside option, second movers opt out with high probability. Over time, however, this willingness to take high outside options seems to gain credibility, and we observe that the value of rejected offers increases over games.[22]

Contributions

Figures 3a and 3b show the share of the pie received by the second mover, conditioned on the second movers contribution and whether contributions were allocated randomly (Figure 3a) or earned (Figure 3b).

[19] Both theoretical models predict immediate agreement, but we observe substantial delay in the lab. Table S12 in the supplementary material reports the cumulative percentages of bargains concluded by period. We do not analyze delay in this paper. Explicit analyzis of delay in alternating bargaining is scarce. This may be due to the multiplicity of equilibria in the alternating offer framework when players are not fully informed (the standard rationale for delay). Embrey *et al.* (2015) explicitly analyze delay in bargaining experiments using the framwork of Abreu & Gul (2000), in which inconsistent claims in a Nash demand game leads to a war of attrition game. In the presence of obstinate types this framework produce testable predictions about delay.

[20] Table S2 reports the WRS test for differences in average offers in the first game. The results show no significant difference between the offers made to players with different outside options in game 1, both when options were earned or randomly allocated. Table S4a and b show average offers and T-tests confirming that offers are substantially below equilibrium in particular for outside option 60.

[21] A frequency chart is provided in supplementary materials in Figure S2. This chart breaks down bargaining outcomes on random and earned outside options, and whether the offer was accepted or the outside option taken showing higher frequencies for binding outside options.

[22] See supplementary materials, Figure S3 and Table S5.

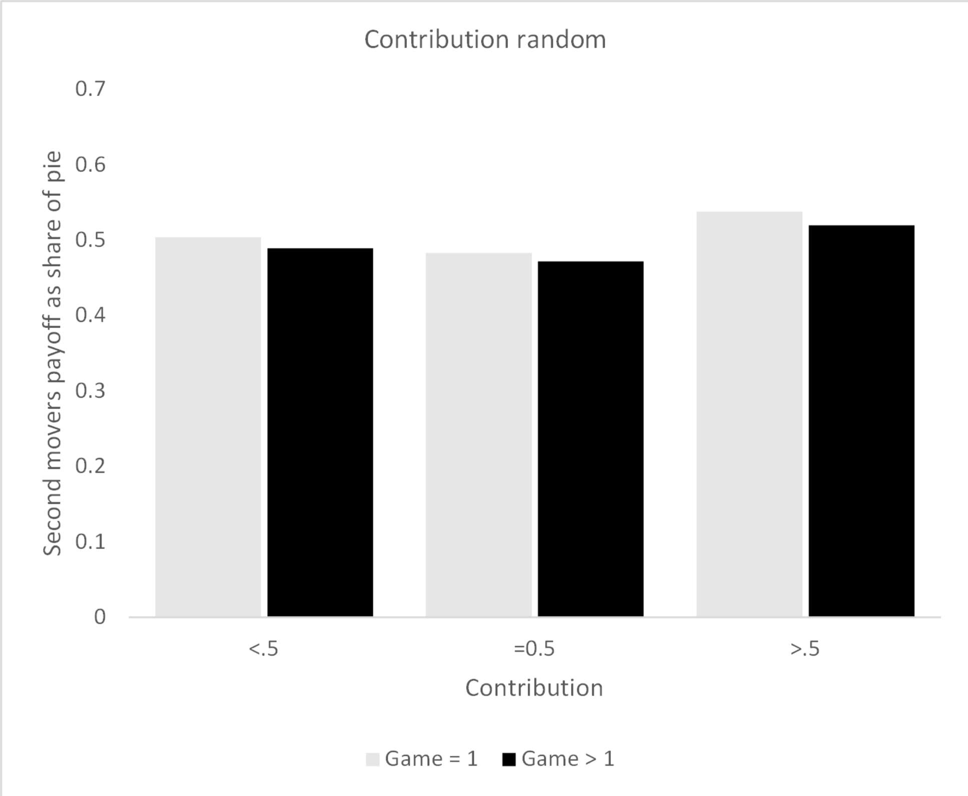


Figure 3a: *Share of the pie received by the second mover: randomly allocated contributions.*

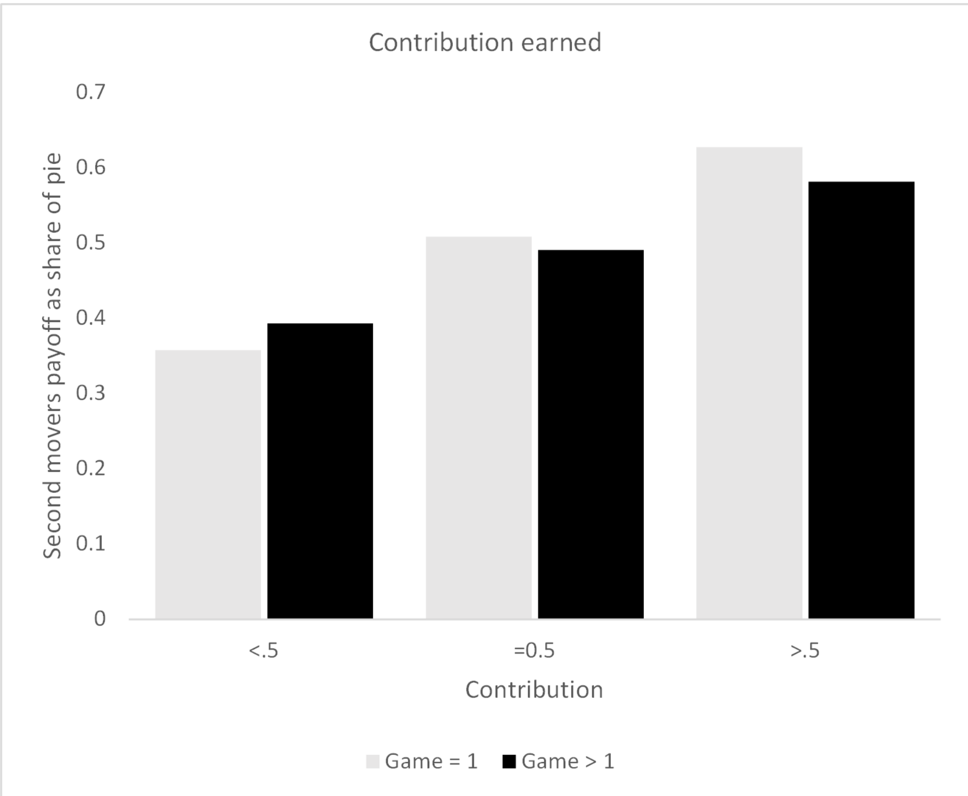


Figure 3b: *Share of the pie received by the second mover: earned contributions*

When contributions are randomly allocated (T3) there is no clear relationship between own contribution and relative payoffs (Figure 3a). Considering both observations in the first game[23] and in all games there is no monotonic increasing relationship between contributions and payoff (Table 3a).[24] Nevertheless, Table 3a shows a significant difference between share of the pie received by second movers who contributed half of the pie and those who contributed more.

This contrasts sharply with behavior when contributions are earned (T4). Figure 3b shows that in the first game the share of the pie received increases monotonically in contributions. WSR-tests confirm that the observed differences are significantly different from zero at the 5% level or better.[25] Looking at behavior from the second game onwards, the monotonic relationship between pie share received and contributions is preserved. This pattern is also present when all games are considered. Furthermore, these differences are significantly different from zero at the 5% level or better (Table 3b).

T3: Average payoff		Contribution $= \frac{1}{2}$	Contribution $> \frac{1}{2}$
Contribution $< \frac{1}{2}$	.492	.244†	.072†
	(.019)		
Contribution $= \frac{1}{2}$	.474		.007†
	(.016)		
Contribution $> \frac{1}{2}$	.525		
	(.012)		
N	146		
# of games session 1	4		
# of games session 2	6		
# subjects	45		

Table 3a: *Second movers' payoff as share of the pie by randomly allocated contributions. Mean (robust standard errors) in column 2. P-values from the T-tests are reported in columns 3 and 4. †One sided test.*

[23] Table S6a in the supplementary material shows the WSR-tests for first game observations of treatment T3. Generally we find no significant difference between the payoffs of different contributors. However, we find that those who contributed a larger share of the pie receive a significantly larger payoff than those who have contributed half pie (5% level significance).

[24] In contrast to this, Meta et al. (1992) find effects of randomly allocated contributions on outcomes using a Nash demand game.

[25] Supplementary material, Table S6a.

T4: Average payoff		Contribution $= \frac{1}{2}$	Contribution $> \frac{1}{2}$
Contribution $< \frac{1}{2}$	.380	.001†	.000†
	(.022)		
Contribution $= \frac{1}{2}$	.495		.005†
	(.008)		
Contribution $> \frac{1}{2}$	.580		
	(.035)		
N	114		
# of games session 1	4		
# of games session 2	4		
# subjects	60		

Table 3b: *Second movers' payoff as share of the pie by earned contributions. Mean (robust standard errors) in column 2. P-values from the T-tests are reported in columns 3 and 4. †One sided test.*

Are the averages in Table 3a and 3b significantly different between the two treatments? T-tests reveal that when contributions are above or below half of the pie, the average payoffs are significantly different at the 10% level or better, while the difference between the coefficients for contributions equaling half the pie is not significantly different from zero.[26]

Thus, there is clear evidence that contributions matter for the payoffs when they are earned, but not when they are randomly allocated. Our interpretation is that entitlements generated under competitive conditions are sufficient for making contributions a salient reference point that impacts on equilibrium behavior.[27]

Looking at offers, they are also monotonically increasing for earned contributions. For randomly allocated contribution the relationship is much weaker.[28] Thus, entitlements generated under competitive conditions are sufficient for forging a relationship between contributions and offers.

In treatments 3 and 4 the pie size varies. Thus, one worry is that results are driven by variation in pie size. In the supplementary materials we run treatment regressions of relative pie share obtained on relative contribution, controlling for initial pie size. These regressions show that the effect of relative contributions is only significant in T4—in which contributions are earned—while the initial size of the pie does not impact on results in either treatment.[29]

Degree of loss aversion

We have established a relationship between received pie shares and offers for contributions at; above; and below one half in our data. This relationship is in line with theory. However,

[26] Table S11 in the supplementary materials.

[27] It is worth noting that our main predictions are significant at the more demanding 0.005 level advocated by Benjamin et al. (2018). I.e., outside options impact significantly when binding regardless of whether they are earned or randomly allocated (Tables 2a and 2b) while contributions only impact significantly when they are earned (Tables 3a and 3b). In the framwork of Benjamin et al. (2018) satisfying the more demanding level of significance increases the probability of the test having high power.

[28] See supplementary materials, Figures S4a and S4b; the WSR-tests for game 1 differences in Table S6b; Levels and T-tests in Table S7a and b.

[29] See regressions in Table S13 of the supplementary materials.

Theorem 2 makes a more daring prediction than this. Contingent on the loss aversion parameter, contributions should map into pie shares received according to the specific functional form of Theorem 2. Adding a noise term, this relationship can be formally tested

$$x_i = f(s_i; \mu) + \varepsilon_i,$$

where $\varepsilon_i \sim N(0, \sigma)$, s_i is the first movers contribution, x_i is the observed payoff relative to the remaining pie, and f corresponds to $x(\bar{s})$ in Theorem 2. Finally, μ is the amount of loss aversion, with $\mu = 0$ meaning no loss aversion. Figure 4 contains the results of testing the relationship using a maximum likelihood estimation.

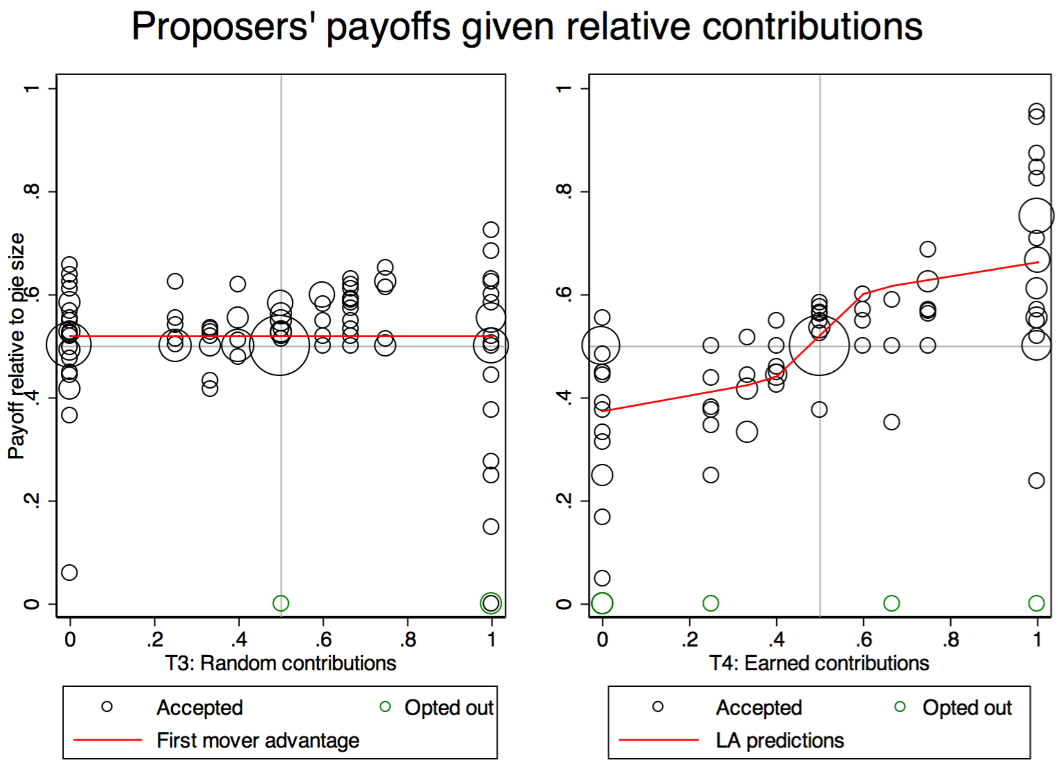


Figure 4: *MLE-estimation of Theorem 2.*

For randomly allocated contributions (T3) we find no significant loss aversion parameter μ, using observations from all games. This is consistent with the result presented above; random allocation of contributions does not generate subjective entitlements, and bargaining outcomes do not respond to randomly allocated contributions. For earned contributions (T4) we estimate a loss aversion parameter of $\mu = 0.414$ with a standard deviation of 0.12. A Chi Square-test reveals that the estimated loss aversion parameter is significantly larger than 0 at a level of 1% or better ($p = 0.000$). Thus, our previous results hold. Entitlements generated under competitive conditions seem to activate contributions as reference points. These reference points in turn impacts on the equilibrium distribution of the pie in a way consistent with Theorem 2.

Note that our $\mu = 0.414$ corresponds to a loss aversion parameter of 1.41 if presented in the common way. This parameter value is within the range typically found in non-strategic decision experiments.

5. Discussion

In what follows, we discuss three alternative theories that potentially could be consistent with our observations: relative loss aversion, risk aversion, and fairness concerns.

Relative loss aversion

Note that we have defined the reference point as being relative. Recall that the utility function is given by

$$U_i(s_i\pi) = \begin{cases} s_i\pi & \text{for} \quad s_i \geq r_i \\ s_i\pi - \mu(r_i\pi - s_i\pi) & \text{for} \quad s_i < r_i \end{cases},$$

and thus the reference point is $r_i\pi$ which changes as the pie size changes. Consider a player 1 who contributed 40 ECU of a total pie of 100 ECU, that is $r_1 = 40\%$. After two rounds of bargaining the pie has shrunk to 81 ECU. Suppose that the players then agree and player 1 gets 34 ECU. As $r_i\pi = 32.4$ ECU the player is in her gain zone. Even though she gets 6 ECU less than she contributed, she gets 42% of the remaining pie. Our specification of the reference point as a share of the pie makes it possible to find stationary equilibrium strategies, but we also think it is reasonable.

So why is it reasonable to use 32.4 ECU as a reference point when the pie has shrunk to 81 ECU? As the pie has shrunk, the subjects now have to focus on the distribution of 81 ECU; as player 2 contributed a larger share of that pie, she may feel entitled to a larger share of the remaining pie of 81 ECU. Such a reasoning would also be consistent with Kahneman and Tversky's (1979) idea of an editing phase. In one of their cases they considered subjects choosing between losses after receiving 2000 first, and argued that a loss of 500 would still be seen as a loss and not as a gain of 1500 since the 2000 was already pocketed.

Risk aversion

It is well known that high risk aversion is a disadvantage in alternating offer bargaining (Roth 1985). Thus, if the subject that contributed the least to the pie also had the highest risk aversion, that could potentially explain the results we found. Such a correlation would result if the one with highest risk aversion also put the least effort into the earning task. Note that the return to effort is risky; it is either 0, 20, 40 or 60 ECU, and this depends on what other participants in the experiment are doing. It is thus indeed plausible that the most risk averse subjects will have the weakest incentives to provide effort, and hence earn the least. Another part of our result that is also consistent with this risk aversion explanation is that high contributors do not get a larger share of the pie when the contribution is random. With random contribution there is no sorting of participants according to risk aversion. Still, we will argue that risk aversion cannot explain our results.

The key argument against risk aversion as the explanation is the observations when outside options are earned. The return to effort is at least as risky in this case as with contributions. That is, earnings follow the same rules in both cases, while subjects may anticipate that the earned outside option matters only when there is 40 or 60 ECUs in the bargaining case, adding to the uncertainty. Thus, we would expect the same sorting by risk aversion in both cases. Now, with an outside option of 40 or 60 ECUs, bargaining power does not matter. With an outside option of 0 or 20 ECUs, however, the more risk averse player should be at a disadvantage, and hence: if risk aversion is driving our results we would expect the player with an outside option of 20 ECU to get a higher payoff than the one with an outside option of 0 ECU. This is not observed in our data.

Fairness

Could outcome oriented models of fairness–such as the ones by Fehr and Schmidt (1999) and Bolton and Ockenfels (2000)–explain the influence of the players' contributions to the outcome of a structured bargaining game? In this class of models, players have preferences over differences in the distribution of the pie. Still, these preferences are invariant to the contributions of the players and thus predict that unequal contributions have no effect on the outcome. Hence, in our set-up the answer is clearly no. One way to bring such fairness preferences into play could be to model explicitly (non-monetary) effort costs incurred to create the contributions, and base fairness comparisons on payoffs net of effort costs. We leave such a task for future research.

An explanation of our results requires a theory where the history matters and where the outcome of the game is not fully determined by the strategy space and payoff. Theories of reciprocity and intentions, such as those of Rabin (1993) and Falk and Fischbacher (2006), use psychological game theory that allows for an impact on beliefs. A requirement for a psychological Nash equilibrium, as compared to a standard Nash equilibrium, is that all beliefs match actual behavior. Thus beliefs cannot depend on prior contribution, except if there are multiple equilibria where prior contributions could serve as a coordination device.

6. Conclusion

While the outside option principle is well documented in bargaining experiments, such experiments also show that match specific contributions with no outside value are—at least partly—compensated for in the final agreement. We show that this behavioral pattern can be rationalized by introducing loss aversion in a model of alternating offer bargaining, in which reference points are given by either outside options or contributions. Our experiment tests such a model. Results replicate previous findings with respect to the outside option principle. As predicted by our model bargaining outcomes are insensitive to whether outside options are earned under competitive conditions or randomly allocated. We also document a strong positive relationship between relative contributions and final payoffs, but only when contributions are earned under competitive conditions. With contributions activated as reference points our model predicts a specific functional relationship between contributions and bargaining outcomes. We find that this relationship is strongly present in the data.

Appendix

Proof of Theorem 1

Consider the outside option $\psi_2 > 0$ as the reference point for player 2. There are two cases to consider:

Case 1: The outside option is not binding.

Let x^* and y^* denote the subgame perfect equilibrium shares in the standard model. Let $\pi = 1$ and suppose that $\psi_2 \leq 1 - x^* < 1 - y^*$. The utility for player 2 is given by $u_2(s_2) = s_2$ for all s_2 such that $s_2 \geq \psi_2$. Hence, the equilibrium condition

$$\begin{aligned} y^* &= x^*\delta \\ 1 - x^* &= (1 - y^*)\delta, \end{aligned}$$

is not affected by the reference point.

Case 2: The outside option is binding.

Now let $\psi_2 > 1 - x^*$ with x^* the proposal that would have been an equilibrium without outside options in the standard model. Clearly, player 2 is better off by simply taking the outside option. Realizing this, the best strategy for player 1 is to offer $x = 1 - \psi_2$.

In both cases, the model with loss aversion yields the same equilibrium prediction as the standard model.

Proof of Theorem 2

We want to prove that the subgame perfect equilibrium solution can be written as the proposal from player 1 as a function $\bar{s}$:

$$x(\bar{s}) = \begin{cases} \frac{1}{1+\delta} + \frac{\delta\mu}{(1+\delta)(1+\mu)}\bar{s} & \text{if} \quad \frac{1+\mu}{1+\delta+\mu} < \bar{s} \leq 1 \\ \frac{(1-\delta)(1+\mu)}{(1+\mu+\delta)(1+\mu-\delta)} + \frac{\mu}{1+\mu-\delta}\bar{s} & \text{if} \quad \frac{\delta}{1+\delta+\mu} < \bar{s} \leq \frac{1+\mu}{1+\delta+\mu} \\ \frac{1}{(1+\delta)(1+\mu)} + \frac{\mu}{(1+\delta)(1+\mu)}\bar{s} & \text{if} \quad 0 \leq \bar{s} \leq \frac{\delta}{1+\delta+\mu} \end{cases},$$

and conversely, that the solution can be written as the proposal from player 2 as a function of $\bar{s}$:

$$y(\bar{s}) = \begin{cases} \frac{\delta}{1+\delta} + \frac{\mu}{(1+\delta)(1+\mu)}\bar{s} & \text{if} \quad \frac{1+\mu}{1+\delta+\mu} < \bar{s} \leq 1 \\ \frac{\delta(1-\delta)}{(1+\mu+\delta)(1+\mu-\delta)} + \frac{\mu}{1+\mu-\delta}\bar{s} & \text{if} \quad \frac{\delta}{1+\delta+\mu} < \bar{s} \leq \frac{1+\mu}{1+\delta+\mu} \\ \frac{\delta}{(1+\delta)(1+\mu)} + \frac{\delta\mu}{(1+\delta)(1+\mu)}\bar{s} & \text{if} \quad 0 \leq \bar{s} \leq \frac{\delta}{1+\delta+\mu} \end{cases}.$$

First, we characterize the equilibrium conditions. Following Rubinstein (1982) we note that the set of equilibrium shares of the pie is given by

$$\Delta = \{(x, y) : x = d_2(y) \text{ and } y = d_1(x)\},$$

where $d_2(y)$ is the maximum share that player 1 can suggest such that player 2 will accept, given that player 2 always suggests a share y. Similarly, $d_1(x)$ is the least player 2 can offer such that player 1 will accept, given that player 1 always proposes a share x. Clearly, $d_1(x)$ satisfies $u_1(d_1(x)) = \delta u_1(x)$, while $d_2(y)$ satisfies $u_2((1 - d_2(y))) = \delta u_2((1 - y))$. It follows, also with the reference point utility function given by 3, that the subgame perfect equilibrium of the game is that player 1 proposes x and player 2 proposes y such that

$$\begin{aligned} u_1(y) &= \delta u_1(x) \\ u_2(1-x) &= \delta u_2(1-y). \end{aligned} \tag{A1}$$

For completeness, the strategies of the players are such that at each stage in the game they propose (x, y) corresponding to the equilibrium conditions (A1) and they accept any offer equal to or better than this.

Next, we show that the solution to (A1) exists and is unique. Note that $x(\bar{s})$ and $y(\bar{s})$ are continuous in $\bar{s}$. There are three cases to consider:

Case 1: $\bar{s} > x > y$.

In this case, player 1 will always be in the loss zone, and her utility is given by $u_1(s_1) = (1 + \mu)s_1\pi - \mu\bar{s}\pi$. The equilibrium conditions are

$$\begin{aligned} u_1(y) &= \delta_1 u_1(x) \Rightarrow (1+\mu)\, y\pi - \mu\bar{s}\pi = (1+\mu)x\delta\pi - \mu\bar{s}\delta\pi \\ u_2(1-x) &= \delta_2 u_2(1-y) \Rightarrow (1-x)\pi = \delta(1-y)\pi. \end{aligned}$$

These are two linear equations with two unknowns, and the unique solution is

$$\begin{aligned} x &= \frac{1}{1+\delta} + \frac{\delta\mu}{(1+\delta)(1+\mu)}\bar{s} \\ y &= \frac{\delta}{1+\delta} + \frac{\mu}{(1+\delta)(1+\mu)}\bar{s}. \end{aligned}$$

Further, we have that $\bar{s} > x$ if

$$x = \frac{1}{1+\delta} + \frac{\delta\mu}{(1+\delta)(1+\mu)}\bar{s} < \bar{s} \Rightarrow \bar{s} > \frac{1+\mu}{1+\delta+\mu}.$$

Case 2: $x \geq \bar{s} > y$.

In this case, each player is in the loss zone only when the player is a responder. The equilibrium conditions in this case are

$$\begin{aligned} (1+\mu)y\pi - \mu\bar{s}\pi &= \delta x\pi \\ (1+\mu)(1-x)\pi - \mu(1-\bar{s})\pi &= \delta(1-y)\pi, \end{aligned}$$

with the unique solution

$$\begin{aligned} x &= \frac{(1-\delta)(1+\mu)}{(1+\mu+\delta)(1+\mu-\delta)} + \frac{\mu}{(1+\mu-\delta)}\bar{s} \\ y &= \frac{\delta(1-\delta)}{(1+\mu+\delta)(1+\mu-\delta)} + \frac{\mu}{1+\mu-\delta}\bar{s}. \end{aligned}$$

Further, we have that $x \geq \bar{s}$ if

$$\frac{(1-\delta)(1+\mu)}{(1+\mu+\delta)(1+\mu-\delta)} + \frac{\mu}{(1+\mu-\delta)}\bar{s} \Rightarrow \bar{s} \leq \frac{1+\mu}{1+\delta+\mu},$$

while $y < \bar{s}$ if

$$\frac{\delta(1-\delta)}{(1+\mu+\delta)(1+\mu-\delta)} + \frac{\mu}{1+\mu-\delta} < \bar{s} \Rightarrow \bar{s} > \frac{\delta}{1+\delta+\mu}.$$

Case 3: $x > y \geq \bar{s}$.

We could solve this case by deriving two linear equations in x and y as in case 1 and 2. However, it is instructive to note that this case is symmetrical to case 1. Player 2 will always be in the loss zone, and his contribution is $1-\bar{s}$. By symmetry the share of the pie player 2 receives as a proposer should be the same as the share player 1 receives as proposer with a similar contribution. Hence, using the equation for x above (in case 1) we have

$$1-y = \frac{1}{1+\delta} + \frac{\delta\mu}{(1+\delta)(1+\mu)}(1-\bar{s}),$$

which gives

$$y = \frac{\delta}{(1+\delta)(1+\mu)} + \frac{\delta\mu}{(1+\delta)(1+\mu)}\bar{s}.$$

Similarly, we can also find x.

Last, we have that $y \geq \bar{s}$ when

$$y = \frac{\delta}{(1+\delta)(1+\mu)} + \frac{\delta\mu}{(1+\delta)(1+\mu)}\bar{s} \geq \bar{s} \Rightarrow \bar{s} \leq \frac{\delta}{1+\delta+\mu}.$$

Calculation of payoffs

In the experiment, players have a common discount factor of 0.9. With this, the equilibrium solutions for x and y can be simplified. With standard preferences we have

$$\begin{aligned} x &= \frac{1}{1+\delta} = \frac{1}{1.9} = 0.526 \\ y &= \frac{\delta}{(1+\delta)} = \frac{0.9}{1.9} = 0.474. \end{aligned}$$

The functional form of x in the case with contributions as reference points is

$$x = x(\bar{s}) = \begin{cases} \frac{1}{1.9} + \frac{0.9}{1.9}\frac{\mu}{1+\mu}\bar{s} & \text{if} \quad \bar{s} > \frac{1+\mu}{1.9+\mu} \\ \frac{\mu}{\mu+0.1}\bar{s} + \frac{0.1}{\mu+0.1}\frac{1+\mu}{1.9+\mu} & \text{if} \quad \frac{0.9}{1.9+\mu} < \bar{s} \leq \frac{1+\mu}{1.9+\mu} \\ \frac{1}{1.9} - \frac{1}{1.9}\frac{\mu}{1+\mu}(1-\bar{s}) & \text{if} \quad \bar{s} \leq \frac{0.9}{1.9+\mu} \end{cases}.$$

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