Framing and Repeated Competition*

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Abstract

We use a unified framework to model rent-seeking (Tullock) contests and games of strategic complements or substitutes. In each game, we compare an 'abstract' frame with an 'economic' frame. We find more competitive behavior under economic than under abstract framing in the contest and in the game of strategic complements, but not in the game of strategic substitutes. Variation in the strategic nature of the game interacts differently with preferences than with beliefs, allowing us to identify that framing operates primarily through beliefs, and diminishes as beliefs are updated. We model beliefs and preferences using a static and a dynamic framework and show that average choices and adaptation behavior can be explained if both preferences and beliefs are more competitive under economic framing. Our results suggest that some of the commonly observed competitive behavior in contest and oligopoly experiments could be explained by non-abstract framing being used in these studies.

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JEL classification: C72, C91, D43, D74, D83

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1 Introduction

How a decision is framed has been shown to crucially impact behavior in laboratory experiments.[1] One view is that games should be framed neutrally to 'let the explicit reward structure be the singular source of valuation' (Smith 1976, p.278). An alternative is to embed the game in meaningful context, enhancing the understanding and external validity but potentially influencing behaviour. In economic experiments, it is common to use either abstract or mildly cooperative context, in which one of the actions is described as generating a positive externality.[2] An exception to this convention are contest and oligopoly experiments that are almost exclusively run using explicit corporate or competitive framing. The resulting behavioral regularities in these experiments are also somewhat unusual: while choices in most other experimental games (e.g. voluntary contributions games, trust games, dictator games) are typically 'pro-social', that is, between Nash equilibria and social optima,[3] they typically are 'anti-social' in contest and oligopoly games.[4] Moreover, while choices in the other games tend to move toward the Nash equilibrium, oligopolies often drift toward the 'Walrasian' perfectly competitive equilibrium, in which individual payoffs are even lower than Nash.[5] These unusual behavioural patterns in the games of competition raise the question to what extent they are caused by framing.

We address the question by comparing the two framing versions in different types of

[1]See, for example, Andreoni (1995) and Liberman et al. (2004) for two seminal studies in economics and psychology. For a survey, see Alekseev et al. (2017) and Gerlach and Jaeger (2016).

[2]For example, voluntary contribution experiments participants typically have an option to contribute to a 'group exchange' that benefits everyone else (Cookson, 2000), in trust games participants have an option to place bills in an envelope, which are multiplied and delivered to another participant (Berg et al., 1995).

[3]See, for example, Ledyard (1995); Charness and Rabin (2002); Chaudhuri (2011); Murphy et al. (2011).

[4]The idea that this difference could be caused by framing dates back at least to Andreoni (1995).

[5]See, for example, Holt (1995); Bigoni and Fort (2013); Offerman et al. (2002). Similar patterns are observed in contest games (Sheremeta, 2013). Note that oligopoly experiments have found high levels of collusion in small fixed groups (Potters and Suetens, 2013) and after many repetitions (Friedman et al., 2015). Because we are interested not in collusive behavior but in the origins of competitive behavior, as found in experiments with large groups or random matching, we designed our games so as to limit factors known to promote collusion.

games. The *economic framing* treatments replicate the framing that is typically used in the corresponding literature: either corporate language from oligopoly experiments (participants are asked to act as a 'manager' who chooses 'how many products to sell') or competitive language from contest experiments (buying 'tokens' to increase the 'share of the prize'). The *abstract framing* treatments do not provide any interpretation for the game and replace potentially loaded terms with generic game-theoretic language ('action', 'other participant').

In each framing condition, we study three games: contest, strategic complements and strategic substitutes, modelled in a unified framework of 'games of competition' and therefore distinguished only by the degree of strategic complementarity and substitutability. The games were designed to have the same payoffs and locations of Nash equilibrium, collusive outcome and competitive equilibrium. In all games, cooperative choices lie below the Nash equilibrium, and competitive choices above it, therefore behavior can be evaluated along a single 'cooperative–competitive' dimension.[6] We compare a hypothesis that economic framing leads participants to expect more competitive behavior from their opponents to a hypothesis that framing triggers competitive preferences. Variation in the degree of strategic complementarity and substitutability across games allows us to identify the relative importance of these two channels. If framing operates primarily through preferences, economic framing should induce more competitive behavior in all games. If framing operates through beliefs, economic framing should induce more competitive behavior in strategic complements, but less competitive behavior in strategic substitutes, while contest should fall between the other two games.

The second feature of our design is repetition, implemented using a repeated single-shot design (Andreoni and Croson, 2008) whereby players are randomly re-matched within their

[6] We define a choice as 'cooperative' if it would be chosen in equilibrium by a pair of pro-social players, i.e. those whose utility is increasing in the payoff of the other participant. A choice is defined as 'competitive' if it would be chosen by a pair of anti-social players, i.e. those whose utility is decreasing in the payoff of the other participant. For more details, see Appendix B.3.

matching group each round. Repetition allows us to test whether the effect of framing lasts for the entire duration of the game, as it would if it affected preferences,[7] or if the effect disappears over time as beliefs are updated in light of feedback. Previous experiments that studied whether framing operates through preferences or beliefs in prisoner's dilemma (Ellingsen et al., 2012), public goods (Dufwenberg et al., 2011) and ultimatum games (Dreber et al., 2013) used one-shot games, thus it is unclear if the observed framing effects would disappear with repetition (similar concerns in social dilemma games were raised in Bernold et al., 2015).

We find that in contest and strategic complements, economic framing makes behavior more competitive, measured either by the average choice or by the frequency of competitive choices.[8] The framing effect in substitutes is not significantly different from zero, but in contest and in complements the difference is significant and the effect size is larger than typically found in other games (12% in prisoner's dilemmas, 6% in public goods games, 11% in trust games, and 10% in dictator games; see Gerlach and Jaeger, 2016). We find that differences between treatments are best explained by a hybrid model in which framing operates mostly through beliefs, and, to a lesser extent, also through preferences. The estimated parameter values suggest that abstract framing triggers slightly pro-social preferences and increased beliefs that others will act pro-socially, while economic framing shifts both preferences (slightly) and beliefs (substantially) in the competitive direction.

These results complement the existing literature on framing effects. It is generally found that abstract framing increases the degree of cooperation compared to economic framing; for instance, there is more cooperation in social dilemmas (Ellingsen et al., 2012; Engel and Rand, 2014; Batson and Moran, 1999; Pillutla and Chen, 1999), and higher transfers

[7]Unless non-standard preferences are interactive and conditional (see Nax et al. 2015; Ackermann and Murphy 2019; Ackermann et al. 2016).

[8]Economic framing increases the average choice across all rounds by 16% in contest, by 60% in strategic complements, and by 6% in strategic substitutes. All games are parametrized such that higher choices are more competitive.

in ultimatum games (Hoffman et al., 1994). Our results extend these findings by showing that abstract framing moderates competitive behavior in the games of competition, but the framing effect decreases with repetition. We also find evidence that framing operates primarily through beliefs, in line with the results in prisoner's dilemma (Ellingsen et al., 2012), public goods (Dufwenberg et al., 2011) and ultimatum games (Dreber et al., 2013).

The games of strategic complements, substitutes and contests have been widely studied in the experimental literature,[9] but almost exclusively with economic framing. Some experiments studied framing in contests (e.g. Chowdhury et al., 2020), but we are not aware of any studies that would have used abstract framing. Abstract framing has been used in the games of substitutes or complements, but it was not compared to other types of frames (Potters and Suetens, 2009, Abbink and Brandts, 2009, Ozkes and Hanaki, 2019).[10] The only exception is a study by Huck et al. (2004) that compares economic framing to abstract framing in Cournot oligopoly. Huck et al. (2004) find more competitive choices under abstract framing compared with economic framing for duopolies, but no significant framing effect in larger markets. Our duopoly results do not reproduce a significant effect in strategic substitutes, but we confirm and extend their more general point that 'frames interact with the objective structure of a game'.

2 Experimental Design

One of the goals of this study is to identify whether framing operates primarily through preferences or through beliefs. We separate these two effects using three games of competition which exhibit different levels of strategic complementarity/substitutability. Variability in the strategic nature of the game results in different predicted framing effects in each

[9] For literature overview, see Dechenaux et al. (2015) and Sheremeta (2013) for contests, and Potters and Suetens (2013) and Engel (2007) for strategic complements and substitutes.

[10] And, indeed, it has been debated whether higher collusion rates observed in some of these studies were caused by abstract framing (Anderson et al., 2015).

game, depending on the mechanism through which framing operates.

Before discussing the details of the experimental design, we will sketch the key identification strategy. First, we assume that economic framing either triggers more competitive preferences than abstract framing or anchors (initial) beliefs regarding opponents' actions/types at more competitive levels. Given this assumption, and given the three games of competition we formulate, we have the following differentiated predicted effects:

Strategic complements: more anti-social preferences and anti-social beliefs both increase the competitiveness of observed behavior.

Strategic substitutes: more anti-social preferences increase competitiveness, but more anti-social beliefs decrease it, resulting in a smaller framing effect than in strategic complements.

Contests: with elements of both substitutes and complements, the predicted framing effect lies between the other two games.

To ensure that the effects pertaining to the variation in the strategic nature of the underlying game are not confounded by other features of the games, we designed all three games to be as similar as possible in all other key aspects.[11]

2.1 Payoff Functions

2.1.1 Proportional Contest

A prize of value V is divided between two players, proportionally to the size of their investments, which we denote x_1 and x_2. All investments are costly and have to be paid using an endowment E. The payoff of player $i \in \{1, 2\}$ is therefore:

[11]This is important, because varying game parameters has been shown to alter behavior given the same instantiations of preferences and beliefs (Murphy and Ackermann, 2015).

$$\pi_i(x_i, x_j) = \frac{x_i}{x_i + x_j} V + E - x_i \tag{1}$$

Standard rent-seeking (Tullock) contests are usually formulated with payoff risk, that is, the prize is not divided proportionally to investments, but rather allocated to either party according to odds defined by the investments. In order to make the contest game more comparable with the games of strategic complements and substitutes, we have replaced the probabilistic prize allocation rule by the proportional payment rule. With this change, contests are equivalent to a Cournot oligopoly with a unit elastic demand curve (as used, for example, in Friedman et al., 2015).[12] The proportional contest is known to exhibit similar behavioral patterns as the probabilistic contest (see Masiliunas et al., 2014, Fallucchi et al., 2013, Chowdhury et al., 2014).

2.1.2 Games of Strategic Complements and Substitutes

The other two games used in this study are the games of strategic substitutes and strategic complements, which include Cournot and Bertrand oligopoly games with imperfect substitutes as special cases. We represent these games using a payoff function introduced by Potters and Suetens (2009). This formulation provides the necessary degrees of freedom to make the games comparable to each other and to the rent-seeking contest. The payoff function has six free parameters:

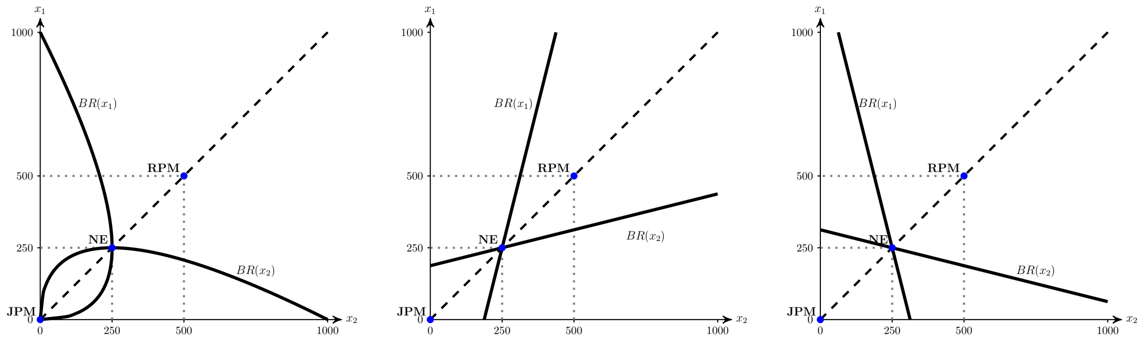
$$\pi_i(x_i, x_j) = a + bx_i + cx_j - dx_i^2 + ex_j^2 + fx_ix_j \tag{2}$$

Crucially, the game is of strategic complements if $\frac{\partial^2 \pi_i}{\partial x_i \partial x_j} = f > 0$, and of strategic substitutes if $\frac{\partial^2 \pi_i}{\partial x_i \partial x_j} = f < 0$.

[12] The payoff function in an n person Cournot game is $\pi_i(x_i, x_{-i}) = a + (P(X) - c)x_i$, and a unit elastic demand function is defined by $P(X) = \frac{b}{\sum_{k=1}^{n} x_k}$. The two are equivalent if $b = V$, $a = E$ and $c = 1$.

2.1.3 Comparability and Parameter Choices

We set the contest parameters to $V = E = 1000$ ECU.[13] To make all three games comparable from a viewpoint of self-interested payoff maximization, the parameters in the games of strategic complements and substitutes were chosen to ensure similar percentages of dominated strategies in all three games and identical location (and payoffs) of the outcomes that correspond to (*i*) Nash equilibrium, (*ii*) joint profit maximization and (*iii*) relative profit maximization. These conditions are satisfied by the following parameter values: $a = 1500$, $b = 0.5$, $c = -1.5$, $d = \frac{2}{1500}$, $e = \frac{1}{1500}$, $f = \frac{1}{1500}$ in the game of strategic complements and $a = 1500$, $b = 0.5$, $c = -1.5$, $d = \frac{2}{2500}$, $e = \frac{3}{2500}$, $f = -\frac{1}{2500}$ in the game of strategic substitutes.[14]



(a) Rent-seeking contest (b) Strategic complements (c) Strategic substitutes

Figure 1: Best-response curves under pure material self-interest.

Figure 1 compares the best-response curves, which are hump-shaped in the contest game, upwards sloping in the game of strategic complements, and downwards sloping in the game of strategic substitutes. Table 1 shows that all three games have a similar range and standard deviation of payoffs and an almost identical percentage of dominated strategies. In all games players face similar optimization incentives: a player would lose on average 160-180 ECU by choosing at random and 490-640 ECU by making the worst

[13]In the experiment, all earnings were expressed in Experimental Currency Units (ECU), converted into cash at the rate 100 ECU = 1 CHF.

[14]A detailed derivation of these parameter values is in Appendix A.

possible choice, compared to the payoff of the best-response, if the opponent is assumed to choose uniformly.

Table 1: Comparison of the contest, strategic complements and substitutes games.

	Contest	Complements	Substitutes
Nash action	250	250	250
Nash payoff	1250	1250	1250
Joint payoff max. action	0	0	0
Joint payoff max. payoff	1500	1500	1500
Relative payoff max. action	500	500	500
Relative payoff max. payoff	1000	1000	1000
Percent of dominated strategies	74.93%	74.83%	74.83%
Worst payoff possible	500	407	448
Best payoff possible	1950	1547	1578
Average payoff s.d.	159	195	170
Loss from random choice	184	176	156
Average 'best-minus-worst response' loss	488	638	533

Our method to identify the relative importance of preferences and beliefs relies on the comparison of behavior in games that differ primarily in terms of their strategic nature.[15] If games differed in other important aspects, variation in treatment effects could not be attributed to the strategic nature. For this reason, it was important to keep the location and payoff of each outcome of interest the same in all three games. Our approach follows Potters and Suetens (2009), but instead of keeping the payoffs on the best-response curve constant across games, we control the location and payoff of the relative payoff maximization point.[16] This feature is important because we seek to test whether economic framing

[15]The standard approach of eliciting beliefs or measuring social preferences in a separate task is problematic for several reasons. Preferences could be context-specific, thus participants who act pro-socially in the post-experimental task (e.g. Murphy et al., 2011) might act anti-socially in the games of competition. For example, Herrmann and Orzen (2008) and Savikhin and Sheremeta (2013) find that the contest environment evokes anti-social behavior in games played subsequently or simultaneously. Direct belief elicitation could influence actions (Hoffmann, 2016) and the quality of elicited beliefs could be low (participants might not be motivated to report accurate beliefs, or reported beliefs could be chosen to justify their behavior to the experimenter; see Schlag et al., 2015, for a detailed discussion).

[16]A change in payoffs on the best-response curve might affect the convergence speed of the best-response dynamics. We favor controlling the payoffs in the competitive outcome than payoffs on the best-response curve since we expect the effect of framing to depend more strongly on the incentives to act competitively than on the incentives to best-respond. In addition, it would not be possible to equalize the best-response

induces competitive preferences or beliefs, thus we also need to know how competitiveness affects behavior. If the payoffs and the location of the relative payoff maximization point differed across games, it would be difficult to attribute differences in framing effects to the strategic nature of the game. Differences in payoffs would affect the costs of relative payoff maximization, thus the game in which spiteful actions are cheaper would be predicted to have a larger framing effect. Differences in the locations of competitive actions could change their salience and the probability that they will be chosen by mistake, potentially explaining differences in competitiveness and the extent to which competitiveness could be further affected by framing.

Identical locations of the outcomes of interest also ensure that the deviations from the Nash equilibrium towards more cooperative or competitive choices decrease payoffs by a similar amount in all games, and the decrease is sufficiently low to detect slight variations in preferences or beliefs. For example, a player with Nash equilibrium beliefs who deviates from the Nash equilibrium action of 250 by 50 and plays 200 would decrease own earnings by 2 ECU (6 ECU in contests), but would increase competitor's earnings by about 50 ECU. Similarly, a deviation to 300 would decrease the competitor's earnings by about 50 ECU, costing 2 ECU in the game of substitutes, 3 ECU in complements and 5 ECU in contest. Therefore, if framing manipulation has an effect on social preferences, a treatment difference should be observed in the final outcomes.

2.2 Other Design Details

We designed the other elements of the experiment to minimize the chances that deviations from the Nash equilibrium prediction occur because of reasons other than preferences or beliefs, and also to keep the design similar to the prior literature.

payoffs across all three games (since the best-response curve is different in contests), while equalizing RPM payoffs is possible.

Action Space

In all three games the strategy space was $\{0, 1, \ldots, 1000\}$. A fine strategy space reduces the chance that an outcome of interest will be observed by pure chance; instead, when an outcome is observed, it is likely to be a result of the properties of that outcome.

Instructions and Timing

Payoffs were explained using a payoff table (reproduced in Appendix G) and a payoff calculator. The two tools complement each other: a table gives a good overview of the payoff space, but only a limited number of payoff combinations can be displayed. A calculator allows payoffs to be calculated for any action profile.[17] We recorded how much time each subject spent using the table and the calculator, as well as what action combinations were entered into the calculator. To ensure that experiments finished in time, we placed time restrictions on each round.[18] If no decision was made within the time limit, the previous round action was implemented. If no decision was made in the first round, a randomly generated action was implemented. Throughout the paper, choices generated at random are excluded from the analysis (i.e. all choices until the first active decision).[19]

[17]For a comparison between the two tools in Cournot oligopoly, see Requate and Waichman (2011).

[18]The limit was 3.5 minutes in each of the first 5 rounds, 2.5 minutes for rounds 5-10, 1.5 minutes for rounds 11-15 and 1 minute for rounds 16-20. We chose this structure of time limits as a pilot study showed that most subjects would not be rushed by such restrictions.

[19]By mistake, in some of the 2019 sessions the laboratory software was started while the participants were still reading the instructions. As a result, some participants did not notice that the experiment had already started and failed to make an active choice within the 3.5 minute time limit given in the first round. This issue affected a third of the participants (compared to less than 3% of participants who did not make an active choice in the first round of 2016 sessions). Only the choices in the first round were affected, as more than 99% of participants from 2019 sessions made an active choice in round 2. Even though we excluded the non-active round 1 choices from the analysis, the remaining number of active choices varies across treatments, and the choices might be of low quality due to potentially being made under severe time pressure. Consequently, we measure the framing effect at the start of the game by comparing decisions in the first 5 rounds, instead of using only the first round data.

Repetition and Matching

The game was repeated for 20 rounds. At the end of the experiment, two randomly drawn rounds were chosen for payment. After each round, participants were informed about their own and their opponent's actions and payoffs. We used two-player games because we expected a small group size to make it easier to understanding the game, form beliefs and calculate best-responses, lowering the chances that deviations from the Nash equilibrium will occur because of computational complexity rather than preferences or beliefs. The game is easy to understand because participants can see the payoff landscape using a simple two-dimensional table.[20] Belief learning in two-player games is arguably less cognitively demanding because players do not need to form and update beliefs about several interaction partners. However, a small group size also makes it more likely that participants will collude (Huck et al., 2004) and it would be difficult to identify the framing effect on competitive behavior if the drive to collude crowded out other motives. We therefore made collusion more difficult by randomly re-matching participants each round. Prior studies generally find behavior to be closer to Nash equilibrium predictions when random matching is used.[21]

Framing

We implemented two variations of each game, one with 'abstract' the other with 'economic' framing. Instructions for all treatments are reproduced in full in Appendix F. Abstract instructions were identical in all three games: players were asked to choose an 'action,

[20]In fact, we find that players on average spent much more time using a payoff table than a payoff calculator (43% compared to 20%).

[21]Davis et al. (2003) find that the frequency of Nash equilibrium play in a Cournot triopoly is higher with random rather than with partner matching, although only when the marginal cost schedule is 'steep'. Baik et al. (2015) find little difference between random and fixed matching in 2- and 3-player contests. Fallucchi and Renner (2016) find no effect of matching in contests when full information is provided, but random matching shifts choices closer to the Nash equilibrium when information about the choices and payoffs of other participants is suppressed.

which is a number between 0 and 1000' and the other party was referred to as the 'other participant'. Behavior in abstract treatments should be driven primarily by the incentive structure, providing a baseline to evaluate behavior in treatments with non-abstract language. Instructions with economic framing followed typical language from previous laboratory experiments,[22] to evaluate whether behavioral patterns in these games are triggered by such language. Framing of the games of strategic complements and substitutes followed Bigoni and Fort (2013), who asked participants to choose the 'quantity produced' and the other party was referred to as a 'competitor'.[23] The economic contest framing was based on Fallucchi et al. (2013) and Masiliunas et al. (2014): players were informed that they will receive a share of the 'prize', depending on how many 'contest tokens' were bought by them and by the 'other participant'.

Sessions

A treatment consists of a game (one out of three), and a frame (one out of two), forming six treatments. The first wave of experiments was run in May and October 2016 and second wave in November and December 2019. In each wave, 24 participants took part in each of the six treatments, with a total of 48 participants per treatment. All experiments were run at the Decision Science Laboratory of ETH Zurich. The average duration of the experiment was 1 hour and average earnings were 32.2 Swiss francs (at the time of the experiment the exchange rate was about 1 CHF = 1 USD). Experiments were programmed using z-Tree

[22]In oligopoly games, subjects are often framed to act as 'managers', and market prices depend on their decisions as well as on those from 'rivals' or other 'firms' (Huck et al., 2000, Huck et al., 2001, Huck et al., 2004, Offerman et al., 2002), 'sellers' (Anderson et al., 2015) or 'competitors' (Gürerk and Selten, 2012, Bigoni and Fort, 2013). In typical contest framing, subjects compete with other 'participants' (Fallucchi et al., 2013, Masiliunas et al., 2014, Chowdhury et al., 2014, Sheremeta, 2010, Sheremeta, 2011)/ 'opponents' (Herrmann and Orzen, 2008, Lim et al., 2014) for a 'prize' (Herrmann and Orzen, 2008, Lim et al., 2014, Fallucchi et al., 2013), 'reward' (Chowdhury et al., 2014, Sheremeta, 2010, Sheremeta, 2011) or for an additional monetary value (Masiliunas et al., 2014) by purchasing 'lottery tickets' (Faravelli and Stanca, 2012), 'contest tokens' (Fallucchi et al., 2013, Abbink et al., 2010) or by making 'bids' (Chowdhury et al., 2014, Sheremeta, 2010, Sheremeta, 2011).

[23]We used such quantity framing in both the games of strategic complements and substitutes, to keep the framing manipulation identical.

(Fischbacher, 2007) and participants were recruited using ORSEE (Greiner, 2015).

3 Hypotheses

Full information about the payoff function was available in all treatments, therefore standard Nash equilibrium predictions (assuming selfish preferences) are identical in all treatments.

Hypothesis $\mathbf{H_0}$. *Choices are not significantly different between treatments with economic and abstract framing.*

Alternative hypotheses are motivated by the psychology literature, which recognizes that behavior is sensitive to how the game is presented (e.g. see Tversky and Kahneman, 1981, Levin et al., 1998). In particular, we will explore the possibilities that either preferences or beliefs are context-dependent.

The first possibility is that *preferences* are context-specific, and thus depend on framing (group identity theories). In contests, economic framing implies that the other participant represents an opposing team, potentially inducing spiteful preference. In fact, it has been found that contests induce group identity and participants subsequently act less pro-socially towards the members of the opposing team compared to the members of their own team (Zaunbrecher et al., 2017). In the games of complements and substitutes, economic framing might suggest that the other party is a member of an outgroup, and thus induce spiteful preference. There is some evidence that the context in which the other participant is embedded affects behavior; for example, both trust and trustworthiness are higher in a trust game when the other participant is referred to as a 'partner' instead of as an 'opponent' (Burnham et al., 2000).

Another possibility is that framing affects not the preferences, but *beliefs* about the type and therefore behavior of the opponent. This is especially plausible at the start of the game, before any feedback has been received. There is prior evidence suggesting that framing primarily affects beliefs rather than preferences (Ellingsen et al., 2012), but there is some disagreement regarding the direction of the effect (Dufwenberg et al., 2011), which we hope to clarify.

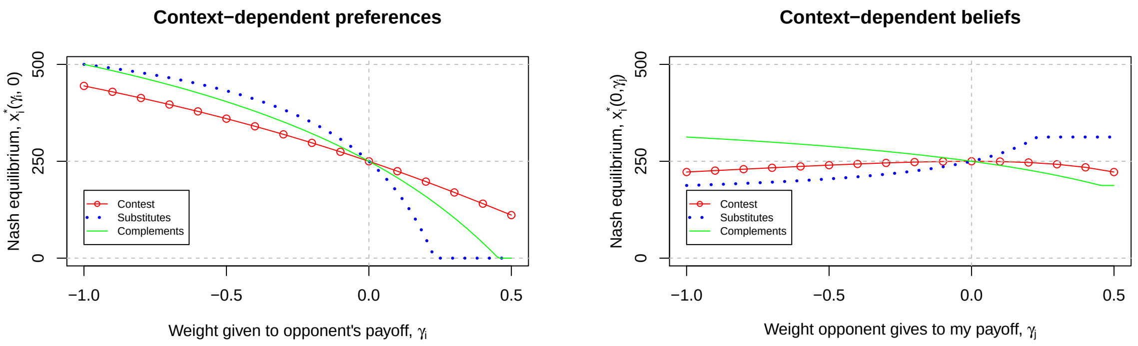
We model context-dependent preferences and beliefs using a simple utility function of the form $u_i(\pi_i, \pi_j) = \pi_i + \gamma_i \pi_j$, for $i \in \{1, 2\}$.[24] Player i is altruistic if $\gamma_i > 0$ and spiteful if $\gamma_i < 0$. We assume that $\gamma_i, \gamma_j \in (-1, 1)$, that is players place a lower weight on opponent's payoffs than on own payoffs. Our theoretical benchmark is the action of player i in a Nash equilibrium, $x_i^*(\gamma_i, \gamma_j)$, derived in Appendix B.

We interpret γ_i as the social preference of player i, and γ_j as the belief of player i about the social preference of j. First, we consider these mechanisms separately. To measure purely the effect of preferences, we calculate how $x_i^*(\gamma_i, \gamma_j)$ depends on γ_i, when γ_j is set to 0. To measure purely the effect of beliefs, we calculate how $x_i^*(\gamma_i, \gamma_j)$ depends on γ_j, when γ_i is set to 0.[25]

In Appendix B, we show that $x_i^*(\gamma_i, 0)$ is decreasing in γ_i, in all three games. This result is illustrated in panel (a) of figure 2. Compared to the benchmark of purely selfish preferences ($\gamma_i = 0$), spitefulness ($\gamma_i < 0$) induces more competitive (higher) and altruism ($\gamma_i > 0$) induces less competitive (lower) choices. According to the context-dependent preference hypothesis ($\mathbf{H_p}$), economic framing shifts preferences towards spitefulness, predicting that in all three games choices will be more competitive than with abstract framing.

[24]This corresponds, for example, to how social preferences are instantiated in the Social Value Orientation (SVO) measure (Murphy and Ackermann, 2014). An alternative assumption would be to allow preference to be interactive (see Nax et al. 2015; Ackermann and Murphy 2019; Ackermann et al. 2016). Appendix C illustrates the predictions of a model with interactive preferences, based on a utility function proposed by Levine (1998). We show that when the interaction between beliefs and preferences is sufficiently high, some of the predictions developed in this section would no longer hold (e.g. the context-dependent belief hypothesis would no longer distinguish strategic complements from substitutes). However, we favor the non-interactive version of preferences and beliefs presented in this section because it has a clear interpretation and distinction between preferences and beliefs.

[25]Of course, framing might operate through both beliefs and preferences at the same time; we will consider such a hybrid model in section 4.4.



(a) Social preferences. (b) Beliefs about opponent's social preferences.

Figure 2: Nash equilibrium action with context-dependent preferences and beliefs

Hypothesis $\mathbf{H_p}$. *Choices are significantly less competitive with abstract framing than with economic framing in all three games.*

Appendix B shows that the effect of beliefs depends on the nature of the game: $x_i^*(0, \gamma_j)$ is decreasing in γ_j in the game of strategic complements, increasing in strategic substitutes, and non-monotonic in the contest game. This result is illustrated in panel (b) of figure 2. The choices of players who expect more altruistic opponents ($\gamma_j > 0$) are less competitive than choices of players who expect more spiteful ($\gamma_j < 0$) opponents in the game of strategic complements, but the pattern is reversed in the game of strategic substitutes. In contests, players who expect more altruistic or more spiteful opponents behave less competitively than players expecting self-regarding opponents ($\gamma_j = 0$). The context-dependent belief hypothesis ($\mathbf{H_b}$) states that economic framing will lead players to expect more spiteful opponents, predicting more competitive choices in the game of strategic complements and less competitive choices in strategic substitutes. The relationship is non-monotonic and smaller in contests. Note that the context-dependent belief hypothesis rests on the assumption that beliefs and preferences are independent; Appendix C shows that it will no longer hold if the interaction between beliefs and preferences is sufficiently high.

Hypothesis $\mathbf{H_b}$. *Choices are significantly less competitive with abstract framing in the* *game of strategic complements, but more competitive in the game of strategic substitutes.*

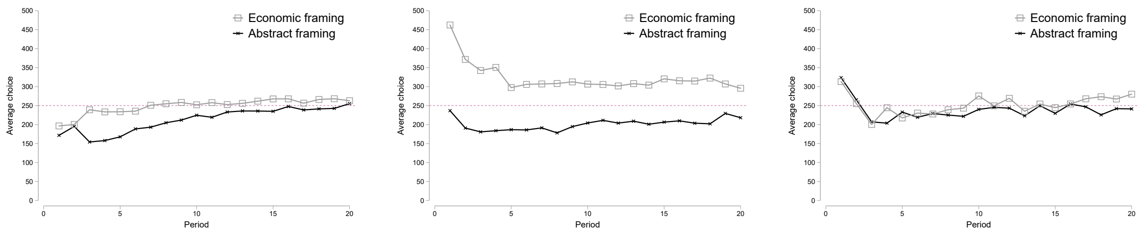
4 Results

4.1 Aggregate Results

Table 2: Average choices across treatments. Standard deviations (in parentheses) are calculated for each matching group and round, and then averaged. MWU is a two-sided Mann-Whitney U test.

		Rounds			Independent
		1-20	1-5	15-20	observations
Contest	Economic	249 (76)	221 (124)	264 (47)	12
	Abstract	214 (73)	169 (129)	245 (49)	12
MWU p-value		0.0377	0.0350	0.3263	
Complements	Economic	322 (103)	361 (178)	311 (72)	12
	Abstract	201 (88)	195 (154)	213 (52)	12
MWU p-value		0.0015	0.0001	0.0243	
Substitutes	Economic	251 (128)	243 (190)	269 (104)	12
	Abstract	238 (133)	245 (180)	242 (110)	12
MWU p-value		1.0	0.9081	0.6033	

We find that economic framing induces more competitive behavior, increasing the average choice from 214 to 249 (16%) in contest, from 201 to 322 (60%) in strategic complements and from 238 to 251 (6%) in strategic substitutes. We evaluate the significance of the framing effect by calculating the average action in each matching group (12 matching groups per treatment) and comparing the values using the Mann-Whitney U-test. Table 2 shows that across all rounds, the framing effect is significant in contest ($p = 0.0377$) and strategic complements ($p = 0.0015$), but not in strategic substitutes ($p = 1.0$). Both the economic size of the effect and the statistical significance in contest and strategic complements are lower at the end of the game (last 5 rounds) than at the start (first 5 rounds). Further evidence for the diminishing framing effect can be seen by plotting the average choice in each treatment over time (figure 3).



(a) Contest (b) Strategic complements (c) Strategic substitutes

Figure 3: Average action over time.

We quantify the framing effect and its change over time by regressing the individual choices on a dummy variable indicating the framing condition, round number and their interaction. Table 3 shows the estimated coefficient values. The framing effect is significant in contests and complements, but not in substitutes. On average, economic framing increases first round choices by 56 points in contest and by 165 points in complements. In complements, the treatment difference decreases by 5 points per round. By the end of the experiment, the estimated treatment effect is significant only in complements. The average framing effect in all rounds is significant in contest (35 points difference) and in strategic complements (121 points difference), but not significantly different in strategic substitutes.

None of the three hypotheses listed in the previous section can fully explain the data. The Nash equilibrium hypothesis ($\mathbf{H_0}$) can be rejected because the framing effect is clearly observed in the contest game and in the game of strategic complements. The context-dependent preference hypothesis ($\mathbf{H_p}$) correctly predicts the treatment effect in contest games and in strategic complements, but fails to explain why such pattern is not observed in strategic substitutes. The context-dependent belief hypothesis ($\mathbf{H_b}$) correctly predicts the ranking of the framing effect across the three games, but the effect in strategic substitutes is insignificant instead of being the opposite of strategic complements. These findings suggest that a combination of context-dependent preferences and beliefs is needed to organize the results, as will be discussed in section 4.4.

Table 3: Random-effects regression (GLS). Standard errors are clustered on the matching group level (24 clusters per game).

	(1) All games	(2) Contest	(3) Complements	(4) Substitutes
Economic framing (round 1)	70.794***	55.939***	164.722***	-4.883
	(3.66)	(2.75)	(5.59)	(-0.15)
Round	1.895**	4.988***	1.253	-0.372
	(2.11)	(4.56)	(0.88)	(-0.22)
Round * Economic framing	-1.509	-2.089	-4.596**	1.897
	(-1.22)	(-1.62)	(-2.09)	(0.90)
Economic framing (round 20)	42.127**	16.257	77.403*	31.157
	(2.13)	(0.79)	(1.77)	(0.92)
Economic framing (rounds 1-20)	56.285***	34.907**	120.650***	13.322
	(3.60)	(2.13)	(3.91)	(0.51)
Number of observations	5708	1897	1905	1906

t statistics in parentheses

Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

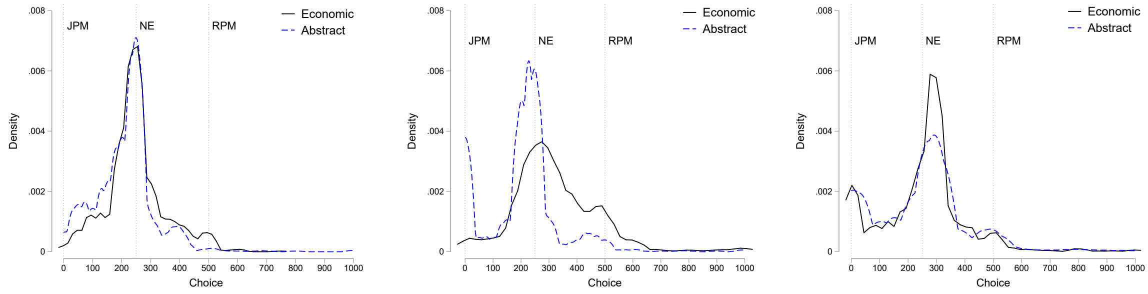
4.2 Classification of Individual and Matching Group Behavior

We have shown that framing has a significant effect on the average action in strategic complements and contest. This section studies how framing affects matching group and individual behavior.

Figure 4 shows the kernel density estimations of individual choices in each treatment.[26] We classify individual choices into three categories (JPM, NE or RPM), based on which of the three outcomes (joint profit maximization point, Nash equilibrium, relative profit maximization point) is closest to the chosen action (a similar classification procedure is used by Huck et al., 2004). The framing effect is strongest in strategic complements, where abstract framing reduces the fraction of RPM choices from 29% to 8% and increases the fraction of JPM choices from 7% to 24% (NE rates remain similar at 64% and 68% respectively). A similar but smaller effect is found in contest, where abstract framing reduces RPM choices from 11% to 6%, but increases JPM rates from 11% to 19% (NE

[26]The evolution of choices by each participant is shown in figures E.4 – E.3 in Appendix E.

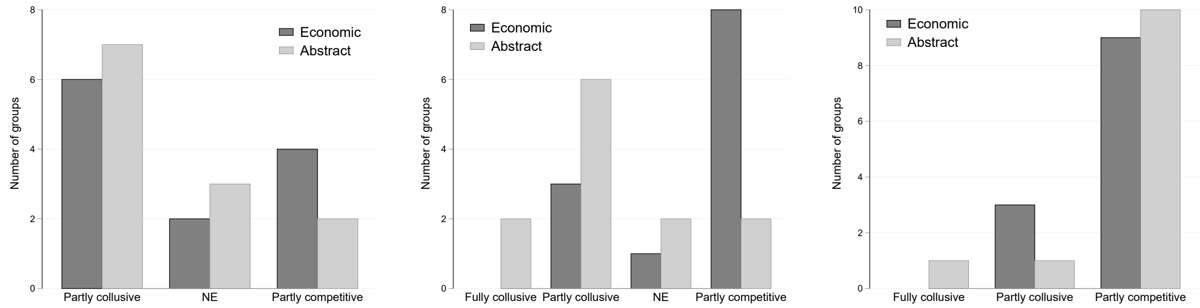
rates are 78% and 75%). Distributions are similar in strategic substitutes, with slightly higher JPM rates (29% vs 20%) and lower NE rates (58% vs 67%) in abstract treatments (RPM rates are 13% in both).



(a) Contest (b) Strategic complements (c) Strategic substitutes

Figure 4: Kernel density estimation using Epanechnikov kernel function.

Classification of individual choices by partitioning the strategy space ignores the data structure. As an alternative, we classify each matching group based on the outcomes most group members chose on most rounds. For example, if a group converges to the Nash equilibrium or is colluding, we would expect most group members to act in line with this prediction. Since there are three main outcomes of interest (collusive outcome is at 0, Nash equilibrium is at 250 and the competitive outcome is at 500), we classify a round as a 'fully collusive round' for matching groups in which most group members (i.e. at least 3 out of 4) choose an action in the 0-50 range, as 'NE round' for groups in which most members choose in the 225-275 range and as 'fully competitive' if the actions are in the 475-525 range. If the action profile does not meet any of these criteria, we classify the round as 'partly collusive' if the choices of most group members are more collusive than the equilibrium prediction (i.e. below 250) and as 'partly competitive' if the majority of choices are more competitive than the equilibrium (i.e. above 250). Otherwise, we leave that round unclassified. We then count the number of rounds a group has been placed into each category, and call the group 'fully collusive'/ 'partly collusive' / 'NE' / 'partly competitive' / 'fully competitive' based on the category to which the group has been assigned in most the rounds (no ties occurred, therefore each group was assigned into one category).



(a) Contest (b) Strategic complements (c) Strategic substitutes

Figure 5: Classification of matching groups.

Figure 5 shows how matching groups were classified in each treatment. No group is classified as fully competitive and only three groups are fully collusive (two in strategic complements and one in substitutes; see figure E.1 in Appendix E for more details). All three colluding groups are found in the abstract framing conditions.[27] In contest and strategic complements, economic framing increases the number of partly competitive groups and decreases the number of NE, fully and partly collusive groups. The large treatment effect in strategic complements is driven in part by higher collusion rates (2 groups colluded fully in abstract framing treatment, none in economic), but mainly by a large difference in partly competitive behavior (2 groups in abstract framing treatment and 8 in economic). In strategic substitutes, most groups are classified as partly competitive and there is little difference between treatments.

[27]Since the games were not designed to study collusion, collusion rates were very low (only 3 out of 72 groups) and we cannot conclude whether colluding is more difficult with economic framing.

4.3 Adaptation and Outcomes in the Long Run

So far we looked only at the effect of framing on aggregate outcomes. Next, we will compare differences in terms of the patterns of adaptation and the long-run outcomes, to test if abstract framing increases the tendency to best-respond and the likelihood of convergence to the Nash equilibrium. In terms of the adaptation process, we compare two rules that could be used our setting: best-responding to the action chosen by the opponent the previous round and imitating the action of the most successful person in the group. Since we study only two-player games, imitate-the-best predicts either choosing the opponents action (if his payoff was higher than own payoff) or choosing the same action as in the previous round. We evaluate the two theories by estimating the following model from Huck et al. (1999):

$$x_i^t - x_i^{t-1} = \beta_0 + \beta_r(r_i^{t-1} - x_i^{t-1}) + \beta_{ib}(ib_i^{t-1} - x_i^{t-1}) + \varepsilon_i^t$$

where r_i^{t-1} is is best reply to the opponents action in round $t-1$ and ib_i^{t-1} is the action of the person in the pair who obtained higher payoffs in $t-1$. The β coefficients measure the importance of each adaptation rule: $\beta_r = 1$ and $\beta_{ib} = 0$ would indicate perfect adjustment to the myopic best-response; $\beta_r = 0$ and $\beta_{ib} = 1$ would indicate perfect imitation.

The first three models in table 4 show the estimated coefficient values in each game when both framing conditions are pooled. The last column pools all three games. The coefficients of both best-response and imitation are significantly above zero in all three games. The best-response coefficient is higher than the coefficient of imitation, which might suggest that best-response is more important than imitation, although Wald test fails to reject the hypothesis that $\beta_r - \beta_{ib}$ is significantly different from zero ($p = 0.1055$ in contest, $p > 0.4$ in the other two games, $p = 0.1092$ when pooled). The importance of imitation also seems to decrease in abstract treatments, although the difference is not

Table 4: Random effects GLS regression. Independent variable is the change in chosen action across rounds. Standard errors are clustered on the matching group level.

	(1) Contest	(2) Complements	(3) Substitutes	(4) All games
β_r	0.355***	0.308***	0.357***	0.335***
	(7.76)	(5.85)	(5.58)	(9.65)
β_{ib}	0.202***	0.241***	0.275***	0.241***
	(3.40)	(4.60)	(4.14)	(6.27)
Abstract	-11.29*	-18.49**	-2.639	-11.29**
	(-1.78)	(-1.99)	(-0.24)	(-1.97)
Abstract * β_r	0.172*	0.0550	-0.115	-0.0147
	(1.84)	(0.53)	(-1.39)	(-0.25)
Abstract * β_{ib}	-0.0907	-0.113	-0.0485	-0.0528
	(-0.82)	(-1.24)	(-0.53)	(-0.91)
Constant	-0.821	-2.394	-20.90***	-7.329**
	(-0.24)	(-0.43)	(-3.16)	(-2.12)
Observations	1801	1809	1810	5420

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

statistically significant (the coefficient for interaction between β_{ib} and abstract framing is not significant in all four models). These conclusions do not change if we additionally control for the game in the pooled model. Table E.1 in Appendix E shows the parameter values estimated separately for each treatment. The results are very similar and there is no significant difference between the coefficients of best-response and imitation (except for the abstract contest, in which Wald test $p = 0.0086$). Overall, even though best-response has a consistently higher coefficient than imitation and there is some indication that the importance of imitation decreases when abstract framing is used, none of these differences are statistically significant. We therefore conclude that both myopic best-response and imitation can explain some patterns of adaptation, but there is no difference between the two and no significant framing effect on the importance of either adaptation rule.

Finally, we test whether framing affects long-run behavior, and specifically the rates of convergence to the Nash equilibrium. If economic framing permanently activates com-

Table 5: Fraction of choices in the neighborhood of NE in rounds 11-20. The neighborhood is measured as a percentage of the range between JPM and RPM choices.

	5% neighborhood		10% neighborhood	
	Economic	Abstract	Economic	Abstract
Contest	42%	50%	69%	71%
Strategic complements	21%	44%	56%	69%
Strategic substitutes	18%	16%	57%	51%

petitive preferences, participants might fail to adapt their choices in the direction of the best-response and convergence rates would be lower. If framing effects are transitory and subject to updating in light of evidence, they should not prevent convergence to Nash equilibrium. We measure convergence by calculating the fraction of observations in the second half of the experiment that are in the neighborhood of the Nash equilibrium, defined in terms of the percentage of the range between the joint payoff maximization and relative payoff maximization points (see Davis, 2011, for a similar approach). Table 4.3 shows that economic framing lowers the convergence rates in the contest games and in strategic complements, but not in the strategic substitutes. We evaluate the statistical significance of treatment differences by comparing the relative frequency of choices in the neighborhood of the Nash equilibrium for each matching group. We find a significant difference only in strategic complements when 5% neighborhood is used (MWU $p = 0.0458$). Figure E.1 (Appendix E) illustrates this difference in strategic complements by plotting the dynamics of average choice in each matching group.

4.4 Static Model of Beliefs and Preferences

Our next goal is to uncover what framing differences across games reveal about the origins of the framing effect. First, we develop a static model in which both beliefs and preferences are context-specific, and estimate the combinations of preferences and beliefs that can best explain our experimental data. As in section 3, we assume the following utility function:[28]

$$u_i(\pi_i, \pi_j) = \pi_i + \gamma_i \pi_j, \text{ for } i \in \{1, 2\} \tag{3}$$

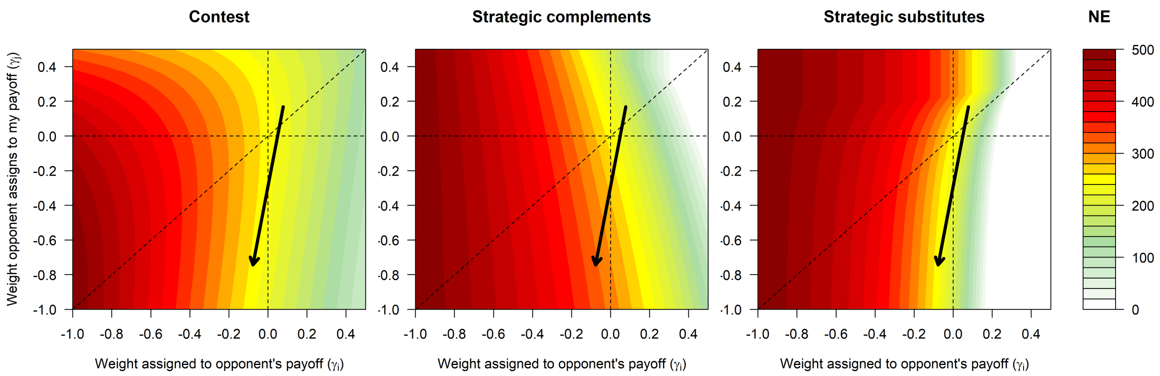


Figure 6: Nash equilibrium quantity as a function of possible combinations of weight attached by self to other player (γ_i) and weight attached by other player to self (γ_j). The arrows indicate the estimated change in beliefs and preferences caused by economic framing.

We are interested in finding the combination of context-dependent social preferences (γ_i) and beliefs about opponent's social preference (γ_j) that can best explain our experimental data. Our solution concept is the Nash equilibrium action, derived from equation (3) (see equations (15) and (14) in Appendix B). Figure 6 illustrates the equilibrium action for a range of parameter values. With standard preferences ($\gamma_i = \gamma_j = 0$), Nash equilibrium is equal to 250 in all three games. A movement along the 45 degree line towards the upper right corner is the usual way to model pro-social preferences, with identical preferences for both players ($\gamma_i = \gamma_j > 0$). In all three games, pro-social preferences decrease the equilibrium action of player i (i.e. behavior becomes more cooperative). Similarly, a movement towards the lower left corner is the usual way to model anti-social preferences

[28]Allowing the preferences and beliefs to be interactive (using the utility function from Levine, 1998) would not improve the explanatory power of the model because any utility specification with interactive preferences can be equivalently represented using the utility function specified in (3), with appropriately chosen weights. For more details and examples, see Appendix C.1.

($\gamma_i = \gamma_j < 0$), which increases the equilibrium action of player i (i.e. behavior becomes more competitive). Movement along the vertical or horizontal lines decomposes the effect into a part that is due to beliefs and a part that is due to preferences. Ceteris paribus, a preference change (horizontal movement) has a similar effect as a change in both preferences and beliefs. Effects due to changes in beliefs differ across the three games. In complements, players who expect the other participant to place a positive weight on their own payoff ($\gamma_i = 0$, $\gamma_j > 0$) would lower their actions, and those expecting a negative weight ($\gamma_i = 0$, $\gamma_j < 0$) would increase them. In substitutes, the effect is reversed. In contests, any change in beliefs would decrease chosen actions.

Next, we look for the combination (γ_i, γ_j) that best fits the data. We allow parameters to be context-specific, but assume no heterogeneity in preferences and beliefs across the population, and no differences between the populations in the three games. We estimate two sets of parameters: (γ_i^a, γ_j^a) for treatments with abstract framing and (γ_i^e, γ_j^e) for treatments with economic framing, by minimizing the mean squared deviation (MSD) between the Nash equilibrium prediction and experimental data. The estimated parameter values indicate anti-social preferences and beliefs with economic framing ($\hat{\gamma}_i^e = -0.08$, $\hat{\gamma}_j^e = -0.74$) and pro-social preferences and beliefs with abstract framing ($\hat{\gamma}_i^a = 0.08$, $\hat{\gamma}_j^a = 0.17$). In figure 6, this change from abstract to economic framing is indicated by an arrow. Note that with both abstract and economic framing the estimated effect is much stronger on beliefs than on preferences. When we allow for either only context-dependent beliefs or only context-dependent preferences, the fit of either model is worse than the hybrid model. The estimated root mean squared deviation equals 140.2 in the hybrid model, 144.1 with only context-dependent beliefs and 143.4 with only context-dependent preferences. These results show that the framing effect observed in our data can be explained by a model in which framing operates mostly through beliefs, but also, to a smaller extent, through preferences.

4.5 Dynamic Model of Beliefs and Preferences

Section 4.4 showed that a static model with context-dependent preferences and beliefs can explain the treatment differences in terms of average choices. This section tests whether a dynamic model of context-dependent preferences or beliefs can explain the adaptation behavior. A dynamic setup allows us to implement a game-theoretic view that beliefs are updated based on the observed history, but preferences are time-invariant.

We model beliefs and preferences in a dynamic setting using a belief learning model, in which observed history is used to form beliefs about opponent's future behavior, and players choose a (noisy) best-response to their beliefs. The starting point of our model is weighted fictitious play (Cheung and Friedman, 1997). In the original model, probabilistic beliefs about each action are determined by counting their empirical frequencies. We modify the model by allowing point beliefs, calculated as a weighted average of observed past choices (see Offerman et al., 2002, for a similar approach). This approach is necessary because of the large strategy space, with which the empirical counts of each action grow too slowly. The second modification adds context-dependent social preferences and beliefs. Beliefs are modeled through the initial beliefs held in the first round. Social preferences are modeled by assuming that players maximize not the expected payoff, but the expected utility, which includes a term for opponent's payoff. Modeled this way, the importance of initial beliefs diminishes over time, while the effect of preferences remains constant in all rounds.

Overall, the belief of player i in round $t \geqslant 2$ is calculated using the following rule:

$$b_i(t) = \frac{\gamma^{t-1} W b_i(1) + \sum_{u=1}^{t-1} (\gamma^{u-1}) h_{-i}(t-u)}{\gamma^{t-1} W + \sum_{u=1}^{t-1} \gamma^{u-1}} \tag{4}$$

where $h_{-i}(t)$ is the choice of the other participant in round t, γ is the discount factor,[29]

[29] If $\gamma = 0$, the belief is equal to the action of the other participant in the previous round and the model reduces to Cournot best-response. If $\gamma = 1$, the belief is equal to the average action of the other participant in all past rounds.

$b_i(1) \in [0, 1000]$ is the initial belief in the first round, and $W \geqslant 1$ is the weight of the initial belief.

The expected utility of action $a \in [0, 1000]$ for player i in round t depends on own payoff and on opponent's payoff:

$$Eu_i(a, b_i(t)) = \pi_i(a, b_i(t)) + \alpha\pi_j(b_i(t), a)$$

with payoff functions defined by equations (1) and (2).

The probability to choose action a is calculated using a logistic choice rule, in which parameter λ measures the sensitivity to expected utility differences:[30]

$$Pr_i^t(a) = \frac{e^{\lambda Eu_i(a,b_i(t))}}{\sum_{a \in A} e^{\lambda Eu_i(a,b_i(t))}}, \quad \text{with } \lambda \in [0, \infty) \tag{5}$$

For each player and each round, we calculate beliefs using equation (4) and the predicted likelihood of the chosen action using equation (5). We round actions to the closest multiple of 5, to reduce the computational complexity. The parameter values of the five free parameters are estimated using log-likelihood maximization, separately for each game and allowing for framing-specific initial beliefs and preferences (as measured by parameters $b(1)$ and α). Estimations were performed using derivative-free optimization routines with various starting values. Standard errors were calculated from the variance-covariance matrix, estimated from the numerical approximation of the Hessian matrix. Standard errors for parameters at the bound are not provided.

Estimated parameter values are displayed in table 6. In each game, the estimated initial beliefs $b(1)$ are more competitive (higher) with economic compared to abstract framing. Similarly, the estimated preference parameter α is more competitive (lower) with economic compared to abstract framing. Note that in this model almost all the estimated preference

[30] Mäs and Nax (2016) have investigated behavioral deviation rates as implied by such a model.

Table 6: Estimated parameter values of a belief learning model with context-dependent preferences and beliefs. Standard errors are in parentheses.

	Contest		Complements		Substitutes	
Parameter	Economic	Abstract	Economic	Abstract	Economic	Abstract
λ (sensitivity)	0.033 (0.0012)	0.033 (0.0012)	0.015 (0.0007)	0.015 (0.0007)	0.014 (0.001)	0.014 (0.001)
γ (discount factor)	0.57 (0.066)	0.57 (0.066)	0.28 (0.10)	0.28 (0.10)	1 (-)	1 (-)
W (weight of initial belief)	62.35 (42.87)	62.35 (42.87)	3.57 (2.81)	3.57 (2.81)	714.29 (4278.60)	714.29 (4278.60)
$b(1)$ (initial belief)	623.47 (31.51)	741.34 (41.52)	999.71 (117.08)	306.62 (90.22)	1000 (-)	84.23 (113.76)
α (other-regarding preference)	0.0044 (0.014)	0.11 (0.015)	-0.087 (0.019)	0.24 (0.02)	-0.16 (0.02)	0.26 (0.055)

parameters are pro-social, in contrast to the anti-social preferences under economic framing estimated in section 4.4. The difference is driven by imperfect sensitivity to expected utility differences added to this model, which biases choices upwards even in the absence of spite.

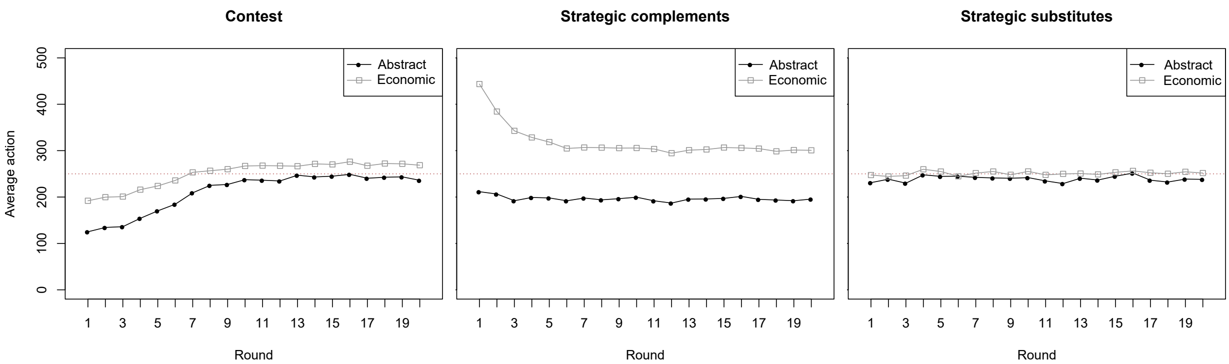


Figure 7: Choice paths simulated with the parameter values from table 6.

Finally, the estimated parameter values are used to simulate the path of choices in each treatment, testing whether belief learning with context-dependent beliefs and preferences can reproduce the empirical choice patterns. The simulated players are randomly paired within a 4-person matching group, just as in the experiment. We simulate the path of choices for 1000 agents, and display the average choices in figure 7. Overall, the simulations closely reproduce the dynamics observed in experiments (compare to figure 3).

5 Concluding Remarks

We find that economic framing as used in typical contest and oligopoly experiments leads to more competitive behavior in contests and in the game of strategic complements. In strategic substitutes, the framing effect is smaller and not significant. The difference between games can be explained with beliefs being more strongly affected by framing than preferences. The finding that the framing effect is increasing in the degree of strategic complementarity can help resolve some puzzles from prior experiments. For example, Huck et al. (2004) find that economic framing has no effect or even reduces the competitiveness of choices in Cournot oligopoly, in contrast to the opposite finding in social dilemma games (Pillutla and Chen, 1999, Engel and Rand, 2014). This difference could be explained by the strategic environment, as Cournot oligopoly is a game of strategic substitutes, while social dilemma games exhibit strategic complementarity (Fischbacher et al., 2001). Our results also complement previous findings about framing in Cournot oligopoly (i.e. strategic substitutes) from Huck et al. (2004), who find that economic framing increases cooperation in duopolies but there is no framing effect in markets with five firms. In our game of strategic substitutes, there is no framing effect despite the use of two-player groups, which may suggest that framing effects in Cournot are relatively weak or design-dependent.[31]

Our study's main focus is on the causes and consequences of the framing effect, therefore we did not discuss the main effect of the strategic complementarity. But since the games were designed to be comparable, we can contribute to the literature by testing whether strategic complements are different from substitutes under either framing condition. Previous literature found that strategic complementarity increases collusion both with standard framing (for an overview, see Suetens and Potters, 2007, or Engel, 2007) and with abstract framing (Potters and Suetens, 2009), although the two effects cannot be

[31]Due to different research goals, we made different design choices than Huck et al. (2004): for example, we did not use the standard Cournot payoff function; we used random matching instead of partner matching; our instructions used different language than the corresponding treatments in Huck et al. (2004).

compared because of variation in design details across studies. We find more cooperation in strategic substitutes than in complements when economic framing is used, but no significant difference with abstract framing (for more details, see Appendix D). The difference could be attributed to the effect the strategic environment has on beliefs and preferences: competitive preferences and beliefs, activated by economic framing, reinforce each other in strategic complements, but offset each other in substitutes.

Why does strategic complementarity decrease cooperation in our experiment, in contrast to the results in the previous literature (as reviewed in Suetens and Potters, 2007)? The discrepancy is most likely due to variance in design details. First, the previous literature used different framing for Cournot (described as quantity competition) and Bertrand games (price competition), while we used the same framing in both strategic complements and substitutes. Second, there are differences in terms of payoff functions, as we followed Potters and Suetens (2009) instead of the standard Cournot and Bertrand payoff function. Third, we used random rather than fixed matching. If fixed matching is used, some participants might attempt to collude and the presence of strategic complementarity creates incentives for other participants to adjust choices in the same direction, boosting the frequency of partly collusive behavior (see Potters and Suetens, 2009, for a discussion of this hypothesis). Re-matching makes collusion difficult and instead might increase partly competitive choices, especially under economic framing. In this environment, strategic complementarity would operate in the opposite direction, boosting the frequency of partly competitive choices. In future research, it would be interesting to test this hypothesis by comparing the effect of the strategic environment across the two matching protocols.

Our approach of separating preferences and beliefs required some simplifying assumptions, which come with several caveats. First, we assumed that preferences are stable (i.e. not interactive or conditional) over the course of the experiment. To address this issue, we calculate the predictions for interactive preferences (Levine, 1998) and show that our results still hold as long as the interaction is sufficiently low. Second, our static framework follows the conventional assumption that beliefs are always correct. In fact, there is evidence that beliefs are often incorrect or misspecified, and the extent of departures from rational expectations may even depend on the strategic nature of the game (Fehr and Tyran, 2008), which might bias our explanations. Third, beliefs, consistent or not, may be self-confirming which creates a chicken-and-egg problem vis-a-vis our explanation (Fudenberg and Levine, 1993). Some of these issues could be addressed in future research by explicitly eliciting and studying the beliefs. Future research would ideally also investigate other types of frames (e.g. 'cooperative' framing commonly used in social dilemma games) and how frames interact with the nature of the game. It would also be very useful to independently measure preferences and study which participants are more susceptible to the framing effects, especially given the recent evidence about the interaction between types and the strategic environment (Savikhin and Sheremeta, 2013; Prediger et al., 2014; Cárdenas et al., 2015).

In sum, our study indicates that framing choices need to be made carefully, because the impact of framing is not uniform and may depend on the nature of the game. We show that a difference between the games of strategic complements and substitutes, found under economic framing, disappears when abstract framing is used. Since these effects are stronger at the start of the game, framing should be of particular importance in short or one-shot experiments. Which type of framing should be used, therefore, depends on the research questions. Economic framing might be more suitable to study specific hypotheses about firm behaviour in oligopolies. Abstract framing might be more suitable to evaluate the effect of game-theoretic features. The comparison of both conditions reveals whether the observed behavioral regularities are driven by the economic incentives, or instead by other social or moral factors that are activated by the provided context. Future studies may proceed in this way to identify what kinds of 'non-economic interventions' (i.e. as driven by non-abstract framing such as information design and nudging) might be useful for firms to complement or substitute standard economic interventions aimed at modifying the strategic incentives of the game via mechanism or market design.

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Online Appendices to "Framing and Repeated Competition" by Aidas Masiliūnas and Heinrich H. Nax

These appendices provide calculations for the parameter values used in strategic substitutes and complements games (Appendix A), calculations of the Nash Equilibrium with non-interactive social preferences and beliefs (Appendix B) and interactive social preferences and beliefs (Appendix C), comparison of strategic complements and substitutes (Appendix D), additional figures illustrating matching group and individual behaviour (Appendix E), instructions (Appendix F) and payoff tables (Appendix G) given to the participants.

A Parameter Values for Strategic Substitutes and Complements

This appendix details how we calculated the parameter values for the games of strategic substitutes and complements so as to keep the locations and payoffs at the Nash equilibrium, joint profit maximization point and relative payoff maximization point constant across the three games. First, it is necessary to calculate all the values of interest in terms of the game parameters. All three outcomes of interest will be symmetric, therefore for brevity we omit the player indexes. Nash equilibrium is calculated the usual way, by taking the first derivative of the profit function and setting it to zero:

$$\{x_1^{NE}, x_2^{NE}\} : x_i^{NE} = \arg\max_{x_i}(\pi_i(x_i, x_j^{NE})), \quad \text{for } i \in \{1, 2\}, j = 3 - i$$

$$\frac{\partial \pi_i(x_i, x_j)}{\partial x_i} = 0 \quad \Leftrightarrow$$

$$b - 2dx_i + fx_j = 0 \Leftrightarrow$$

$$x_i = \frac{b}{2d} + \frac{f}{2d}x_j \tag{6}$$

The slope of the best-response function, which we denote by δ, is equal to $\frac{f}{2d}$.

Nash equilibrium follows from equation (6):

$$x^{NE} = \frac{b}{2d - f} \tag{7}$$

$$\pi^{NE} = a + (b + c)\frac{b}{2d - f} + (e + f - d)\left(\frac{b}{2d - f}\right)^2 \tag{8}$$

Relative profit maximization is calculated by taking the derivative of the payoff difference between the two players:

$$\{x_1^{RPM}, x_2^{RPM}\} : x_i^{RPM} = \arg\max_{x_i}(\pi_i(x_i, x_j^{RPM}) - \pi_j(x_j^{RPM}, x_i)), \quad \text{for } i \in \{1,2\}, j = 3-i$$

We express the payoff difference and its derivative using the parameters of the game:

$$\pi_i(x_i, x_j) - \pi_j(x_j, x_i) = (b-c)(x_i - x_j) - (d+e)(x_i^2 - x_j^2)$$

$$\frac{\partial(\pi_i(x_i, x_j) - \pi_j(x_j, x_i))}{\partial x_i} = b - c - 2(d+e)x_i$$

$$\frac{\partial(\pi_i(x_i, x_j) - \pi_j(x_j, x_i))}{\partial x_i} = 0 \quad \Leftrightarrow \quad x^{RPM} = \frac{b-c}{2(d+e)} \tag{9}$$

Equation (9) defines the location of the relative payoff maximization point. The profits at this point are:

$$\pi^{RPM} = a + \frac{b^2 - c^2}{2(d+e)} + (e + f - d)\left(\frac{b-c}{2(d+e)}\right)^2 \tag{10}$$

Joint profit maximization point is calculated by taking the derivative of the sum of profits earned by both players:

$$\{x_1^{JPM}, x_2^{JPM}\} : x_i^{JPM} = \arg\max_{x_i}(\pi_i(x_i, x_j^{JPM}) + \pi_j(x_j^{JPM}, x_i)), \quad \text{for } i \in \{1,2\}, j = 3-i$$

We express the sum of payoffs and its derivative using the parameters of the game:

$$\pi_i(x_i, x_j) + \pi_j(x_j, x_i) = 2a + (b+c)(x_i + x_j) + (e-d)(x_i^2 + x_j^2) + 2f x_i x_j$$

$$\frac{\partial \pi_i(x_i, x_j) + \pi_j(x_j, x_i)}{\partial x_i} = b + c + 2(e-d)x_i + 2f x_j$$

To calculate the joint profit maximization point we would usually set the derivative to zero. However, our goal is to make the joint profit maximization points equal across the three games, and in contests joint profits are maximized at $x^{JPM} = 0$, i.e. at the bottom of the strategy space. We want joint profits in the games of strategic complements and substitutes to be maximized at the same point, but since it is a corner point, the derivative does not necessarily need to be equal to zero. We therefore at first do not place any restrictions, and later show that the parameter values that satisfy other conditions also ensure that joint profits are maximized at zero. This way, we save one degree of freedom and can therefore additionally control the slopes of the best-response functions.

If joint profits are maximized at $x^{JPM} = 0$, payoffs at this point are equal to:

$$\pi^{JPM} = \pi_i(0,0) = a \tag{11}$$

Since we want to equalize the locations of the outcomes of interest, profits at these locations and control the slope, we first express all these outcomes of interest in terms of the game parameters:

$$\begin{cases} x^{NE} = \frac{b}{2d-f} \\ \pi^{NE} = a + (b+c)\frac{b}{2d-f} + (e+f-d)\left(\frac{b}{2d-f}\right)^2 \\ x^{RPM} = \frac{b-c}{2(d+e)} \\ \pi^{RPM} = a + \frac{b^2-c^2}{2(d+e)} + (e+f-d)\left(\frac{b-c}{2(d+e)}\right)^2 \\ \pi^{JPM} = a \\ \delta = \frac{f}{2d} \end{cases} \tag{12}$$

We solve this system of equations to obtain the parameter values that generate the desirable outcomes of interest:

$$\begin{cases} a = \pi^{JPM} \\ b = x^{NE}\frac{1-\delta}{\delta}f \\ c = f(\frac{1-\delta}{\delta})(2x^{RPM} - 3x^{NE}) - 2\frac{a-\pi^{RPM}}{x^{RPM}} \\ d = \frac{d}{2\delta} \\ e = \frac{a-\pi^{RPM}}{(x^{RPM})^2} + (2\frac{1-\delta}{\delta}\frac{x^{NE}}{x^{RPM}} + \frac{2\delta-3}{2\delta})f \\ f = \dfrac{\pi^{NE} - a - x^{NE}(x^{NE} - 2x^{RPM})\left(\frac{a-\pi^{RPM}}{(x^{RPM})^2}\right)}{\frac{2-2\delta}{\delta}x^{NE}\left(x^{RPM} + \frac{(x^{NE})^2}{x^{RPM}} - 2x^{NE}\right)} \end{cases} \tag{13}$$

To make the game comparable to contests, we set the values as follows: $x^{NE} = 250$, $\pi^{NE} = 1250$, $x^{RPM} = 500$, $\pi^{RPM} = 1000$, $\pi^{JPM} = 1500$. The last variable, slope of the best-response function, determines whether the game is of complements or of substitutes. For the game of complements, we set $\delta = 0.25$. For the game of substitutes we set $\delta = -0.25$. This ensures a similar number of dominated strategies and the range of payoffs across the three games. The absolute value of the slope of the best-response function also needs to be below 1 to ensure that the best-response dynamics converge to the Nash equilibrium. The parameter values for the games of complements and substitutes that satisfy (13) are listed in section 2.1.3.

It is straightforward to verify that with these parameter values $x^{JPM} = 0$. Since in both games $f = d - e$, joint profits cannot be maximized at an interior point because the slope of the best-response functions is equal to 1, and the intercept is non-zero, so the best-response curves never intersect. Joint profits thus have to be maximized at a corner. $x_i = 1000$ cannot be a part of a joint-profit maximizing strategy, because the derivative of joint profits with respect to x_i is negative at the point $x_i = 1000$. If the other participant is choosing 0, joint profits are maximized by choosing 0 too, therefore overall joint profits are maximized at $x_i = 0$, for $i \in \{1, 2\}$.

B Nash Equilibrium with Social Preferences and Beliefs

B.1 Contest

Assume that the utility function of player $i \in \{1, 2\}$ is $u_i(\pi_i, \pi_j) = \pi_i + \gamma_i \pi_j$, where payoffs are defined by equation (1). Denote the action of player i in the Nash equilibrium by $x_i^*(\gamma_i, \gamma_j)$. In contests, the Nash equilibrium action of player i depends on preferences and beliefs:

$$x_i^*(\gamma_i, \gamma_j) = \frac{V(1-\gamma_j)(1-\gamma_i)^2}{(2-\gamma_i-\gamma_j)^2} \tag{14}$$

The derivative of the Nash equilibrium action with respect to γ_i is negative if:

$$\frac{\partial x_i^*(\gamma_i, \gamma_j)}{\partial \gamma_i} < 0 \Leftrightarrow$$
$$-2(1-\gamma_j)(1-\gamma_i)(2-\gamma_i-\gamma_j)^2 V + 2(1-\gamma_j)(1-\gamma_i)^2(2-\gamma_i-\gamma_j)V < 0$$

This inequality is always satisfied because we assume that $\gamma_i < 1$ and $\gamma_j < 1$. The derivative with respect to γ_j is negative if:

$$\frac{\partial x_i^*(\gamma_i, \gamma_j)}{\partial \gamma_j} < 0 \Leftrightarrow$$
$$-V(1-\gamma_i)^2(2-\gamma_i-\gamma_j)^2 + 2V(1-\gamma_j)(1-\gamma_i)^2(2-\gamma_i-\gamma_j) < 0$$

Since $\gamma_i < 1$ and $\gamma_j < 1$, the condition reduces to $\gamma_i < \gamma_j$. This implies that more pro-social beliefs decrease equilibrium action if player's social preference is below the belief about the opponent's social preference. In other words, if the preference γ_i is held constant, both a lower belief and a higher belief would decrease the equilibrium action, compared to the case when $\gamma_j = \gamma_i$. The effect on beliefs on equilibrium action in contests is therefore non-monotonic.

Overall, equilibrium action decreases when preferences become more pro-social, in all three games. The effect of beliefs, however, depends on the game. More pro-social beliefs decrease equilibrium action in the game of strategic complements, increase them in the game of strategic substitutes and the relationship is non-monotonic in contest games. Figure 2 in section 3 illustrates these findings, plotting the equilibrium action with standard beliefs ($\gamma_j = 0$) for a range of social preferences (panel a) and the equilibrium action with standard preferences ($\gamma_i = 0$) for a range of beliefs about opponent's social preference (panel b).

B.2 Strategic Complements and Substitutes

Again, the utility function of player $i \in \{1,2\}$ is $u_i(\pi_i, \pi_j) = \pi_i + \gamma_i \pi_j$ with payoffs from equation (2), and the action of player i in the Nash equilibrium is $x_i^*(\gamma_i, \gamma_j)$. It can be shown that the relationship between Nash equilibrium and parameters γ_i and γ_j has the following form:

$$x_i^*(\gamma_i, \gamma_j) = \frac{2(b + \gamma_i c)(d - \gamma_j e) + f(1 + \gamma_i)(b + \gamma_j c)}{4(\gamma_i e - d)(\gamma_j e - d) - f^2(1 + \gamma_i)(1 + \gamma_j)} \tag{15}$$

To determine how social preferences and beliefs change equilibrium actions, we calculate the sign of derivatives of $x_i^*(\gamma_i, \gamma_j)$, with respect to γ_i and γ_j:

$$\frac{\partial x_i^*(\gamma_i, \gamma_j)}{\partial \gamma_i} < 0 \Leftrightarrow$$
$$(2cd + bf - 2ce\gamma_j + cf\gamma_j)(4e^2\gamma_i\gamma_j + 4d^2 - 4de\gamma_i - 4de\gamma_j - f^2 - f^2\gamma_i\gamma_j - f^2\gamma_i - f^2\gamma_j)-$$
$$-(2cd\gamma_i - 2be\gamma_j - 2ce\gamma_i\gamma_j + 2bd + cf\gamma_i\gamma_j + bf\gamma_i + cf\gamma_j + bf)(4e^2\gamma_j - 4ed - f^2 - f^2\gamma_j) < 0$$

We are particularly interested in isolating the effect of social preferences, under standard beliefs. The derivative of the Nash equilibrium at $\gamma_j = 0$ is negative if:

$$\begin{aligned} &- (2cd + bf)(4de + f^2)\gamma_i + (2cd + bf)(4d^2 - f^2)+ \\ &+ (2cd + bf)(4de + f^2)\gamma_i - (4de + f^2)(2bd + bf) < 0 \Leftrightarrow \\ &8d(cd - be) - 2f^2(c + b) + 4bf(d - e) < 0 \end{aligned} \tag{16}$$

It can be verified that with the parameter values used in the experiment, equation (16) is satisfied for both substitutes and complements. If beliefs are standard, then more pro-social preferences (higher γ_i) decrease the equilibrium action of player i.

Next, we calculate the sign of derivative of $x_i^*(\gamma_i, \gamma_j)$ with respect to γ_j:

$$\frac{\partial x_i^*(\gamma_i, \gamma_j)}{\partial \gamma_j} < 0 \Leftrightarrow$$
$$(-2be - 2ce\gamma_i + cf + cf\gamma_i)(4d^2 - 4de\gamma_j - 4de\gamma_i + 4e^2\gamma_i\gamma_j - f^2 - f^2\gamma_i - f^2\gamma_j - f^2\gamma_i\gamma_j)-$$
$$-(2bd - 2be\gamma_j + 2cd\gamma_i - 2ce\gamma_i\gamma_j + bf + bf\gamma_i + cf\gamma_j + cf\gamma_i\gamma_j)(4e^2\gamma_i - 4de - f^2 - f^2\gamma_i) < 0$$

With standard social preferences, $\gamma_i = 0$ and the derivative is negative if:

$$(cf - 2be)(4d^2 - f^2) + (2bd + bf)(4de + f^2) < 0 \tag{17}$$

It can be verified that with the parameter values used in the experiment, equation

(17) is satisfied for the games of strategic complements, but not for the games of strategic substitutes. Pro-social beliefs therefore decrease equilibrium choices in the strategic complements games, but increase them in the game of strategic substitutes.

B.3 Equilibrium with Coinciding Preferences and Beliefs

If it is common knowledge that participants have the same social preference, the utility function simplifies to $u_i(\pi_i, \pi_j) = \pi_i + \gamma\pi_j$, for any $i \in \{1, 2\}$. This is a special case of the utility function introduced in section B.2, with an assumption that $\gamma_i = \gamma_j = \gamma$. We calculate the equilibrium action $x_i^*(\gamma)$ to identify how the equilibrium action responds to a simultaneous change in preferences and beliefs. It can be shown that in strategic complements and substitutes, equation (15) reduces to:

$$x_i^*(\gamma) = \frac{b + \gamma c}{2d - f - \gamma(2e + f)} \tag{18}$$

With the parameters values used in the experiment, in both strategic complements and substitutes equation (18) reduces to:

$$x_i^*(\gamma) = \frac{1 - 3\gamma}{1 - \gamma} 250$$

Note that $\frac{\partial x_i^*(\gamma)}{\partial \gamma} = \frac{-500}{(1-\gamma)^2} < 0$. This means that if beliefs and preferences coincide, higher pro-sociality, as measured by a higher value of γ, decreases the action predicted in Nash equilibrium. In addition, with the parameters used in the experiment, a joint change in beliefs and preferences affects Nash equilibrium action in strategic complements in the exact same way as in strategic substitutes. Differences between these two games would therefore indicate that beliefs and preferences are affected differently.

In contest, the Nash equilibrium calculation from (14) reduces to $x_i^*(\gamma) = \frac{V(1-\gamma)}{4}$, and with $V = 1000$, the derivative is $\frac{\partial x_i^*(\gamma)}{\partial \gamma} = -250$. Thus higher pro-sociality also decreases the equilibrium action, just as in strategic complements and substitutes.

C Nash Equilibrium with Interactive Social Preferences

Throughout the paper, we assumed that preferences and beliefs are independent. In this appendix, we relax this assumption, allowing the two to interact. For example, people could act more altruistically towards opponents believed to be altruistic, and more spitefully towards the spiteful types. We model such interdependence between preferences and beliefs using a utility function from Levine (1998):

$$u_i(\pi_i, \pi_j) = \pi_i + \frac{a_i + \lambda a_j}{1 + \lambda} \pi_j \tag{19}$$

where π_i is the payoff obtained by player $i \in \{1,2\}$, a_i is the preference of player i, a_j is the belief about opponent's type and $\lambda \in [0,1]$ measures the regard that players have for opponent's type. If $\lambda = 0$, the utility function reduces to the non-interactive model of pure altruism, explained in section 3 (with $\gamma_i = a_i$). In this non-interactive model, social preferences of participant i change only the weight that i's utility function assigns on j's payoff, while i's beliefs change only the weight that the opponent j is expected to assign to i's payoff. If $\lambda \in (0,1)$, beliefs and preferences affect both weights, but i's preferences affect the weight i places on j's payoff more than the weight that j places on i's payoff. From (19), an increase in a_j by some amount δ would increase the weight that i places on j's payoff by $\delta\frac{1}{1+\lambda}$ and would increase the weight that j places on i's payoff by $\delta\frac{\lambda}{1+\lambda}$. If $\lambda = 1$, each weight is equal to the average of preferences and beliefs, thus changes in preferences affect both weights in the same way.

We will calculate how the theoretical predictions in the games of strategic complements, substitutes and contest change when we allow for interactive preferences. It can be shown that in strategic complements and substitutes the Nash equilibrium action with the utility function in (19) is calculated by:

$$x_i^*(a_i,a_j) = \frac{2(b+\frac{a_i+\lambda a_j}{1+\lambda}c)(d-\frac{a_j+\lambda a_i}{1+\lambda}e) + f(1+\frac{a_i+\lambda a_j}{1+\lambda})(b+\frac{a_j+\lambda a_i}{1+\lambda}c)}{4(\frac{a_i+\lambda a_j}{1+\lambda}e-d)(\frac{a_j+\lambda a_i}{1+\lambda}e-d) - f^2(1+\frac{a_i+\lambda a_j}{1+\lambda})(1+\frac{a_j+\lambda a_i}{1+\lambda})} \tag{20}$$

In contest, the Nash equilibrium action is:

$$x_i^*(a_i,a_j) = \frac{V(1-\frac{a_j+\lambda a_i}{1+\lambda})(1-\frac{a_i+\lambda a_j}{1+\lambda})^2}{(2-a_i-a_j)^2} \tag{21}$$

Figure C.1 illustrates the relationship between the equilibrium action of player i, preference a_i and belief a_j for various levels of interactiveness (i.e. different values of λ). If $\lambda = 0$, predictions coincide with the model without interactive preferences (shown in figure 6). If $\lambda = 1$, preferences are indistinguishable from beliefs, since each affects weights a_i and a_j in the same way. For intermediate values, such as $\lambda = 0.5$ illustrated in the middle row (close to the best-fitting value estimated by Levine, 1998), a change in either beliefs or preferences affects both weights, but preferences have a stronger effect on the weight assigned to opponent's payoff (a_i) than on the weight the opponent assigns on participant's payoff (a_j); effects of beliefs are just the opposite.

A natural question is whether the predictions developed in section 3 still hold when the utility function is assumed to be interactive. Figure C.1 shows that in general, the answer is no. When λ is sufficiently high, the distinction between preferences and beliefs is blurred, and the context-dependent belief hypothesis no longer distinguishes strategic substitutes from strategic complements. This result can be seen more easily by plotting the responsiveness of Nash equilibrium to changes in only beliefs (assuming standard preferences) or preferences (assuming standard beliefs). The top row of figure C.2 shows the predictions for $\lambda = 0$, equivalent to the non-interactive model illustrated in figure 2. Nash equilibrium decreases as preferences get more pro-social in each game, but the effects of

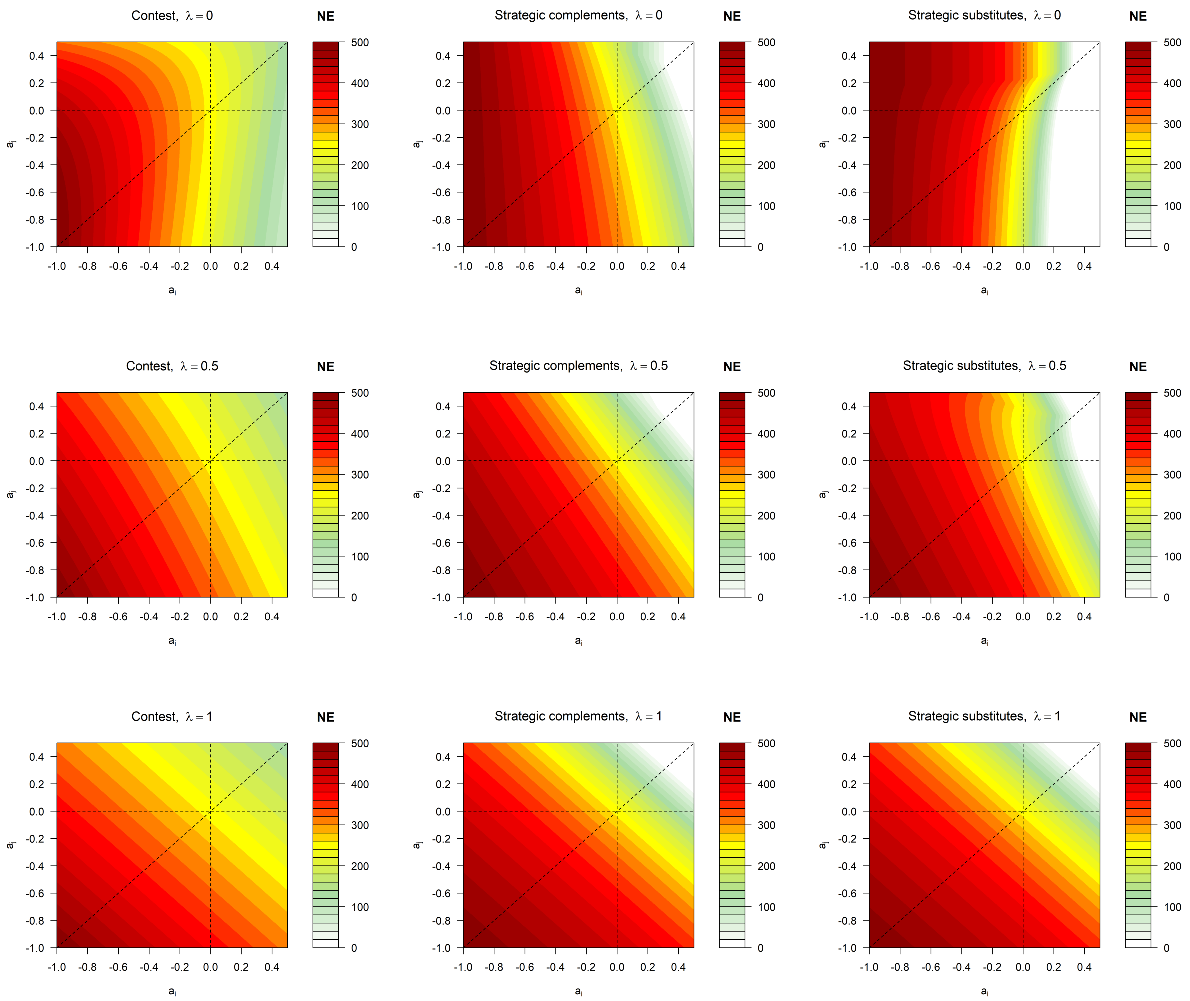


Figure C.1: Nash equilibrium action with context-dependent preferences and beliefs

beliefs depend on the game. However, the middle row shows that the distinction between substitutes and complements diminishes when preferences are sufficiently interactive. In that case, the context-dependent belief model predicts a similar change in equilibrium action in all three games. In the extreme case $\lambda = 1$ (bottom row), predictions in strategic complements and substitutes are identical. We thus conclude that the context-dependent belief hypothesis ($\mathbf{H_b}$) holds only when preferences are assumed to be non-interactive.

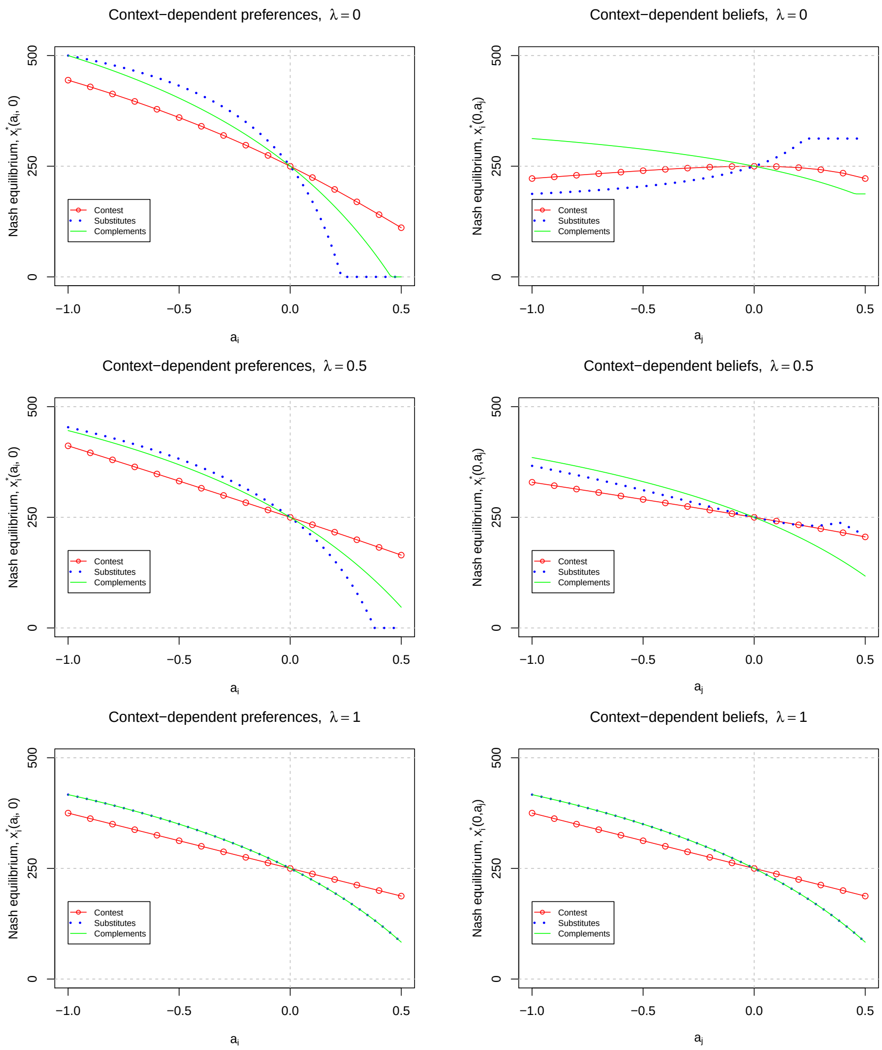
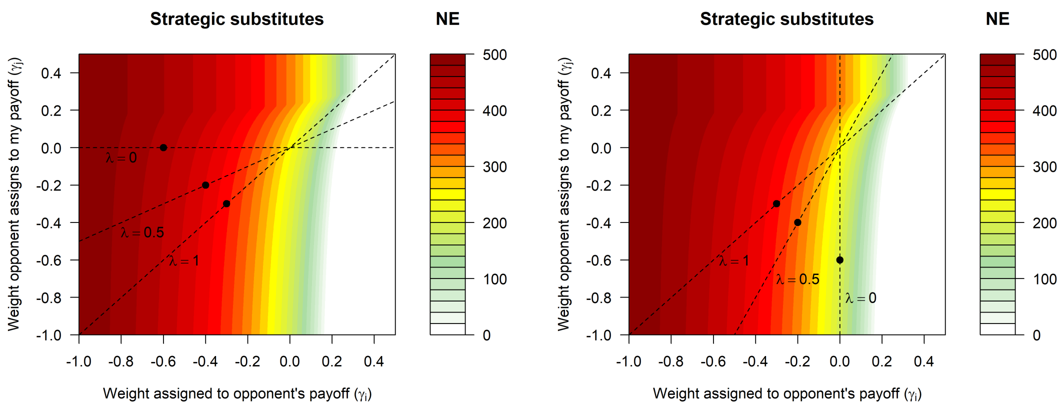


Figure C.2: Nash equilibrium action with interactive context-dependent preferences and beliefs

The connection between the non-interactive and interactive preferences, as well as the intuition behind the changes in the predicted effect of context-dependent beliefs in the game of substitutes is illustrated in figure C.3, which shows the Nash equilibrium action for each combination of weights assigned by players i and j (denoted by γ_i and γ_j, as in equation (3)). A change in the preference parameter a_i is illustrated by a movement along some dashed line in panel (a). When preferences are not interactive ($\lambda = 0$), changes in preferences affect only the weight assigned to opponent's payoff (γ_i), translating into a horizontal movement along the '$\lambda = 0$' line. For example, a person with anti-social preferences ($a_i = 0, a_j = -0.6$) would assign a weight of $\gamma_i = -0.6$ to opponent's payoff. If $\lambda > 0$, a change in preferences also affects the weight the opponent is expected to assign to i's payoff. For example, if $\lambda = 0.5$, anti-social preferences ($a_i = 0, a_j = -0.6$) would translate into a weight $\gamma_i = -0.4$ assigned to opponent's payoff, and an expectation that j will assign a weight of $\gamma_j = -0.2$ to i's payoff. This combination of weights is marked on the '$\lambda = 0.5$' line in figure C.3 (a). Any other change in preference would translate into movements along the diagonal dashed line (marked by $\lambda = 0.5$), instead of a horizontal movement, since spiteful participants expect opponents to be spiteful as well. If $\lambda = 1$, preferences affect both weights in the same way: anti-social preferences ($a_i = 0, a_j = -0.6$) would translate into a weights $\gamma_i = \gamma_j = -0.3$ (marked on the '$\lambda = 1$' line). Other changes in preferences would be represented by movements along this 45-degree line.



(a) Preferences

(b) Beliefs

Figure C.3: Nash equilibrium action in strategic substitutes for interactive context-dependent preferences and beliefs

Panel (b) of figure C.3 illustrates changes in weights and equilibrium action from pro-social or anti-social beliefs. If preferences are not interactive ($\lambda = 0$), beliefs change only the weight γ_j, translating into vertical movement along the '$\lambda = 0$' line. For example, standard preferences but anti-social beliefs ($a_i = 0, a_j = -0.6$) would translate into an expectation that the opponent will assign a weight of $\gamma_j = -0.6$ to the payoff of i. With interactive preferences, participants would also act more spitefully towards opponents who are expected to be spiteful. For example, if $\lambda = 0.5$, anti-social beliefs ($a_i = 0, a_j = -0.6$) would translate into a weight $\gamma_i = -0.2$ assigned to opponent's payoff, and an expectation that j will assign a weight of $\gamma_j = -0.4$ to i's payoff. This point is marked in figure C.3 (b); other values of beliefs would be represented by locations along the '$\lambda = 0.5$' line. If $\lambda = 1$, beliefs have the same effect on each weight, just as was the case with preferences, translating into movements along the 45-degree line.

Overall, figure C.3 shows why the context-dependent preferences hypothesis in the strategic substitutes game would hold even with interactive preferences, but the context-dependent belief hypothesis would not. In figure C.3 (a), more anti-social preferences always induce higher, i.e. more anti-social equilibrium choices, regardless of the value of λ. But the effect of beliefs in figure C.3 (b) depends on the value of λ: once it reaches a certain value, the prediction from the non-interactive model will no longer hold, and anti-social beliefs would induce competitive behavior even in the game of strategic substitutes. The change happens because the effect of pro-social best-responses to opponent's anti-social choices, inherent in the strategic substitutes game, is outweighed by the inclination to behave anti-socially towards opponents who are expected to be more anti-social. Figure C.3 (b) shows that $\lambda = 0.5$ is sufficient to overturn the context-dependent belief hypotheses, since a downwards movement along the '$\lambda = 0.5$' line leads to higher (more competitive) equilibrium actions, in contrast to the movement along the '$\lambda = 0$' line.

C.1 Estimation of a Static Model with Interactive Social Preferences

We replicate the estimation procedure from section 4.4, but allow the social preferences to be interactive. We use the utility function from Levine (1998), and treat λ as an additional parameter to be estimated (see equation (19)). Overall, we jointly estimate a set of five parameters: preferences and beliefs in economic treatments (a_i^e, a_j^e), preferences and beliefs in abstract treatments (a_i^a, a_j^a) and the parameter measuring interactiveness (λ). We restrict $0 \leqslant \lambda \leqslant 1$, and search for the parameter values that minimize the mean squared deviation between experimental data and the Nash equilibrium with interactive preferences (specified in equations (20) and (21)). The best-fitting non-interactive model found in section 4.4 is equivalent to a model with interactive preferences and parameters: $\hat{a}_i^e = -0.08$, $\hat{a}_j^e = -0.74$, $\hat{a}_i^a = 0.08$, $\hat{a}_j^a = 0.17$, $\lambda = 0$. We find that no model with interactive preferences can further improve the fit. Instead, there are multiple combinations of parameters that provide the same fit (root MSD = 140.2) as the best-fitting non-interactive model. This multiplicity is a result of multiple ways in which the same equilibrium prediction can be made in the model of interactive social preferences. In particular, all best-fitting models make the same prediction of choosing (254, 324, 248) under abstract framing and (230, 196, 237) under economic framing, respectively for contest, strategic complements and substitutes.

Figure C.4 illustrates the intuition behind this result by comparing two parameter combinations that have the same fit. Figures in the top row show the non-interactive model, replicating figure 6. The difference between abstract and economic framing is explained by a large change in beliefs (from 0.17 in abstract to -0.74 in economic) and a smaller change in preferences (from 0.08 in abstract to -0.08 in economic). The second model, illustrated in the bottom row, has interactive preferences with $\lambda = 0.16$. In this model, the difference between treatments is best explained by a large change in the a_j parameter (from 0.19

to -0.87) and almost no change in a_i (from 0.06 to 0.05). However, since the preferences are interactive, the a_j parameter affects both the belief and the preference (to a smaller extent). The resulting weights placed on one's own payoff and the payoff of the opponent are exactly the same as in the non-interactive version: $(-0.08, -0.74)$ in economic and $(0.08, 0.17)$ in abstract treatments.

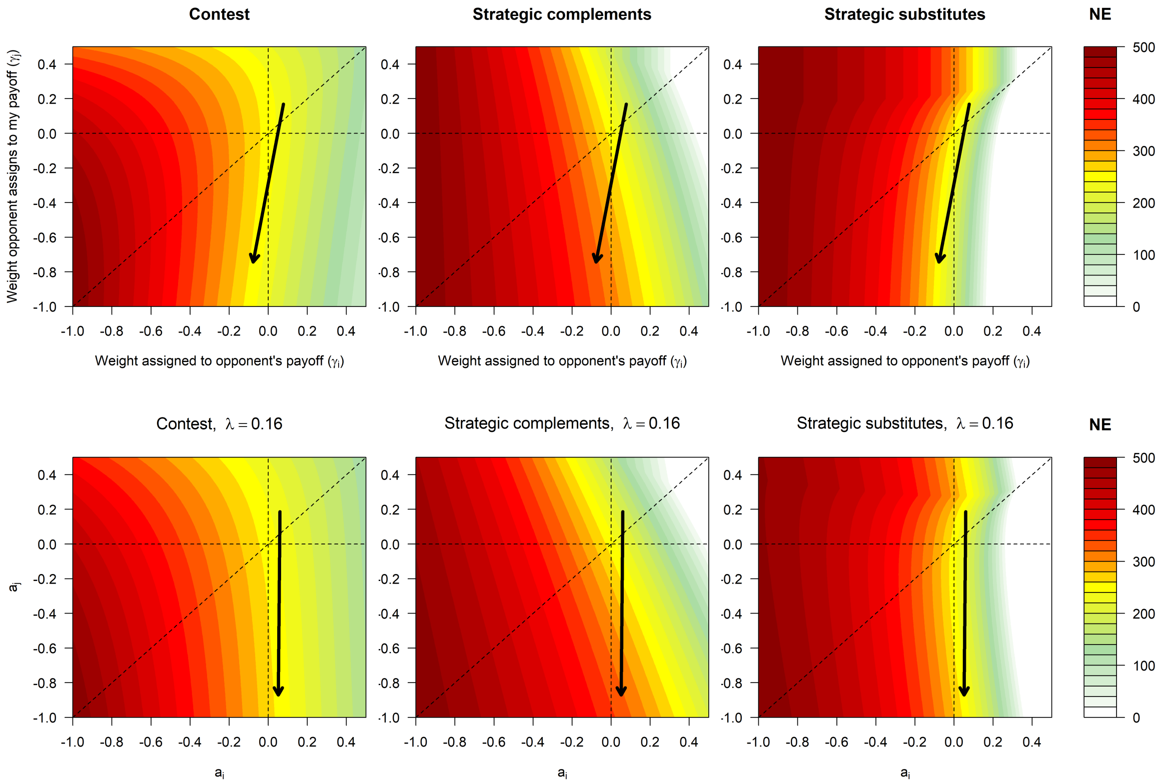


Figure C.4: Best-fitting values of preferences and beliefs with non-interactive preferences and beliefs (top row) and interactive preferences and beliefs (bottom row). The arrows indicate the estimated change in beliefs and preferences caused by economic framing.

Overall, it is not surprising that the addition of interactive preferences cannot further improve the fit, because any utility specification with interactive social preferences can be projected into a non-interactive version by finding an set of (γ_i, γ_j) parameters for any set of (a_i, a_j, λ) parameters from the interactive model. The calculation is straightforward and follows from equations (3) and (19):

$$\gamma_i = a_i + \frac{\lambda * a_j}{1+\lambda}, \qquad \gamma_j = a_j + \frac{\lambda * a_i}{1+\lambda}$$

D Difference between Strategic Complements and Substitutes

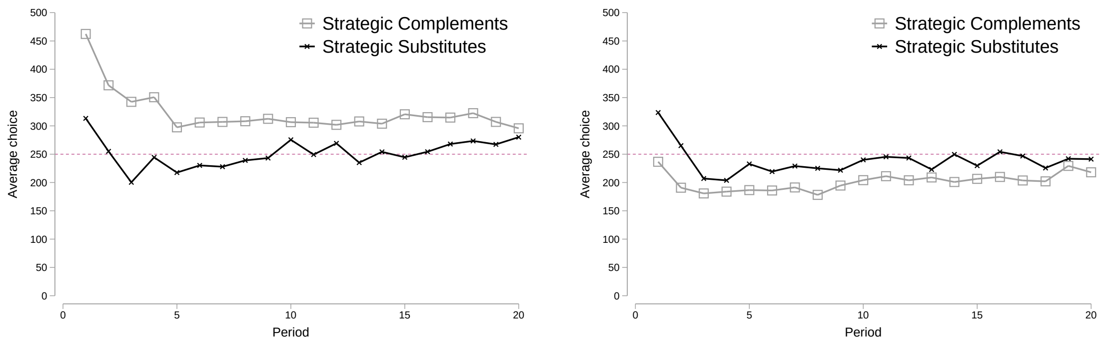
This appendix discusses the difference between the games of strategic complements and strategic substitutes, either under abstract or under economic framing. We follow the analysis from section 4.1, but compare games across the two framing conditions, instead of comparing framing conditions across games. When we compare average choices either in all rounds, or only in the first or last 5 rounds (see table 2), we find a significant difference between complements and substitutes with economic framing, both overall (MWU $p = 0.0153$) and at the start of the game ($p = 0.0018$), but not at the end ($p = 0.2482$). With abstract framing, the differences are not significant (all $p > 0.1$). Very similar results are found if the games are compared in a regression (table D.1), the only difference being the additional marginally significant effect with abstract framing at the start of the game ($p = 0.088$). Figure D.1 shows the evolution of these differences over time. Overall, we conclude that behavior is more cooperative in strategic substitutes than strategic complements when economic framing is used, but there is no significant difference between the two games when abstract language is used. We also find that the effect found in the economic framing conditions decreases over time and becomes insignificant at the end of the experiment.

Table D.1: Random effects GLS regression. Standard errors clustered on the matching group level (24 clusters per framing condition.)

	(1) Economic	(2) Abstract
Complements (round 1)	117.089***	-52.514*
	(3.81)	(-1.71)
Round	1.525	-0.372
	(1.18)	(-0.22)
Round * Complements	-4.867**	1.626
	(-2.30)	(0.74)
Complements (round 20)	24.622	-21.625
	(0.70)	(-0.51)
Complements	70.334***	-36.993
	(2.69)	(-1.20)
Observations	1899	1912

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$



(a) Economic framing (b) Abstract framing

Figure D.1: Average action over time.

E Tables and Figures

Table E.1: Random effects GLS regression. Independent variable is the change in chosen action across rounds. Standard errors are clustered on the matching group level.

	Economic framing			Abstract framing		
	(1)	(2)	(3)	(4)	(5)	(6)
	Complements	Substitutes	Contest	Complements	Substitutes	Contest
β_r	0.308***	0.357***	0.355***	0.363***	0.241***	0.527***
	(5.72)	(5.46)	(7.59)	(3.99)	(4.46)	(6.33)
β_{ib}	0.241***	0.275***	0.202***	0.128*	0.227***	0.112
	(4.50)	(4.05)	(3.33)	(1.66)	(3.46)	(1.17)
Const.	-2.394	-20.90***	-0.821	-20.88***	-23.54***	-12.11**
	(-0.42)	(-3.09)	(-0.23)	(-2.76)	(-2.59)	(-2.22)
N	902	901	912	907	909	889

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

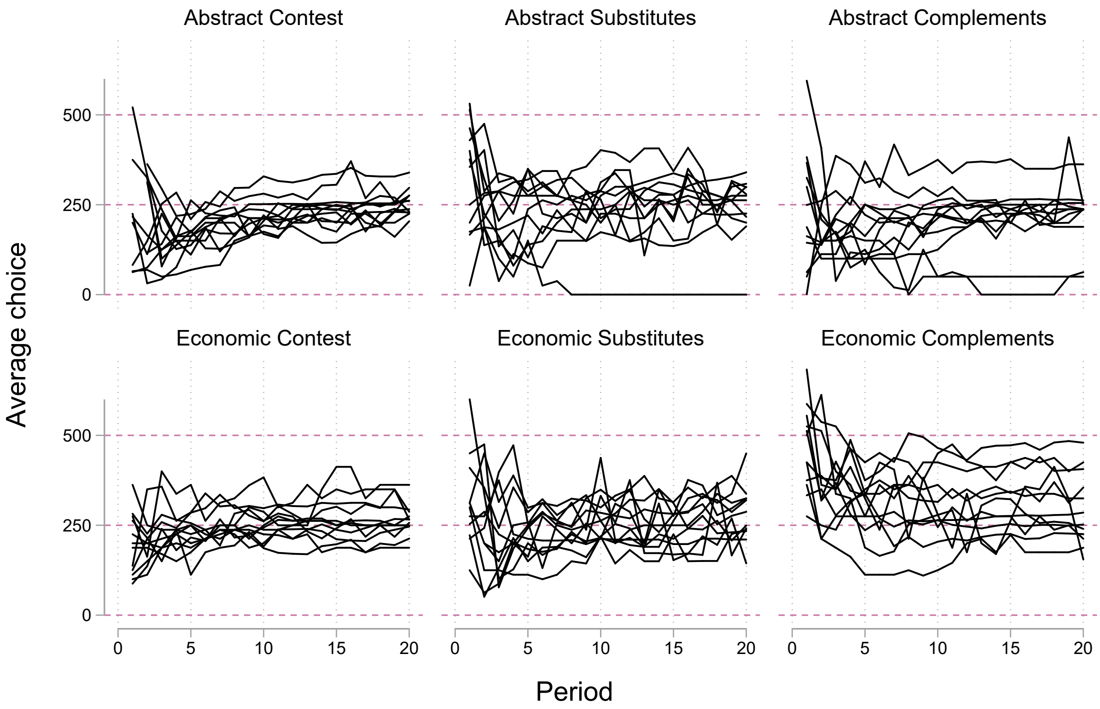


Figure E.1: Average choices in each matching group.

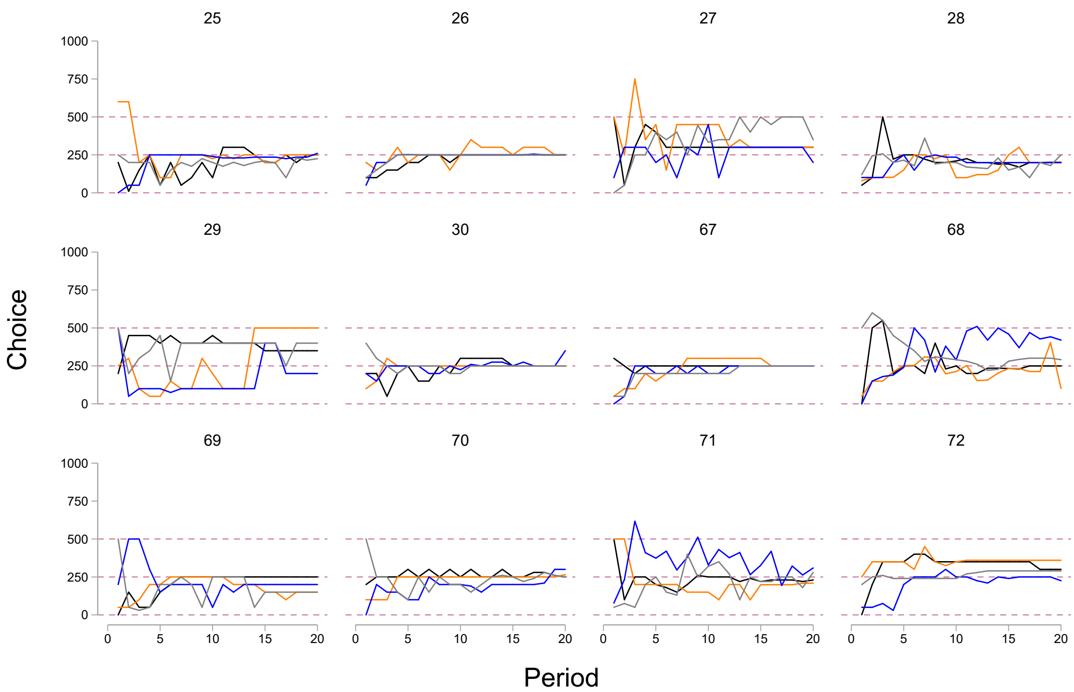


Figure E.2: Choices of each participant in Economic Contest, by matching group

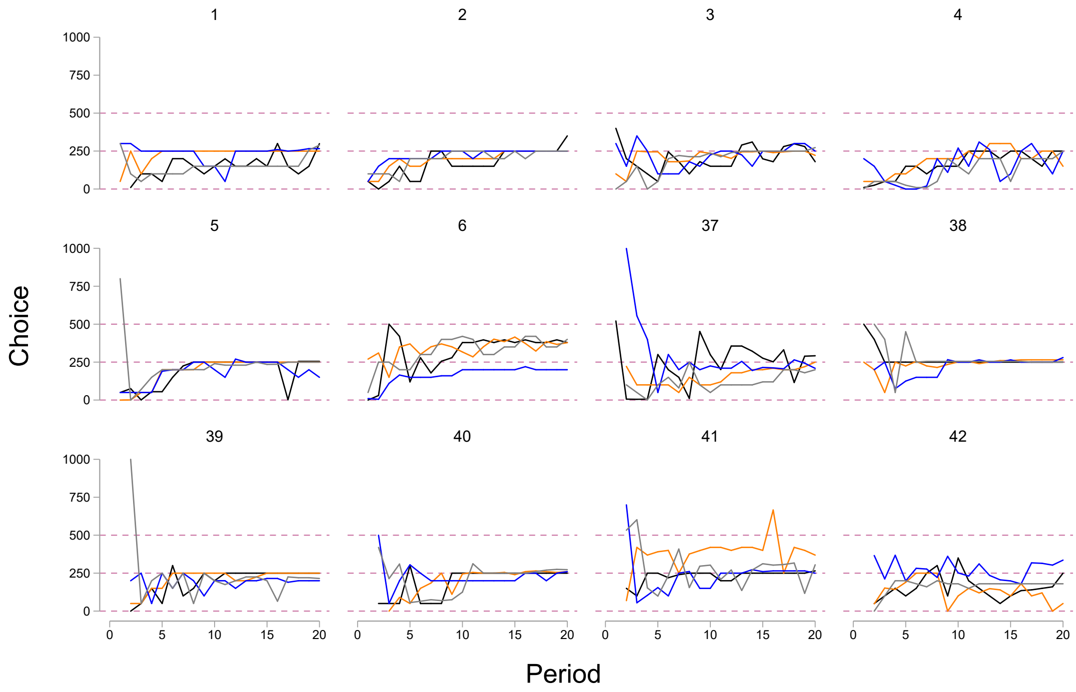


Figure E.3: Choices of each participant in Abstract Contest, by matching group

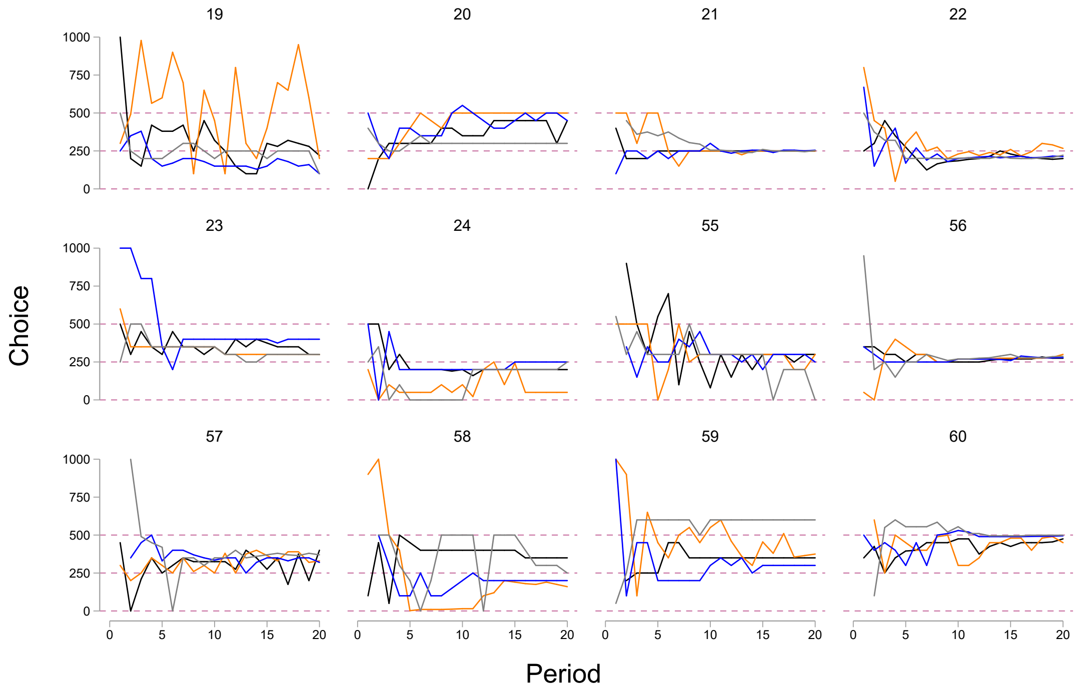


Figure E.4: Choices of each participant in Economic Complements, by matching group

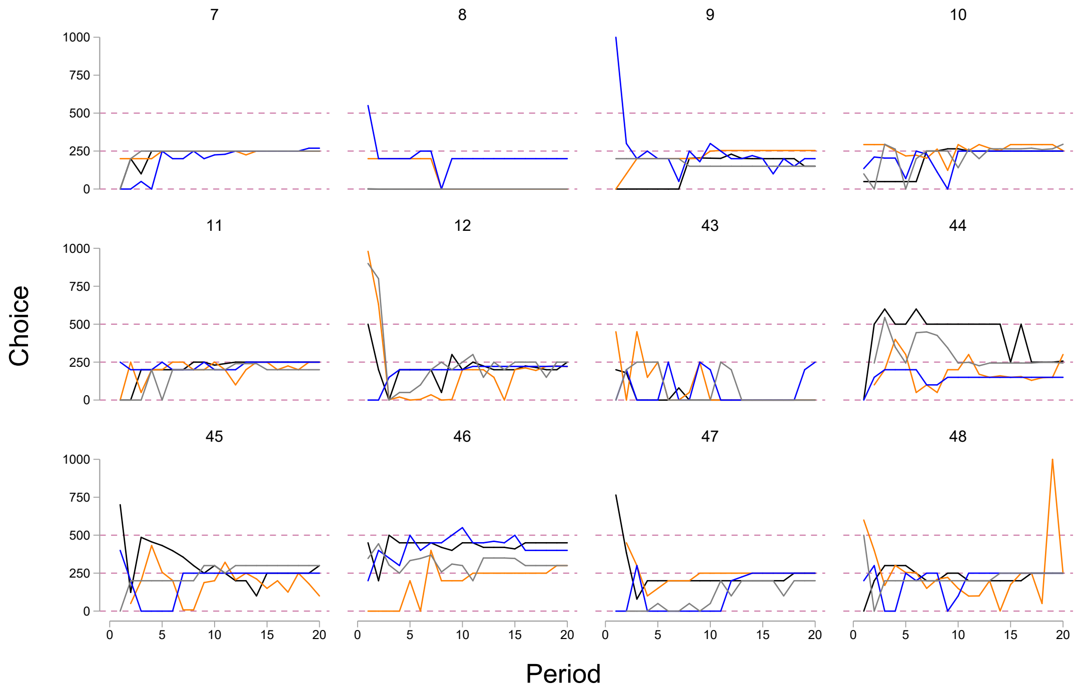


Figure E.5: Choices of each participant in Abstract Complements, by matching group

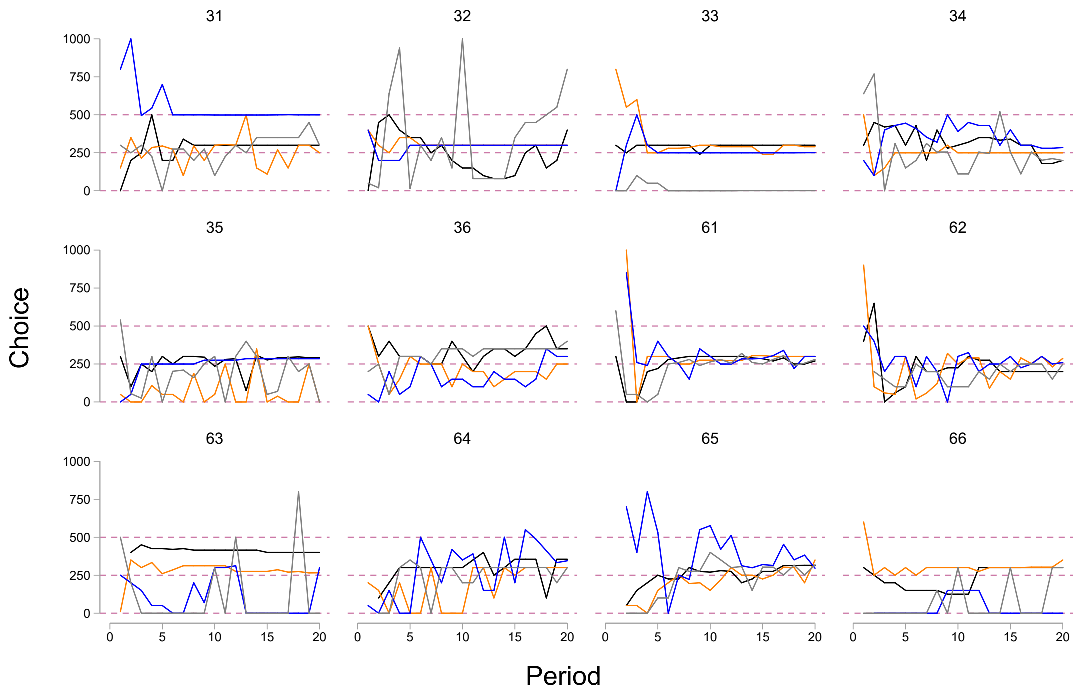


Figure E.6: Choices of each participant in Economic Substitutes, by matching group

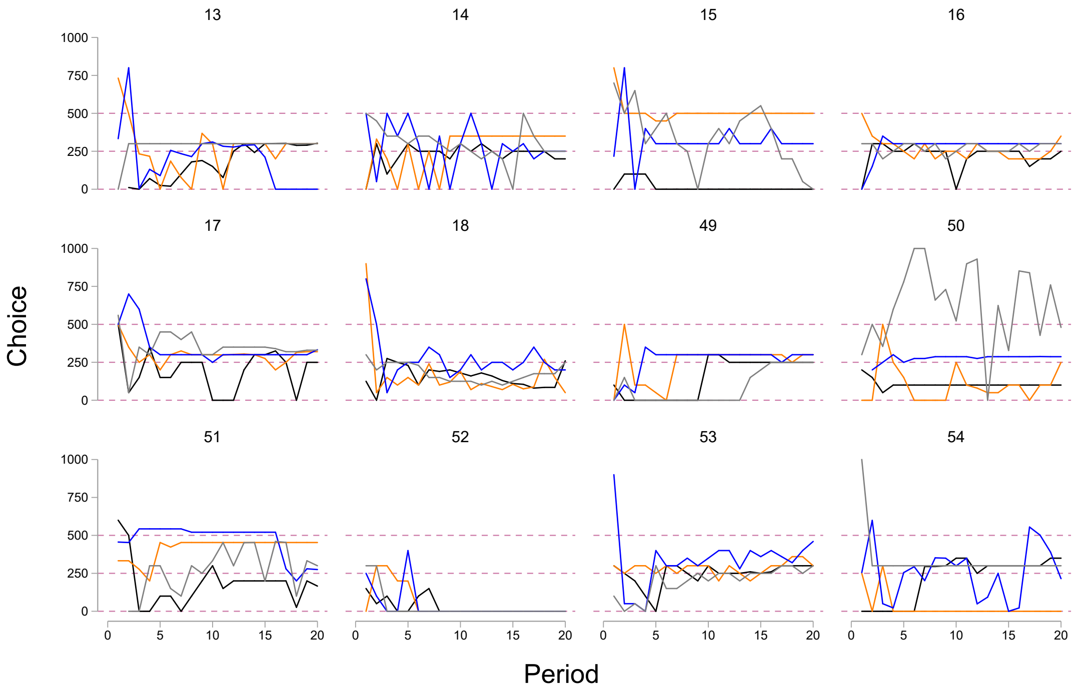


Figure E.7: Choices of each participant in Abstract Substitutes, by matching group

F Instructions

We reproduce the instructions for all treatments. We used the same instructions both for the game of complements and for the game of substitutes. The instructions with abstract framing are identical in all three games. Below we highlight the parts of the instructions that differ between economic and abstract framing, therefore the abstract version is reproduced twice: we highlight differences with respect to oligopoly framing in the first version and with respect to the contest game in the second version.

F.1 Contest Game, Economic framing

INSTRUCTIONS

Welcome to the experiment. Please read these instructions carefully. They are identical for all the participants with whom you will interact during this experiment. If you have any questions, please raise your hand. One of the experimenters will come to you and answer your questions. From now on communication with other participants is not allowed. Please also switch off your mobile phone at this moment.

In this experiment you can earn money. How much you earn depends on your decisions and on the decisions of other participants. During the experiment we will refer to ECU (Experimental Currency Unit) instead of CHF. The total amount of ECU that you will have earned during the experiment will be converted into cash and paid confidentially at the end of the experiment. The conversion rate used to convert your ECU into your cash payment will be **100 ECU = 1 CHF**.

The experiment consists of 20 rounds. Each round comes with a certain time limit that you will see in the top right corner of your screen. Time limit will change over rounds: you will have more time in early rounds and less time in later rounds. To make a choice, you must enter your action into the field at the top and click OK at the bottom right before the time runs out. At the end of the experiment, 2 rounds out of these 20 will be randomly selected for payment. All rounds have an equal chance to be selected. Your earnings from the selected rounds will be added up, converted into cash and paid to you in private. In addition, you will receive a show-up fee of 7 CHF.

In each round you will be paired with another participant. You will not know who the other participant is and this participant will be assigned by the computer at random. Each round the computer will match you to a randomly chosen new participant. The participants with whom you will interact will face the same task as you and will have the same information and payoff function. The task and the payoff function will be the same in all rounds.

In each round you will receive an endowment of 1000 ECU. You will decide how many of these points they want to use to buy ‘contest tokens’. Each contest token costs 1 ECU, so you can purchase up to 1000 of these tokens. You will keep any part of the endowment that you do not spend on contest tokens.

After choosing how many contest tokens to purchase, you and the other participant will share the prize of 1000 ECU. Your share of the prize will be equal to the number of tokens you have purchased divided by the total number of contest tokens purchased by you and by the other participant with whom you were paired:

$$\text{Share of the prize} = \frac{\text{(Number of tokens you bought)}}{\text{(Number of tokens you bought) + (Number of tokens the other participant bought)}} \times 100\%$$

For example, if you buy the same number of tokens as the other participant, your share would be equal to 50%, which means that you would receive 500 ECU. You also retain any part of the endowment that you did not spend on purchasing tokens, therefore your payoff is:

Payoff = 1000 ECU - Number of tokens purchased + (Share of the prize)*1000 ECU

The exact way of how your payoff depends on the tokens purchased by you and by the other participant is also shown by a payoff table or a payoff calculator, which will be available on the computer screen when you will be making your decision. You will have an option to use either a payoff table or a payoff calculator. The payoff table shows your payoffs for some combinations of the number of tokens purchased by you and by the other participant. The payoff calculator allows you to enter any number of tokens for you and for the other participant, and displays resulting payoffs for you and for the other participant.

At the end of each round, you will be informed about your round income, as well as the number of tokens purchased and the payoff of the other participant with whom you were paired.

At the end of the experiment you will be informed about your income in ECU from the rounds that were randomly selected for payment. Income from these rounds will be summed up, converted into CHF and paid in private once you complete a short questionnaire. Please stay seated until we ask you to come to receive the earnings.

If you have any further questions, please raise your hand now. The experiment will start once everyone has finished reading the instructions.

F.2 Contest game, Abstract Framing

INSTRUCTIONS

Welcome to the experiment. Please read these instructions carefully. They are identical for all the participants with whom you will interact during this experiment. If you have any questions, please raise your hand. One of the experimenters will come to you and answer your questions. From now on communication with other participants is not allowed. Please also switch off your mobile phone at this moment.

In this experiment you can earn money. How much you earn depends on your decisions and on the decisions of other participants. During the experiment we will refer to ECU

(Experimental Currency Unit) instead of CHF. The total amount of ECU that you will have earned during the experiment will be converted into cash and paid confidentially at the end of the experiment. The conversion rate used to convert your ECU into your cash payment will be **100 ECU = 1 CHF**.

The experiment consists of 20 rounds. Each round comes with a certain time limit that you will see in the top right corner of your screen. Time limit will change over rounds: you will have more time in early rounds and less time in later rounds. To make a choice, you must enter your action into the field at the top and click OK at the bottom right before the time runs out. At the end of the experiment, 2 rounds out of these 20 will be randomly selected for payment. All rounds have an equal chance to be selected. Your earnings from the selected rounds will be added up, converted into cash and paid to you in private. In addition, you will receive a show-up fee of 7 CHF.

In each round you will be paired with another participant. You will not know who the other participant is and this participant will be assigned by the computer at random. Each round the computer will match you to a randomly chosen new participant.

In each round you will choose an action, which is a number between 0 and 1000. Your payoff will depend on the number you chose and on the number chosen by the other participant. The participants with whom you will interact will face the same task as you and will have the same information and payoff function. The task and the payoff function will be the same in all rounds.

The exact way of how your payoff depends on your action and the action of the other participant is shown by a payoff table or a payoff calculator, which will be available on the computer screen when you will be making your decision. You will have an option to use either a payoff table or a payoff calculator. The payoff table shows your payoffs for some combinations of your action and the action of the other participant. The payoff calculator allows you to enter any action for yourself and for the other participant, and displays resulting payoffs for you and for the other participant.

At the end of each round, you will be informed about your round income, as well as the action and the payoff of the other participant with whom you were paired.

At the end of the experiment you will be informed about your income in ECU from the rounds that were randomly selected for payment. Income from these rounds will be summed up, converted into CHF and paid in private once you complete a short questionnaire. Please stay seated until we ask you to come to receive the earnings.

If you have any further questions, please raise your hand now. The experiment will start once everyone has finished reading the instructions.

F.3 Strategic Complements and Substitutes, Economic framing

INSTRUCTIONS

Welcome to the experiment. Please read these instructions carefully. They are identical for all the participants with whom you will interact during this experiment. If you have any questions, please raise your hand. One of the experimenters will come to you and answer your questions. From now on communication with other participants is not allowed. Please also switch off your mobile phone at this moment.

In this experiment you can earn money. How much you earn depends on your decisions and on the decisions of other participants. During the experiment we will refer to ECU (Experimental Currency Unit) instead of CHF. The total amount of ECU that you will have earned during the experiment will be converted into cash and paid confidentially at the end of the experiment. The conversion rate used to convert your ECU into your cash payment will be 100 ECU = 1 CHF.

The experiment consists of 20 rounds. Each round comes with a certain time limit that you will see in the top right corner of your screen. Time limit will change over rounds: you will have more time in early rounds and less time in later rounds. To make a choice, you must enter your action into the field at the top and click OK at the bottom right before the time runs out. At the end of the experiment, 2 rounds out of these 20 will be randomly selected for payment. All rounds have an equal chance to be selected. Your earnings from the selected rounds will be added up, converted into cash and paid to you in private. In addition, you will receive a show-up fee of 7 CHF.

During this experiment, you will be asked to act as the manager of a firm which produces and sells a given product: your task consists of deciding how many product units to put on the market in every period. Your firm has one competitor that sells on the same market a product which is exactly identical to yours. You will not know who the other competitor is and this competitor will be assigned by the computer at random. Each round the computer will match you to a randomly chosen new competitor.

In each round you will choose how many products to produce, between 0 and 1000. Your payoff will depend on your quantity produced and on the quantity produced by your competitor. Your competitor will face the same task as you and will have the same information and payoff function. The task and the payoff function will be the same in all rounds.

The exact way of how your payoff depends on your quantity produced and on the quantity produced by your competitor is shown by a payoff table or a payoff calculator, which will be available on the computer screen when you will be making your decision. You will have an option to use either a payoff table or a payoff calculator. The payoff table shows your payoffs for some combinations of your production and the production of your competitor. The payoff calculator allows you to enter any production for yourself and for your competitor, and displays resulting payoffs for you and for your competitor.

At the end of each round, you will be informed about your round income, as well as the action and the payoff of your competitor.

At the end of the experiment you will be informed about your income in ECU from the rounds that were randomly selected for payment. Income from these rounds will be summed up, converted into CHF and paid in private once you complete a short questionnaire. Please stay seated until we ask you to come to receive the earnings.

If you have any further questions, please raise your hand now. The experiment will start once everyone has finished reading the instructions.

F.4 Strategic Complements and Substitutes, Abstract Framing

INSTRUCTIONS

Welcome to the experiment. Please read these instructions carefully. They are identical for all the participants with whom you will interact during this experiment. If you have any questions, please raise your hand. One of the experimenters will come to you and answer your questions. From now on communication with other participants is not allowed. Please also switch off your mobile phone at this moment.

In this experiment you can earn money. How much you earn depends on your decisions and on the decisions of other participants. During the experiment we will refer to ECU (Experimental Currency Unit) instead of CHF. The total amount of ECU that you will have earned during the experiment will be converted into cash and paid confidentially at the end of the experiment. The conversion rate used to convert your ECU into your cash payment will be **100 ECU = 1 CHF.**

The experiment consists of 20 rounds. Each round comes with a certain time limit that you will see in the top right corner of your screen. Time limit will change over rounds: you will have more time in early rounds and less time in later rounds. To make a choice, you must enter your action into the field at the top and click OK at the bottom right before the time runs out. At the end of the experiment, 2 rounds out of these 20 will be randomly selected for payment. All rounds have an equal chance to be selected. Your earnings from the selected rounds will be added up, converted into cash and paid to you in private. In addition, you will receive a show-up fee of 7 CHF.

In each round you will be paired with another participant. You will not know who the other participant is and this participant will be assigned by the computer at random. Each round the computer will match you to a randomly chosen new participant.

In each round you will choose an action, which is a number between 0 and 1000. Your payoff will depend on the number you chose and on the number chosen by the other participant. The participants with whom you will interact will face the same task as you and will have the same information and payoff function. The task and the payoff function will be the same in all rounds.

The exact way of how your payoff depends on your action and the action of the other participant is shown by a payoff table or a payoff calculator, which will be available on the computer screen when you will be making your decision. You will have an option to use either a payoff table or a payoff calculator. The payoff table shows your payoffs for some combinations of your action and the action of the other participant. The payoff calculator allows you to enter any action for yourself and for the other participant, and displays resulting payoffs for you and for the other participant.

At the end of each round, you will be informed about your round income, as well as the action and the payoff of the other participant with whom you were paired.

At the end of the experiment you will be informed about your income in ECU from the rounds that were randomly selected for payment. Income from these rounds will be summed up, converted into CHF and paid in private once you complete a short questionnaire. Please stay seated until we ask you to come to receive the earnings.

If you have any further questions, please raise your hand now. The experiment will start once everyone has finished reading the instructions.

G Payoff Tables

Best-responses are marked in grey, joint profit maximization point in green, Nash equilibrium in yellow, relative profit maximization point in red. Tables provided to the participants were not marked. Action labels in treatments with economic framing were adjusted accordingly: 'My action' was labelled as 'My tokens' in economic contest, and as 'My production' in economic complements and substitutes; 'Other's action' was labelled as 'Tokens purchased by the other participant' in economic contest, and as 'Production of my competitor' in economic complements and substitutes.

Table G.1: Payoff table for the contest game

My	Other's action																				
action	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
0	1500	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
50	1950	1450	1283	1200	1150	1117	1093	1075	1061	1050	1041	1033	1027	1021	1017	1013	1009	1006	1003	1000	998
100	1900	1567	1400	1300	1233	1186	1150	1122	1100	1082	1067	1054	1043	1033	1025	1018	1011	1005	1000	995	991
150	1850	1600	1450	1350	1279	1225	1183	1150	1123	1100	1081	1064	1050	1038	1026	1017	1008	1000	993	986	980
200	1800	1600	1467	1371	1300	1244	1200	1164	1133	1108	1086	1067	1050	1035	1022	1011	1000	990	982	974	967
250	1750	1583	1464	1375	1306	1250	1205	1167	1135	1107	1083	1063	1044	1028	1013	1000	988	977	967	958	950
300	1700	1557	1450	1367	1300	1245	1200	1162	1129	1100	1075	1053	1033	1016	1000	986	973	961	950	940	931
350	1650	1525	1428	1350	1286	1233	1188	1150	1117	1088	1062	1039	1018	1000	983	968	954	942	930	919	909
400	1600	1489	1400	1327	1267	1215	1171	1133	1100	1071	1044	1021	1000	981	964	948	933	920	908	896	886
450	1550	1450	1368	1300	1242	1193	1150	1113	1079	1050	1024	1000	979	959	941	925	910	896	883	871	860
500	1500	1409	1333	1269	1214	1167	1125	1088	1056	1026	1000	976	955	935	917	900	885	870	857	845	833
550	1450	1367	1296	1236	1183	1138	1097	1061	1029	1000	974	950	928	908	890	873	857	843	829	817	805
600	1400	1323	1257	1200	1150	1106	1067	1032	1000	971	945	922	900	880	862	844	829	814	800	787	775
650	1350	1279	1217	1163	1115	1072	1034	1000	969	941	915	892	870	850	831	814	798	783	769	756	744
700	1300	1233	1175	1124	1078	1037	1000	967	936	909	883	860	838	819	800	783	767	752	738	724	712
750	1250	1188	1132	1083	1039	1000	964	932	902	875	850	827	806	786	767	750	734	719	705	691	679
800	1200	1141	1089	1042	1000	962	927	896	867	840	815	793	771	752	733	716	700	685	671	657	644
850	1150	1094	1045	1000	960	923	889	858	830	804	780	757	736	717	698	681	665	650	636	622	609
900	1100	1047	1000	957	918	883	850	820	792	767	743	721	700	681	663	645	629	614	600	586	574
950	1050	1000	955	914	876	842	810	781	754	729	705	683	663	644	626	609	593	578	564	550	537
1000	1000	952	909	870	833	800	769	741	714	690	667	645	625	606	588	571	556	541	526	513	500

Table G.2: Payoff table for the game of strategic complements

My action	Other's action																				
	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
0	1500	1427	1357	1290	1227	1167	1110	1057	1007	960	917	877	840	807	777	750	727	707	690	677	667
50	1522	1450	1382	1317	1255	1197	1142	1090	1042	997	955	917	882	850	822	797	775	757	742	730	722
100	1537	1467	1400	1337	1277	1220	1167	1117	1070	1027	987	950	917	887	860	837	817	800	787	777	770
150	1545	1477	1412	1350	1292	1237	1185	1137	1092	1050	1012	977	945	917	892	870	852	837	825	817	812
200	1547	1480	1417	1357	1300	1247	1197	1150	1107	1067	1030	997	967	940	917	897	880	867	857	850	847
250	1542	1477	1415	1357	1302	1250	1202	1157	1115	1077	1042	1010	982	957	935	917	902	890	882	877	875
300	1530	1467	1407	1350	1297	1247	1200	1157	1117	1080	1047	1017	990	967	947	930	917	907	900	897	897
350	1512	1450	1392	1337	1285	1237	1192	1150	1112	1077	1045	1017	992	970	952	937	925	917	912	910	912
400	1487	1427	1370	1317	1267	1220	1177	1137	1100	1067	1037	1010	987	967	950	937	927	920	917	917	920
450	1455	1397	1342	1290	1242	1197	1155	1117	1082	1050	1022	997	975	957	942	930	922	917	915	917	922
500	1417	1360	1307	1257	1210	1167	1127	1090	1057	1027	1000	977	957	940	927	917	910	907	907	910	917
550	1372	1317	1265	1217	1172	1130	1092	1057	1025	997	972	950	932	917	905	897	892	890	892	897	905
600	1320	1267	1217	1170	1127	1087	1050	1017	987	960	937	917	900	887	877	870	867	867	870	877	887
650	1262	1210	1162	1117	1075	1037	1002	970	942	917	895	877	862	850	842	837	835	837	842	850	862
700	1197	1147	1100	1057	1017	980	947	917	890	867	847	830	817	807	800	797	797	800	807	817	830
750	1125	1077	1032	990	952	917	885	857	832	810	792	777	765	757	752	750	752	757	765	777	792
800	1047	1000	957	917	880	847	817	790	767	747	730	717	707	700	697	697	700	707	717	730	747
850	962	917	875	837	802	770	742	717	695	677	662	650	642	637	635	637	642	650	662	677	695
900	870	827	787	750	717	687	660	637	617	600	587	577	570	567	567	570	577	587	600	617	637
950	772	730	692	657	625	597	572	550	532	517	505	497	492	490	492	497	505	517	532	550	572
1000	667	627	590	557	527	500	477	457	440	427	417	410	407	407	410	417	427	440	457	477	500

Table G.3: Payoff table for the game of strategic substitutes

My action	Other's action																				
	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
0	1500	1428	1362	1302	1248	1200	1158	1122	1092	1068	1050	1038	1032	1032	1038	1050	1068	1092	1122	1158	1200
50	1523	1450	1383	1322	1267	1218	1175	1138	1107	1082	1063	1050	1043	1042	1047	1058	1075	1098	1127	1162	1203
100	1542	1468	1400	1338	1282	1232	1188	1150	1118	1092	1072	1058	1050	1048	1052	1062	1078	1100	1128	1162	1202
150	1557	1482	1413	1350	1293	1242	1197	1158	1125	1098	1077	1062	1053	1050	1053	1062	1077	1098	1125	1158	1197
200	1568	1492	1422	1358	1300	1248	1202	1162	1128	1100	1078	1062	1052	1048	1050	1058	1072	1092	1118	1150	1188
250	1575	1498	1427	1362	1303	1250	1203	1162	1127	1098	1075	1058	1047	1042	1043	1050	1063	1082	1107	1138	1175
300	1578	1500	1428	1362	1302	1248	1200	1158	1122	1092	1068	1050	1038	1032	1032	1038	1050	1068	1092	1122	1158
350	1577	1498	1425	1358	1297	1242	1193	1150	1113	1082	1057	1038	1025	1018	1017	1022	1033	1050	1073	1102	1137
400	1572	1492	1418	1350	1288	1232	1182	1138	1100	1068	1042	1022	1008	1000	998	1002	1012	1028	1050	1078	1112
450	1563	1482	1407	1338	1275	1218	1167	1122	1083	1050	1023	1002	987	978	975	978	987	1002	1023	1050	1083
500	1550	1468	1392	1322	1258	1200	1148	1102	1062	1028	1000	978	962	952	948	950	958	972	992	1018	1050
550	1533	1450	1373	1302	1237	1178	1125	1078	1037	1002	973	950	933	922	917	918	925	938	957	982	1013
600	1512	1428	1350	1278	1212	1152	1098	1050	1008	972	942	918	900	888	882	882	888	900	918	942	972
650	1487	1402	1323	1250	1183	1122	1067	1018	975	938	907	882	863	850	843	842	847	858	875	898	927
700	1458	1372	1292	1218	1150	1088	1032	982	938	900	868	842	822	808	800	798	802	812	828	850	878
750	1425	1338	1257	1182	1113	1050	993	942	897	858	825	798	777	762	753	750	753	762	777	798	825
800	1388	1300	1218	1142	1072	1008	950	898	852	812	778	750	728	712	702	698	700	708	722	742	768
850	1347	1258	1175	1098	1027	962	903	850	803	762	727	698	675	658	647	642	643	650	663	682	707
900	1302	1212	1128	1050	978	912	852	798	750	708	672	642	618	600	588	582	582	588	600	618	642
950	1253	1162	1077	998	925	858	797	742	693	650	613	582	557	538	525	518	517	522	533	550	573
1000	1200	1108	1022	942	868	800	738	682	632	588	550	518	492	472	458	450	448	452	462	478	500