Reference points in sequential bargaining: Theory and experiment*

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Abstract

We introduce loss aversion in an 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, i.e., outside options do not affect the equilibrium unless they are binding. 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's predictions in the laboratory. As predicted, only binding outside options impact the division of the pie. Data also show that contributions matter for bargaining outcomes when they are activated as reference points, but not quite as predicted by our theory. Proposers gain a higher share of the pie only when they have contributed a higher share than the opponent has.

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1. Introduction

In negotiations, a match-specific surplus is created by parties that contribute resources. Contributed resources are often legally owned by the agent, but may have little or no value outside the match. The legal property rights over the surplus, however, are typically undefined until the parties agree to a contract. With standard preferences, the distribution of contributions with zero outside value is irrelevant for the final distribution of the surplus for most bargaining protocols, and in particular with alternating-offer bargaining as in Rubinstein (1982). In contrast to this, a mounting body of experimental evidence suggests that such contributions can forcefully impact bargaining behavior. In particular, the bargainer contributing relatively more to the surplus, or with the higher entitlement, tends to capture more in the final agreement (Meta et al. 1992; Hackett 1993; Gächter & Riedl 2005, 2006; Birkeland 2013; Karagözoğlu & Riedl 2014; Baranski 2018; Feltovich 2019). Thus, differences in contributions seem to generate forceful psychological property rights to the surplus.

Conventional theory also predicts that what a bargainer obtains if she terminates bargaining may impact 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 an infinite-horizon, alternating-offers model. Introducing loss aversion 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 contributions. Moreover, 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's predictions. In contrast to many other models used in bargaining experiments, the equilibrium of our model is unique. Thus, we obtain a benchmark against which to evaluate behavior. Our approach to the activation of reference points is in the spirit of Fehr et al. (2011), Hart and Moore (2008) and Fehr et al. (2009). Outside options and contributions are activated as reference points only when players become entitled to them under competitive conditions. It is well known from the experimental literature that subjective entitlements are generated by effort rather than luck (Gächter & Riedl 2005; Karagözoğlu & Riedl 2014; 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). In the experiment, a competitive condition is induced by a real-effort tournament in which contributions and outside options are earned. We contrast this condition with one in which contributions and outside options are randomly allocated.

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 bargaining outcomes in the same way. 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.

Furthermore, data lend support to the prediction that relative contributions matter for bargaining outcomes only when they are earned. In particular, we find a relationship between earned contributions and bargaining outcomes that to some extent corresponds to the predictions of our theory. A proposer that has earned a higher share of contributions also gets a larger share of the pie in bargaining; but contrary to our prediction, this is not true for responders.

Why focus on outside options and contributions as candidates for reference points? An outside option is a player's maximin payoff in the bargaining game. Because 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; see Keskin (2022) and O'Donoghue and Sprenger (2018) for an overview of applications of reference-dependent preferences. Empirical evidence from the field and the lab indicates that such dependencies can be powerful determinants of economic outcomes.[1]

The key contribution of our paper is demonstrating that reference dependence also can matter in alternating-offer bargaining situations, both theoretically and empirically. There is a theoretical literature on reference points in alternating-offer bargaining. Kohler (2013) explores alternating-offer bargaining with Fehr–Schmidt preferences, with a reference point at equal division of the surplus. Hyndman (2011) formulates a model in which proposers' rights are randomly allocated each period, and players assign utility minus infinity to any outcome below the reference point. In Li (2007) and Driesen et al. (2012), reference points are formed on the basis of offers in the present game, whereas in Compte and Jehiel (2003), they are formed on the basis of offers in the preceding game. In Shalev (2002), loss aversion is equivalent to higher impatience. In our model, however, the focus is on reference points formed on the basis of what players bring into the bargaining situation. 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 Kőszegi and Rabin (2006). We are not aware of other papers modeling the impact of such reference points in alternating-offer bargaining. Note also that because our model assumes complete and perfect information, and has a unique equilibrium, expectations-based reference points of the Kőszegi and Rabin (2006) kind would give the same results as in the standard model.

Several experimental papers find that reference points impact the final distribution of the surplus under different bargaining protocols. For example, the papers of Karagozoglu and Keskin (2018*a*) for cooperative bargaining where bargainers choose their reference points; Sloof et

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

al. (2004), Ellingsen and Johannesson (2001, 2004), and Sonnemanns et al. (2001) for one-shot hold-up problems, and Christiansen and Kagel (2019) for legislative bargaining. Experimental evidence on the impact of reference points in alternating-offer bargaining, however, is scant. We are aware of only one such contribution. Birkeland (2013) explores the impact of reference points generated by moral motivations. Contributions are first earned in a production phase. Subsequently, bargaining follows an alternating-offer protocol either with or without access to an outside option. The outside option authorizes a third party, without material stakes in the solution, to impose a binding agreement. In the presence of the outside option, bargainers with higher relative contributions capture more of the surplus while efficiency losses are reduced. This is interpreted as evidence that entitlements generate moral obligations when bargainers have access to neutral third-party resolutions.

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, Birkeland (2013), Cappelen et al. (2007), and Hoffman and 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; 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.[2] 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 matter briefly at the end of the paper.

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 the model's 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 model with loss-averse bargainers. There are two players $i \in \{1, 2\}$ that bargain over a perfectly divisible pie (surplus) θ. Let s_i denote 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 odd periods, and player 2 is the proposer in even periods. Note that we use the terms as follows: Player 1 is the player that sends the first offer as a proposer, and player 2 receives that offer as a responder. If the offer is rejected and the responder does not use the outside option, then their roles as proposer and responder switch, but player 1 and player 2 still refer to the same players.

The responder can accept the offer, reject the offer, or take her outside option. Bargaining

[2] 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.

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 $\delta \in (0, 1)$. The game starts at period 1.

Let $\psi_i \geq 0$ denote the outside option of player i, where ψ_i is measured as a share of the pie. If a player terminates bargaining by taking her outside option, the opponent gets nothing. If player i get a share s_i of the pie θ, we assume player i's utility can be written as

$$U_i(s_i\theta) = u_i(s_i)\theta,$$

where u_i is player i's utility function over shares s_i. The shape of the utility function will be the only difference between the standard model (Rubinstein 1982; 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. 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

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

The equilibrium condition with linear utility is then

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

Notice that utility is proportional to θ 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, which were not included in the Rubinstein (1982) model, matter only if they are binding. That is, if player 2 as a responder receives an offer $1 - x \geq \psi_2$, the player has no incentive to take the outside option. Nonbinding outside options thus have no impact on the equilibrium, and this is irrespective of whether none, only one, or both players have such outside options.[3] On the other hand, if the equilibrium (x^* and y^*) in the game without

[3] With outside options, the uniqueness of the equilibrium is conditioned on one specific feature of our protocol, i.e., that only responders can opt out. Protocols where the proposer can opt out if a proposal is

outside options provides a player with less than her outside option, e.g., $1 - x^* < \psi_2$, then the outside option does impact the player's equilibrium share. In the first round, player 1 will have to make a better offer that gives player 2 at least ψ_2. And similarly, if player 1's outside option is binding, then player 2 - when acting as proposer - will have to offer player 1 at least the outside option. Outside options of zero have no impact on the equilibrium of the game.

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.[4]

In the following, player i's reference point is specified as a share of the pie. As the pie shrinks when players disagree, the players have to settle on sharing the remaining pie, thus determining each player's relative share of what is left. It is thus reasonable to assume that the reference point is also determined by the relative share. Let r_i denote player i's reference point measured as a share of the pie. In addition to the linear payoff $s_i\theta$, a player suffers a loss if her outcome is below the reference point, i.e., when $s_i < r_i$. Recall that the utility function is given by $U_i(s_i\theta) = u_i(s_i)\theta$ with

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

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. 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 bargaining game and can stem from either outside options or contributions in our model. Because 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 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.[5]

We now analyze the equilibrium for the two different reference points separately. Consider

rejected can generate multiple equilibria (see Shaked (1994) and Ponsatí and Sákovics (1998)).

[4]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)).

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

first the case in which the reference points are given by outside options.

As with standard preferences, the outside option matters only 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 equilibrium behavior.*

Proof. See Appendix A.1. ■

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.[6]

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 let $\bar{s}$ denote 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 for the proposal from player 1 can be written 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 A.2. ■

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 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 θ that goes to player 1 with $1-x(\bar{s})$ to player 2. As usual, player 1, the first mover, has an advantage.

[6]Note that outside options in our game differ from disagreement points that players get if they do not agree (e.g., as in Feltovich (2019)). With a pie of 80, where each has a disagreement point of 20, they effectively bargain over the surplus of 40. In our case, if one player uses an outside option of 20, she gets 20, the other gets zero, and the remaining 60 is lost.

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 $(1-x)\theta = \delta(1-y)\theta$. 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, because rejecting the offer will remove the loss given by $\mu\left[(1-\bar{s})-(1-x)\right]\theta$. 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 $\bar{s}$ ($\frac{1+\mu}{1+\delta+\mu} < \bar{s} \leq 1$), player 1's contribution is substantially higher than that of player 2. Because 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 her 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 her loss by rejecting and making a counteroffer. Thus player 2, when acting as the proposer, 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 around 50%—where equilibrium shares are close to contributions—expands with loss aversion, whereas 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, because the player with the smaller contribution now can credibly hold out for a larger share. Note also that the equilibrium distribution is less asymmetric than the distribution of reference points, in line with the findings in Gächter and Riedl (2006).

3. Design and procedures

Design

The centerpiece of our design is that loss aversion impacts equilibrium behavior only when contributions form reference points. Competitive conditions are induced in the experiment by a costly effort task in which outside options and contributions, respectively, are earned. We expect that this procedure will induce the formation of stronger reference points than when outside options and contributions are randomly allocated. By Theorem 1, we conjecture that behavior is identical when the outside option is randomly allocated and when it is earned. By Theorem 2, we conjecture behavior to be closer to the standard Rubinstein and Binmore models when contributions are randomly allocated compared to when contributions are earned and subjects' reference points have a stronger impact on bargaining behavior.

Implementation

We implement an alternating-offer bargaining protocol as close as possible to the model presented in section 2. A common discount factor is induced by letting the pie and the outside options shrink by a fixed rate of 10 percent after each bargaining round.[7] Bargaining proceeds until an agreement is reached, the responder opts out, or the value of the pie falls below a fixed threshold (5 experimental currency units (ECUs)).

We use blocks of eight subjects. Subjects stay within blocks, and unique subjects are used in all treatments. In our analysis, we regard average behavior within blocks as independent observations. Subjects play six games and are randomly matched between games. A random half of the subjects start as the proposer in games $1-3$, whereas the other half start as the proposer in games $4-6$.

Our design has four treatments, but is not a 2×2 factorial design. In Experiment 1, consisting of treatments Outside option Random (OR) and Outside option Earned (OE), the pie size (S) is held constant at $S = 80$ ECUs, and an outside option worth $w_i \in \{20, 60\}$ ECUs is allocated to each of the subjects. In OR, the allocation of w_i on subjects is random, whereas in OE it is based on the ranking of subjects in a costly effort task performed prior to bargaining (more on the effort task below). Following the set-up in Binmore et al. (1989), subjects can exercise their outside option only when they are responders. If the outside option is used, the proposer gets a payoff of zero whereas the responder gets her outside option (which is worth 20 or 60).

In Experiment 2, consisting of treatments Contribution Random (CR) and Contribution Earned (CE), all subjects have an outside option of zero that can be exercised whenever they are the responder. In CR and CE, a contribution worth $z_i \in \{20, 60\}$ ECUs is allocated to each of the subjects, and the pie size in a match is the sum of contributions by the subjects, that is, $S = z_R + z_P$ with $S \in \{40, 80, 120\}$, where R denotes the responder and P the proposer in a match. In CR, the allocation of z_i on subjects is random, whereas in CE it is based on the ranking of subjects in a costly effort task performed prior to bargaining.

Prior to each bargaining game, subjects are informed about their matches' outside options (OR and OE) or contributions (CR and CE), respectively.

The costly effort tasks used in OE and CE are identical, and based on Erkal et al. (2011). Subjects are given a string of five random letters and a key assigning a number to each letter in the alphabet. The task is to translate the letters of a string of corresponding numbers. Performance is measured as the number of correctly coded strings over the 10 minutes allocated to the task. w_i and z_i, respectively, are allocated according to performance scores in the following manner: the half with the highest score are allocated 60 ECUs as their w_i or z_i, whereas the lower half are allocated 20 ECUs as their w_i or z_i.

When performing the effort task in OE and CE, subjects do not know what type of game they will play later in the session. That is, at the beginning of the session, they are informed that the experiment consists of two parts, and that they will be informed about the content of these parts right before they take place.

To sum up, our four treatments are as follows:

[7] See Heggedal and McKay (2022) for a discussion of discounting procedures in experiments.

OR: Positive valued outside option. Pie size constant. Allocation of outside options is random.

OE: Positive valued outside option. Pie size constant. Allocation of outside options is based on effort task.

CR: Zero valued outside option. Pie size is the sum of contributions. Allocation of contributions is random.

CE: Zero valued outside option. Pie size is the sum of contributions. Allocation of contributions is based on effort task.

Hypotheses

A pre-study plan for the experiment, including results from a pilot study, was posted at the AEA RCT registry on 25/04/2019.[8] We follow the pre-study plan in the set up of hypotheses and significance testing. More than one thing changes as we move from OR to CR and from OE to CE, respectively. We do not compare these treatment effects formally, and underline this fact by using the terminology "Experiment 1" and "Experiment 2".

In Experiment 1 (Outside option), our main analysis addresses, for given outside options, the treatment effects π_{OR} vs. π_{OE}, where π is measured by the average payoffs of the responders at the moment games end. In Experiment 2 (Contribution), our main analysis addresses, for given contributions, the treatment effects π_{CR} vs. π_{CE}. To compare outcomes in games with different pie sizes, we normalize outcomes by dividing by pie size S. For significance testing of treatment differences, we use Wilcoxon rank-sum tests with matching blocks as independent observations. In addition, we also use the within-subjects variation in the treatments to compare behavior conditioned on type matching (i.e., for fixed w_i or z_i, we use variation generated by the random sequence of $w_j, z_j \in (20, 60)$). For significance testing of these matched-pairs data, we use Wilcoxon signed-rank tests.

We have the following main hypotheses:

- **Hypothesis 1** (by Theorem 1): The payoffs to **responders** in treatments with random allocations of outside options are the same as payoffs in treatments with earned outside options, in otherwise similar bargaining matches. Because there are four possible combinations of outside options, this gives four subhypotheses (recall that R denotes the responder and P denotes the proposer in a match):

H1a: Given $w_R = 20$ and $w_P = 20$: $\pi_{OR} = \pi_{OE}$;

H1b: Given $w_R = 20$ and $w_P = 60$: $\pi_{OR} = \pi_{OE}$;

H1c: Given $w_R = 60$ and $w_P = 20$: $\pi_{OR} = \pi_{OE}$;

H1d: Given $w_R = 60$ and $w_P = 60$: $\pi_{OR} = \pi_{OE}$.

- **Hypothesis 2** (by Theorem 2): The payoffs to **responders** with the relatively higher contribution in a match are larger in treatments with earned contributions than in treatments with random contributions. That is:

[8] https://www.socialscienceregistry.org/trials/6446

H2a: Given $z_R = 20$ and $z_P = 20$: $\pi_{CR} = \pi_{CE}$;

H2b: Given $z_R = 20$ and $z_P = 60$: $\pi_{CR} > \pi_{CE}$;

H2c: Given $z_R = 60$ and $z_P = 20$: $\pi_{CR} < \pi_{CE}$;

H2d: Given $z_R = 60$ and $z_P = 60$: $\pi_{CR} = \pi_{CE}$.

Thus, when the responder has the lower contribution, the responder benefits if reference points are less important ($\pi_{CR} > \pi_{CE}$), whereas if the responder has the higher contribution, the responder benefits if the reference points are more important ($\pi_{CR} < \pi_{CE}$). If contributions are equal, the strength of reference points should not matter.

Based on results from a pilot study with a 3.6 percentage point difference in H2c, we estimated that we would have a 90% power to detect effects of similar size.

Data collection

Data were collected in the Research Lab at BI Norwegian Business School in Oslo in the period October 2021 to April 2022. Subjects were recruited from the general student population of BI Norwegian Business School. Recruitment and subject management were administered through ORSEE (Greiner 2015). On arrival, subjects were randomly allocated to cubicles (to break up social ties). Written instructions were handed out and read aloud by the administrator (to achieve public knowledge of the rules). A full set of instructions is provided in the supplementary online materials. All decisions were taken anonymously in a network of computers. At the conclusion of a session, subjects were paid privately based on accumulated ECUs from all games played. The exchange rate was set to equalize expected payoffs between treatments. The protocol was implemented in zTree (Fischbacher 2007).

A total of 264 subjects participated in the experiment, distributed on eight independent blocks in treatments OE, CR, and CE, and nine independent blocks in treatment OR. On average, subjects earned 371 NOK.

4. Results

We primarily focus on responders' payoffs, both comparing average differences across treatments as well as variation within treatments across different types of matches. All reported p-values are based on two-sided tests. The first section analyzes the outside option treatments (i.e., Experiment 1), whereas the next section analyzes the contribution treatments (i.e., Experiment 2).[9]

Outside options

Figure 1 shows the average payoff of responders as a share of the pie at the moment games end, conditioned on the value of both subjects' outside options in a match (responders' options are listed first), and by treatment, i.e., whether outside options were allocated randomly (OR) or earned (OE).

[9] Results excluding all games ending with the use of outside options are given in Appendix A.5. Those results are similar to the ones presented here.

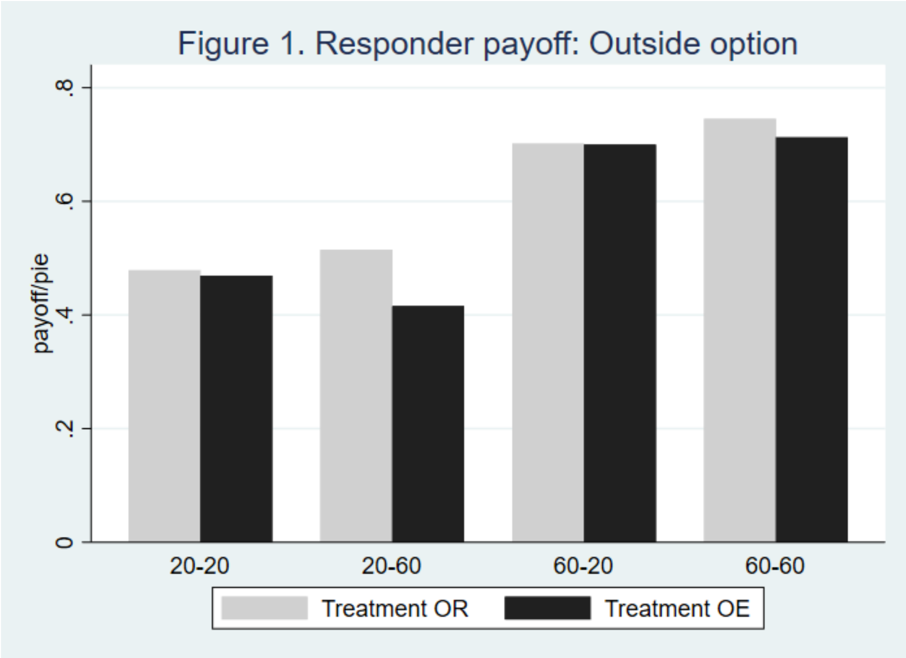

Figure 1: Payoff according to the distribution of outside options. Outside options are given as responder-proposer, e.g., 20-60 implies that the proposer has an outside option of 60.

From Figure 1, we can see that there is little or no treatment effect, perhaps with the exception of 20-60 matches in which the responder has an outside option of 20 whereas the proposer has an outside option of 60. This impression is supported by significance testing. Table 1 reports the results of Wilcoxon rank-sum tests of treatment differences over the different match types.

Table 1. Wilcoxon rank-sum–Outside option: π is the responder's payoff and w_P and w_R are outside options for the proposer and the responder, respectively.

Treatment measures	Mean π_{OR}	Mean π_{OE}	Difference in means	p-value (exact)
H1a: $w_R = 20$ & $w_P = 20$	0.479	0.469	0.009	1.000
H1b: $w_R = 20$ & $w_P = 60$	0.515	0.416	0.099	0.145
H1c: $w_R = 60$ & $w_P = 20$	0.702	0.700	0.002	0.864
H1d: $w_R = 60$ & $w_P = 60$	0.745	0.713	0.033	0.200

From Table 1, we see that there are no significant differences in outside options treatments between randomly allocated options and earned options.[10] Although there is a sizable difference in means in 20-60 matches between OR and OE treatments, we cannot reject the null of no differences at conventional levels of significance. We conclude that these findings are in line with hypotheses H1a–d and Theorem 1: With outside options as reference points, loss aversion does not impact equilibrium behavior.

Turning to within-treatment variation, we see from Figure 1 that responders get a smaller payoff when they have an outside option of 20 than when they have an outside option of 60. This observation cannot be tested by within-subjects tests, because subjects have fixed outside

[10] In the pre-study plan, we did not clearly specify the normalization we use for payoffs in our analysis (i.e., dividing payoffs by pie size), and as a robustness check, we show in Appendix A.3 that our main results are largely the same when payoffs are not normalized.

options throughout the experiment. However, parametric regressions with dummies for each match type, using variation in matches between subjects within treatments, lend support to the observation (see Appendix A.4). This finding is in line with the model and the outside-option principle: responders with binding outside options get a larger payoff than do responders with nonbinding outside options.

Table 2 reports the results of Wilcoxon signed-rank tests of differences within subjects' payoffs (when they are responders), depending on whether their opponents have outside options with value 20 or 60.

Table 2. Wilcoxon signed-rank–Outside option: π is the responder's payoff and w_P and w_R are the outside options for the proposer and the responder, respectively.

Treatment measures	Mean $w_P = 20$	Mean $w_P = 60$	Difference in means	p-value (exact)
π_{OR} & $w_R = 20$	0.487	0.495	−0.08	0.617
π_{OR} & $w_R = 60$	0.701	0.747	−0.046	0.017
π_{OE} & $w_R = 20$	0.494	0.425	0.069	0.109
π_{OE} & $w_R = 60$	0.713	0.713	−0.000	0.578

From Table 2, we see the null of no differences is rejected at conventional levels of significance only in the OR treatment when the responder has an outside option of 60 (second row). In this case, the responder gets a lower payoff if the proposer has a high outside option. This finding is at odds with the theory: the equilibrium offer is equal to the responder's outside option when this is 60. When the outside option is earned, however, the responder's payoff is independent of the proposer's outside option, as we expect from theory.

We can only speculate about why we get this deviation from theory in the OR treatment. It may be just a spurious finding, or it may be related to different uses of outside options in the different treatments. Perhaps earnings induce an entitlement to the outside options, and thus increase the willingness to use these. This is indeed what we see in the data. In the OR treatment, 25.9 percent of matches ended bargaining with the responder taking her outside option, whereas the corresponding number in the OE treatment is 40.6 percent (see Appendix A.6, Table A.6). Bargaining ends mostly in the first round in both treatments, with mean end-round equal to 1.25 and 1.21 in OR and OE, respectively (see Table A.9 in Appendix A.7 and Figure A.3 for frequency plots). That bargaining ends early is in line with theory, whereas the substantial use of outside options is not. We discuss the use of outside options in Section 5.

Contribution

Figure 2 shows the average payoff of responders as a share of the pie at the moment games end, conditioned on the value of both subjects' contributions in a match (responders' contributions are listed first), and by treatment, i.e., whether contributions were allocated randomly (CR) or earned (CE).

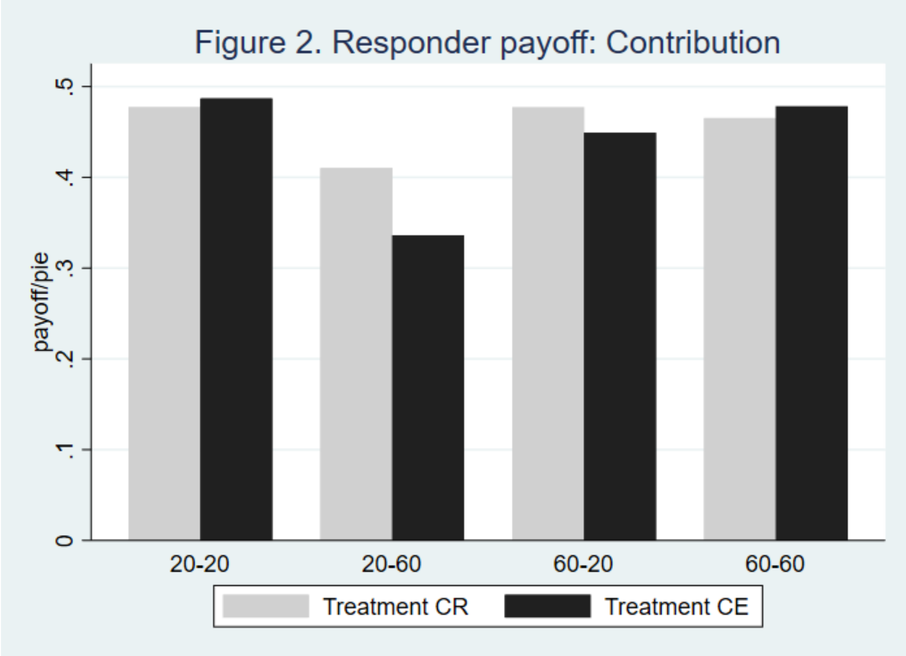

Figure 2: Responder's payoff according to the distribution of contributions. Contributions are given as responder-proposer, e.g., 20-60 implies that the proposer contributed 60 and the responder contributed 20.

From Figure 2, we can see that there is little or no treatment effect, except perhaps in the 20-60 matches. This impression is supported by significance testing. Table 3 reports results of Wilcoxon rank-sum tests of treatment differences over the different match types.

Table 3. Wilcoxon rank-sum–Contribution: π is the responder's payoff and z_P and z_R are the contributions for the proposer and the responder, respectively.

Treatment measures	Mean π_{CR}	Mean π_{CE}	Difference in means	p-value (exact)
H2a: $z_R = 20$ & $z_P = 20$	0.477	0.487	-0.010	0.613
H2b: $z_R = 20$ & $z_P = 60$	0.410	0.336	0.074	0.072
H2c: $z_R = 60$ & $z_P = 20$	0.477	0.449	0.028	0.613
H2d: $z_R = 60$ & $z_P = 60$	0.465	0.478	-0.013	0.866

From Table 3, we see that the only significant difference between randomly allocated contributions and earned contributions occurs when we analyze matches with $z_R = 20$ and $z_P = 60$. Arguably, a p-value of 7.2% is not that convincing, but from theory (Theorem 2) we expect $\pi_{CR} > \pi_{CE}$, and thus a one-sided test could be more appropriate than a two-sided test in this case. If so, the relevant p-value is 3.6%. From theory, we also expect $\pi_{CR} < \pi_{CE}$ when $z_R = 60$ and $z_P = 20$, but we cannot reject the null of no differences between randomly allocated contributions and earned contributions in this case. We conclude that these findings are in line with hypotheses H2a, H2b, and H2d, but not H2c, indicating that formation of contributions as reference points through a costly effort task impacts payoffs only when the responder has the relatively low contribution in a match.

In fact, looking at within-treatment variation, we see from Figure 2 that payoffs for responders are the same across all match types, except for in 20-60 matches where the payoff is lower. This observation is supported by results from parametric regressions with dummies for each match type, using variation in matches between subjects within treatments (see Appendix A.4). Moreover, the observation is supported by results from Wilcoxon signed-rank tests of within-subjects differences in payoffs (when they are responders) depending on whether their opponents have a contribution of 20 or 60, reported in Table 4.

Table 4. Wilcoxon signed-rank–Contribution: π is the responder's payoff and z_P and z_R are the contributions for the proposer and the responder, respectively.

Treatment measures	Mean $z_P = 20$	Mean $z_P = 60$	Difference in means	p-value (exact)
π_{CR} & $z_R = 20$	0.479	0.420	0.059	0.036
π_{CR} & $z_R = 60$	0.494	0.474	0.020	0.978
π_{CE} & $z_R = 20$	0.457	0.347	0.110	0.019
π_{CE} & $z_R = 60$	0.444	0.347	−0.034	0.342

From Table 4, we see in cases where the responder has a contribution of 20 that her relative payoff is significantly higher when her opponent also has a low contribution than when her opponent has a high contribution, in both treatment CR and treatment CE. This is in line with Theorem 2. In contrast, and at odds with the theory, we do not find support for a difference in payoffs depending on the opponent's contribution when the responder has a contribution of 60.

Outside options have a value of zero in the contribution treatments and are used considerably less than in the outside-options treatments. In the CR treatment, 5.8 percent of matches ended bargaining with the responder taking her outside option, whereas the corresponding number in the CE treatment is 9.4 percent (see Figure A.6 in Appendix A.6). Theory predicts no delay in any treatment, and although the finding for the contribution treatments is closer to theory, we still observe delay. The mean end-round is equal to 1.56 and 1.91 in CR and CE, respectively (see Table A.9 in Appendix A.7, and Figure $A.3$ for frequency plots).[11]

The result that it does not matter what the opponent's contribution is ($z_P = 20$ vs. $z_P = 60$) when the responder has a contribution of 60 in the CE treatment is at odds with our theory. In both cases, the responder gets slightly less than 50%. This result is more in line with the standard solution without reference points, and constitutes a slight first-mover advantage. On the other hand, the opponent's contribution ($z_P = 20$ vs. $z_P = 60$) matters when the responder has a contribution of 20, which runs against theories without reference points. A possible explanation based on risk aversion and self-serving principles of justice is given in the discussion in Section 5.

To conclude, our results show that, in line with theory, when a responder's contribution is lower than her opponent's, her payoff is also lower. Moreover, the data support the conjecture

[11]The model predicts immediate agreement, but we observe some delay in the lab. We do not analyze delay in this paper. Explicit analysis of delay in alternating bargaining is scarce. This scarcity may be due to the multiplicity of equilibria in the alternating-offer framework when players are not fully informed (the standard rationale for delay). Karagözoglu and Keskin (2018b) analyze delay in a setting similar to ours, with disutility from deviating from what is considered fair. Embrey et al. (2015) explicitly analyze delay in bargaining experiments using the framework of Abreu and Gul (2000) on bargaining in the presence of obstinate types, whereas Heggedal, Helland, and Knutsen (2022) analyze the effect of outside options on delay in such a framework.

that the costly effort task helps in the formation of contributions as reference points. Seen through the lens of our model, this interpretation implies that the loss-aversion parameter is larger when contributions are earned than when they are randomly allocated. In Appendix A.8, we examine this interpretation further by calibrating the loss-aversion parameter of the model.

5. Discussion

In what follows, we discuss four alternative theories – self-serving bias, relative loss aversion, risk aversion, and fairness concerns – and to what extent they can account for our observations.

Self-serving bias

If subjects have a self-serving bias, we would expect proposers to propose an equal split when the responder has contributed relatively more but a proportional split if the proposer has contributed the most. Thus if the proposer, in the CE treatment, contributed 20 and the responder contributed 60, the proposer would propose a 40-40 split, whereas if the proposer contributed 60 while the responder contributed 20, the self-serving principle of justice would be to suggest a 60-20 split. A responder with self-serving principles of justice will hold the opposite ideal, wanting a 20-60 split in the first case and 40-40 in the latter. The responder then has to choose between accepting the proposal or declining to continue bargaining. Continued bargaining involves considerable risk, especially because the opponent can opt out and leave both with zero payoff. A risk-averse responder could thus prefer the proposal over the risky prospect of continued bargaining. It is well known that having a high aversion for risk is a disadvantage in alternating-offer bargaining (Roth 1985). As a consequence, the pie will tend to be split according to the proposer's view, that is, evenly, except when the proposer has the relatively higher contribution. In the CR treatment, there is no entitlement to the contributions and hence we do not expect them to matter, and hence an equal split should be common in all cases. This would predict that there is a difference between the two treatments only when the proposer has a relatively higher contribution, that is, when the proposer contributes 60 and the responder contributes 20.

An observation that further supports this interpretation is the results from our pilot study, reported in the pre-study plan. In the pilot study, there was no outside option in the CR or CE treatments. In this case, the risk associated with continued bargaining is much lower, because there is no risk that the opponent opts out. In the pilot study, we indeed found a difference between CR and CE also in the asymmetric case when the responder has the higher contribution. However, the design caused problems with potentially correlated observations, and these observations are thus not included in the current version of the paper.

Relative loss aversion

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

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

and thus the reference point is $r_i\theta$ which changes as the pie size changes. Consider a player 1 who contributed 40 ECUs of a total pie of 100 ECUs, that is $r_1 = 40\%$. After two rounds of bargaining, the pie has shrunk to 81 ECUs. Suppose that the players then agree and player 1 gets 34 ECUs. Because $r_i\theta = 32.4$ ECUs, the player is in her gain zone. Even though she gets 6 ECUs 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. Although we think this assumption is reasonable, we do not have separate evidence to support it.

An argument in favor of the relative reference point is that such a reasoning would 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, because the 2000 was already pocketed. If the pie has shrunk from 100 to 81, the players have to bargain over the distribution of 81 and may have pocketed a loss. And, because player 2 contributed a larger share of that pie, she may feel entitled to a larger share of the remaining pie of 81 ECUs. Note also that the proposer had to press a button to produce a pie diagram showing the relative distribution of the remaining pie before she could submit the proposal. The same pie diagram was also shown to the responder. These diagrams also invokes a framing in terms of relative shares. Still, because we cannot show independent evidence for the assumption that reference points are relative, a caveat with the theoretical result is that this assumption may be wrong.

Risk aversion

As pointed out above, having a high aversion for risk is a disadvantage in alternating-offer bargaining. Thus, if the subject that contributed the least to the pie also had the highest aversion for risk, that could potentially explain the results we found. Such a correlation would result if the one with the highest aversion for risk also put the least effort into the earning task. Note that the return to effort is risky; it is either 20 or 60 ECUs, 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 a random contribution, there is no sorting of participants according to risk aversion. Still, we will argue that this sorting by 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. Thus, we would expect the same sorting by risk aversion when outside options are earned. But we do not observe similar differences between treatments T1 and T2.

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 on 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. In a recent paper, Karagözoglu and Keskin (2018) introduce fairness concerns to a bargaining model where the utility function forms are just like in the prospect theoretic utility function used in our paper. Thus, in their model, players' fairness judgments act as a reference point and there is no model technical difference between the two concepts.

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 contributions, except if there are multiple equilibria where prior contributions could serve as a coordination device.

The use of outside options

Outside options are used more than theory would predict. A responder who receives a proposal below the outside option would be better off taking the outside option than accepting. Knowing this, the proposer should, in theory, not send such a proposal.

Contrary to this prediction, we find that a considerable share of games end with the use of outside options. In the OE treatment, this share is as high as 40%. In the contribution treatment, where the outside option is to get nothing, 5.7% of the games in treatment CR and 9.4% of the games in treatment CE ended with the use of outside options. Note also, from Figure $A.3$ and Table $A.9$, that most games that end with the use of outside options end in period 1 (see Appendix A.7). To investigate the use of outside options further, we thus look at the proposal in the first round.

Fairness views may explain some of the use of outside options. A proposer may think that the outside option would give the responder an unfair share of the pie, and hope that a more equal distribution would be accepted, and thus offer below the outside option when this is high. Similarly, for contributed shares, players may hold different views about fairness, especially when contributions are unequal, and thus prefer to end the game with a zero outside option rather than fighting for a higher share.

This result is consistent with the results in Table $A.8$ in Appendix A.6. In the outside option treatments, when the first offer is lower than the outside option, 80% (OR) and 65% (OE) of the games end with the use of outside options. The frequencies are much lower (9% (OR) and 24% (OE)) when the first offer is above the outside option.

In the contribution treatments, outside options are always zero, and it would be better to accept any offer larger than zero than to use the option. Still, we see a similar pattern here: When initial offers give the respondent less than the respondent contributed, 11.5% (CR) and 17.7% (CE) of the games end with the use of outside options. When the respondent is offered the contributed share or more, the shares ending with the use of outside options are much lower

(3.6% and 6.4%, respectively). This indicates that a responder who thinks the offer is too low may prefer to end the game immediately rather than fight for a fair share.

The interpretation that the use of outside options is related to conflicting fairness rules is supported by the observations in Table $A.7$ in the appendix. In the outside option treatments, we see that the use of outside options is much higher when the responder has an outside option of 60 (out of a pie of 80). It may be tempting for a proposer to suggest a more even distribution, resulting in a frequent use of outside options in these cases, particularly when the proposer's outside option is 20. In this case, about half the games end with the outside option being used.

Similarly, in the contribution treatment, conflicting fairness views will be most prevalent when contributions are unequal: 20 versus 60. Again, we see a much higher use of outside options in these games, particularly when contributions are earned. Then 16% of these games result in outside options being used, whereas only 5.3% and 1.6% in 20-20 and 60-60 matches, respectively, end with outside options when the contributions are equal.

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 stronger positive relationship between relative contributions and final payoffs when contributions are earned under competitive conditions. With contributions activated as reference points, our model predicts a specific relationship between contributions and bargaining outcomes. We find that this relationship is present in the data, but contrary to predictions, this pattern occurs only when the proposer has the higher contribution.

Appendix

A.1 Proof of Theorem 1

Consider the outside option $\psi_i \geq 0$ as the reference point for player i. There are three cases to consider:

Case 1: $\psi_1 \leq y^*$ **and** $\psi_2 \leq 1-x^*$ No outside option is binding.

Let x^* and y^* denote the subgame perfect equilibrium shares in the standard model. Because the solution is stationary, $\theta = 1$ is essentially only a scaling factor and to simplify notation, we can let $\theta = 1$ without loss of generality. Suppose that the outside option is not binding, neither for player 1 $\psi_1 \geq x^* > y^*$ nor for player 2 $\psi_2 \leq 1 - x^* < 1 - y^*$. The utility for player i is given by $u_i(s_i) = s_i$ for all s_i such that $s_i \geq \psi_i$. Hence, the equilibrium condition

$$y^* = x^*\delta$$
$$1 - x^* = (1 - y^*)\delta,$$

is not affected by the reference point.

Case 2: $\psi_2 > 1 - x^*$ The outside option for player 2 is binding.

Now let $\psi_2 > 1 - x^*$ where x^* is 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.

Case 3: $\psi_1 > y^*$ **and** $\psi_2 \leq 1 - x^*$ The outside option for player 1 is binding, but not for player 2.

In this case $\psi_1 > y^*$, with y^* player 2's proposal that would have been an equilibrium in the standard model. Using backward induction, we start in period two assuming the first offer from player 1 has been rejected. As in case 2, player 2 now will offer player 1 her outside option, and player 2 is left with a share $1 - \psi_1 > 1 - y^*$. That is, player 2 cannot obtain $1 - y^*$ in the second period, but must settle for less. There are now two subcases: **(a)** $\psi_2 \leq \delta(1 - \psi_1)$. In this case, player 1 can offer player 2 a share $\delta(1 - \psi_1)$ in the first round, and player 2 will accept, as she can get no more in the second round. **(b)** $1 - x^* \geq \psi_2 > \delta(1 - \psi_1)$. Now player 2 can obtain more than $\delta(1 - \psi_1)$ by using the outside option. The equilibrium is like that in case 2 above: Player 1 will offer player 2 her outside option.

Note that in cases 2 and 3, it can be the case that $\psi_1 + \psi_2 > 1$. In that case, the equilibrium outcome may be in the loss zone for player 2. But although the marginal utility is higher in the loss zone, the outcome is determined by the outside option and marginal utility has no bearing on the equilibrium. Loss aversion thus has no impact on the equilibrium.

A.2 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 $u_1(d_1(x^*)) = \delta u_1(x^*)$, whereas $d_2(y^*)$ 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, depending on whether players are in their loss or gain zones:

Case 1: $\bar{s} > x^* > y^*$. Player 1 is always in the loss zone and player 2 is always in the gain zone.

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

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

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

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

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: $x^* \geq \bar{s} > y^*$. Each player is in the loss zone only when the player is a responder. Because each player is in the loss zone only when the player is a responder, the equilibrium conditions in this case are

$$(1+\mu)y^*\theta - \mu\bar{s}\theta = \delta x^*\theta$$
$$(1+\mu)(1-x^*)\theta - \mu(1-\bar{s})\theta = \delta(1-y^*)\theta,$$

with the unique solution

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

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

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

while $y^* < \bar{s}$ if

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

Case 3: $x^* > y^* \geq \bar{s}$. Player 2 is always in the loss zone, and player 1 is always in the gain zone.

We could solve this case by deriving two linear equations in x^* and y^* as in cases 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 her 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 a 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

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

A.3 Wilcoxon rank-sum tests on absolute payoffs

Table $A.1$. Wilcoxon rank-sum, absolute payoffs: Outside option

Treatment measures	Difference (means)	p-value (exact)
Given $w_R = 20$ and $w_P = 20$: π_{OR} vs. π_{OE}	1.123	1.00
Given $w_R = 20$ and $w_P = 60$: π_{OR} vs. π_{OE}	8.226	0.145
Given $w_R = 60$ and $w_P = 20$: π_{OR} vs. π_{OE}	0.424	0.864
Given $w_R = 60$ and $w_P = 60$: π_{OR} vs. π_{OE}	3.273	0.088

Table $A.2$. Wilcoxon rank-sum, absolute payoffs: Contribution

Treatments	Difference (means)	p-value (exact)
Given $z_R = 20$ and $z_P = 20$: π_{CR} vs. π_{CE}	-0.327	0.715
Given $z_R = 20$ and $z_P = 60$: π_{CR} vs. π_{CE}	5.803	0.072
Given $z_R = 60$ and $z_P = 20$: π_{CR} vs. π_{CE}	4.186	0.463
Given $z_R = 60$ and $z_P = 60$: π_{CR} vs. π_{CE}	-0.046	0.613

A.4 Parametric regressions on match types

Table $A.3$: Regressions with dummies for match types. Dependent variable, responder's payoff.

VARIABLES	(1) Outside Option random	(2) Outside Option earned	(3) Contribution random	(4) Contribution earned
MatchType = 2, 20-60	0.04	-0.05	-0.07***	-0.15**
	(0.03)	(0.06)	(0.02)	(0.05)
MatchType = 3, 60-20	0.22***	0.23**	-0.00	-0.04
	(0.03)	(0.07)	(0.03)	(0.06)
MatchType = 4, 60-60	0.27***	0.24***	-0.01	-0.01
	(0.03)	(0.07)	(0.02)	(0.03)
Constant, 20-20	0.48***	0.47***	0.48***	0.49***
	(0.03)	(0.06)	(0.01)	(0.03)
Observations	216	192	192	192
R-squared	0.41	0.43	0.04	0.12

Standard errors clustered on independent blocks in parentheses; *** p<0.01, ** p<0.05, * p<0.1

A.5 Main results excluding games that end by use of outside options

This subsection reports the main results when we exclude all games that ended with outside options being used.

Outside-options treatments

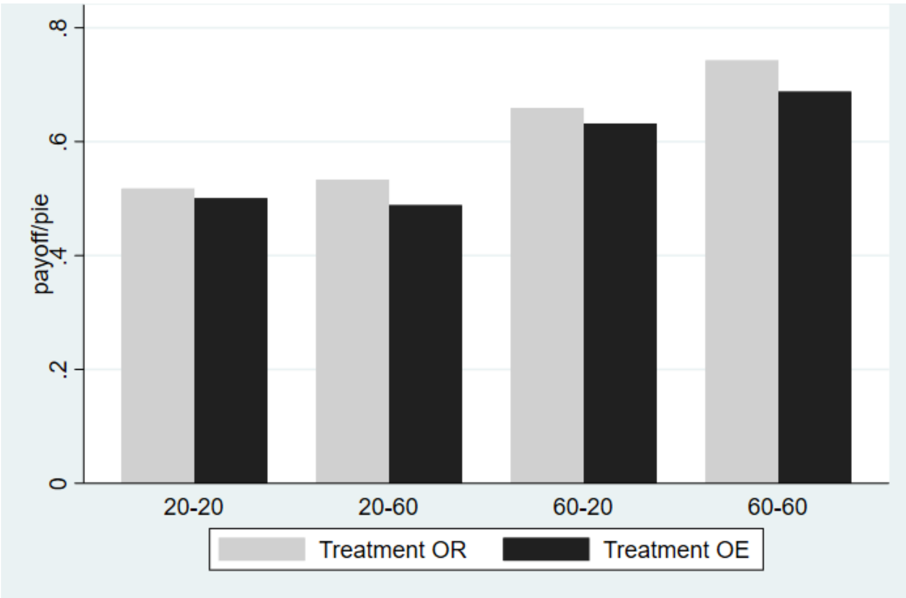

Figure A.1: Responder's payoff excluding the use of outside options. Outside options are given as responder-proposer, e.g., 20-60 implies that the proposer has an outside option of 60.

Table A.4. Wilcoxon rank-sum–Excluding use of outside options: π is the responder's payoff and w_P and w_R are the outside options for the proposer and the responder, respectively.

Treatment measures	Mean π_{OR}	Mean π_{OE}	Difference in means	p-value (exact)
Given $w_R = 20$ & $w_P = 20$	0.518	0.501	0.017	0.627
Given $w_R = 20$ & $w_P = 60$	0.533	0.488	0.045	0.388
Given $w_R = 60$ & $w_P = 20$	0.659	0.632	0.027	0.397
Given $w_R = 60$ & $w_P = 60$	0.743	0.689	0.055	0.200

Contributions treatments

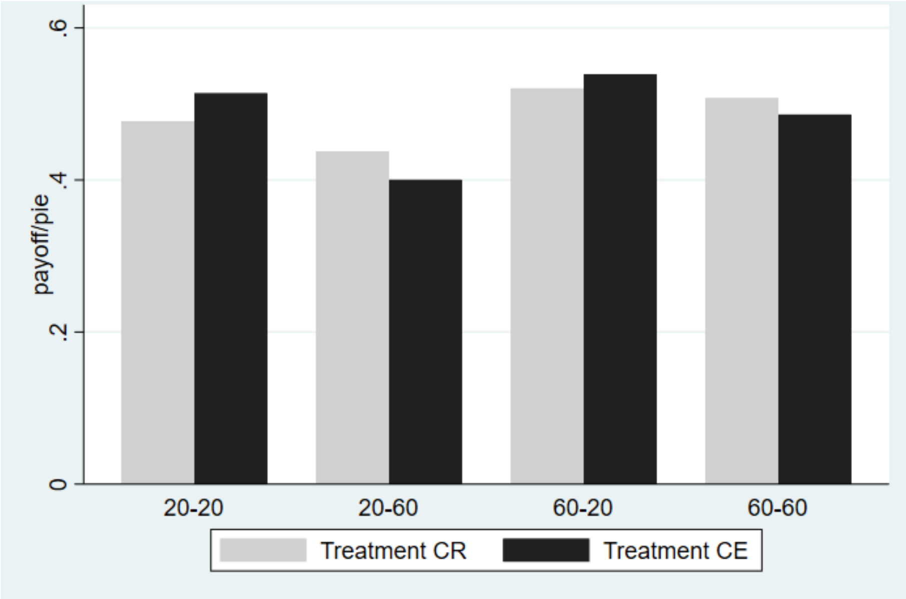

Figure A.2: Responder's payoff excluding the use of outside options. Contributions are given as responder-proposer, e.g., 20-60 implies that the proposer contributed 60 and the responder contributed 20.

Table $A.5$. Wilcoxon rank-sum–Excluding use of outside options: π is the responder's payoff and z_P and z_R are the contributions for the proposer and the responder, respectively.

Treatment measures	Mean π_{CR}	Mean π_{CE}	Difference in means	p-value (exact)
Given $z_R = 20$ & $z_P = 20$	0.477	0.514	-0.037	0.029
Given $z_R = 20$ & $z_P = 60$	0.438	0.400	0.037	0.281
Given $z_R = 60$ & $z_P = 20$	0.520	0.539	-0.019	0.955
Given $z_R = 60$ & $z_P = 60$	0.508	0.486	0.021	0.071

A.6 Use of outside options

This subsection reports fractions of games that ended with the use of outside options.

Table $A.6$. Fractions of games ended by the use of outside options over treatments.

Treatment OR	Treatment OE	Treatment CR	Treatment CE
0.259	0.406	0.057	0.094

Table $A.7$. Fractions of games ended by the responder using the outside option over treatments and match types. Match types are given as responder-proposer positions (outside option or contribution).

Match type	Treatment OR	Treatment OE	Treatment CR	Treatment CE
20–20	0.111	0.125	0.000	0.053
20–60	0.065	0.304	0.063	0.160
60–20	0.468	0.576	0.083	0.167
60–60	0.333	0.398	0.083	0.016

Table $A.8$. Fractions of games ended by the responder using the outside option over treatments and first offers. First offers are offers in the first round, and are categorized as high if the offer is equal to or above the responder's position (outside option or contribution) and low otherwise.

First Offer	Treatment OR	Treatment OE	Treatment CR	Treatment CE
Low	0.804	0.649	0.115	0.1763
High	0.091	0.243	0.036	0.064

A.7 Delay

This subsection reports results on the end round of games. We note that most games ended in period 1, as theory predicts. This was most clearly so in the outside-option treatments, with slightly more delays in the contribution treatments. In the contribution treatments, we also note that the games that extended over many periods tended to end with the use of the zero outside option. Perhaps these zero outside options served as a way to end games where the opponent made unreasonable proposals.

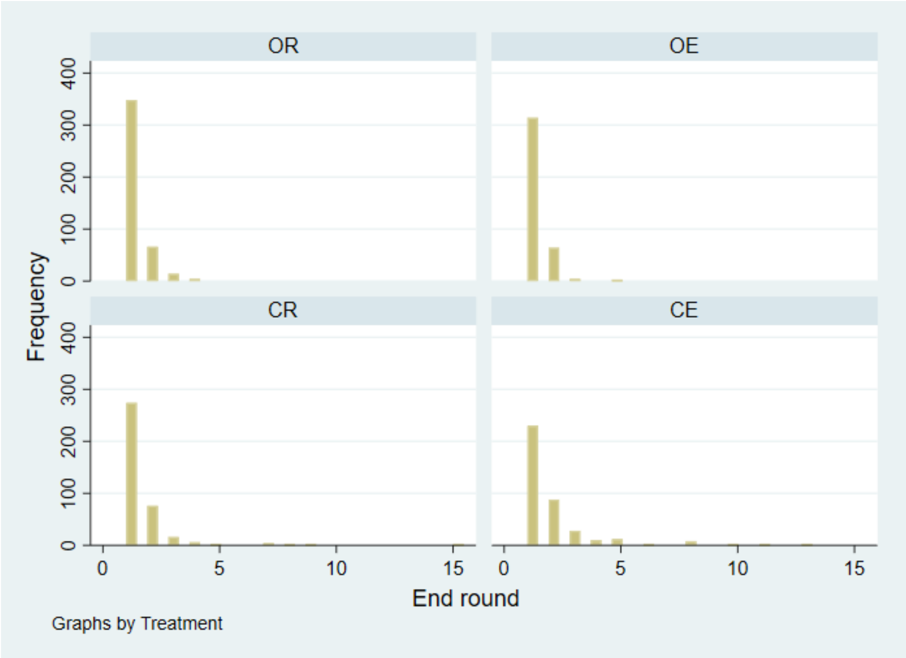

Figure $A.3$ Frequency of end rounds of matches, by treatments.

Table $A.9$. Average end period of games over treatments and whether the game ends with the use of outside options (No/Yes).

Outside option used	Treatment OR	Treatment OE	Treatment CR	Treatment CE
No	1.268	1.193	1.541	1.793
Yes	1.179	1.231	1.909	3.056

Table $A.10$ Frequency of end rounds of matches, by treatments.

VARIABLES	(1) End Period
Game = 2	0.11
	(0.16)
Game = 3	0.00
	(0.11)
Game = 4	0.05
	(0.15)
Game = 5	-0.20
	(0.14)
Game = 6	0.11
	(0.22)
Treatment = 2	-0.04
	(0.07)
Treatment = 3	0.32**
	(0.12)
Treatment = 4	0.67**
	(0.25)
Constant	1.23***
	(0.12)
Observations	792
R-squared	0.06

Standard errors clustered on independent blocks in parentheses; *** p<0.01, ** p<0.05, * p<0.1

A.8 Degree of loss aversion

We have established a relationship in the data between the contribution of the responder and her payoff: when she has a low contribution and faces an opponent with a high contribution, her payoff is lower than in other cases. This relationship is in line with theory. Moreover, our initial conjecture that the costly effort task helps in the formation of contributions as reference points is also supported by our data. Seen through the lens of our model, this interpretation means that the loss-aversion parameter is larger when contributions are earned than when they are randomly allocated. We examine this interpretation by calibrating the loss-aversion parameter of the model.

Consider the following equation

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

where s_i is a responder i's contribution relative to her opponent's contribution, π_i is the responder's payoff relative to the pie size, f corresponds to $x(\bar{s})$ in Theorem 2, and the noise term $\varepsilon_i \sim N(0, \sigma)$. Finally, μ is the magnitude of loss aversion, with $\mu = 0$ meaning no loss aversion. We use the maximum likelihood method to estimate μ.

For random contributions (treatment CR), we estimate a loss-aversion parameter of $\mu = 0.199$ with a p-value 0.042, whereas for earned contributions (treatment CE), we estimate a loss-aversion parameter of $\mu = 0.311$ with a p-value 0.018. Observations are not independent in these estimations and we should be careful about giving too much weight to the precision of the estimates. Our estimates of μ correspond to loss-aversion parameters of 1.199 and 1.311, for CR and CE, respectively, if presented in the common way (i.e., $\lambda = 1 + \mu$). These values are at the low end of the range typically found in nonstrategic decision experiments (see Abdellaoui et al. 2007).

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