Do upfront investments increase cooperation? An experimental approach

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Abstract

A vast literature in economics and the social sciences has investigated institutions that foster cooperation, and has shown that a policy is more successful at increasing cooperation when it is endogenously chosen than when it is exogenously imposed. In this literature, it has always been implicitly assumed the presence of an enforcement mechanism. We investigate whether voluntary, decentralized upfront investments increase cooperation in settings where there is no enforcement mechanism and cooperation is not easily sustained voluntarily. We study whether this effect depends on the investments being endogenous or exogenous. Such investments are a cost that individuals have to incur before deciding whether to cooperate or not, and increase the payoff resulting from the choice to cooperate. We find that cooperation rarely emerges in treatments where investments are not possible. Introducing endogenous investment opportunities boosts overall cooperation levels. If low investments are implemented endogenously, cooperation is lower than when the same investments are exogenous. When investments are high, cooperation is not significantly different between the endogenous and the exogenous conditions. This is consistent with low investments being interpreted as a signal for unwillingness to cooperate, triggering non-cooperative choices.

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1 Introduction

The tension between opportunistic and cooperative behavior, resulting from a misalignment of individual and group interests, is pervasive in human interactions. A vast literature in economics and the social sciences has therefore investigated institutions that foster cooperation.[1] Part of this literature has experimentally analyzed the effects on cooperative behavior of exogenous and endogenous institutions, and has shown that a given policy is more successful at increasing cooperation when it is endogenously chosen than when it is exogenously imposed (Tyran and Feld [2006], Dal Bó et al. [2010], Sutter et al. [2010], Markussen et al. [2014a], Kamei [2016]).

In these prior experiments, subjects are presented with different institutions and decide, through voting, on the rules governing their interactions. Putting an institution to the vote, however, does not imply it will be adopted.[2] Moreover, the focus has been mostly on formal and informal sanctions (so that subjects choose whether and how much to punish free-riders), and it has been implicitly assumed the presence of an enforcement mechanism. However, in many circumstances agents cannot choose or vote for an enforcement institution. Even if institutional arrangements exist, cooperation is not always easily enforced. This is the case, for instance, for groups where agents, even though willing to cooperate, are not willing to punish,[3] or when there is no institution with coercive power. A prominent example is given by international environmental agreements. Environmental treaties lack behind in their effectiveness in reducing global greenhouse gas emissions, and this is thought to be associated with the lack of a functioning enforcement mechanism capable of mitigating the inherent free-rider problem. This is the kind of situations that we address in this paper.

We investigate whether voluntary decentralized upfront investments help promoting cooperation in a social dilemma, and whether this effect depends on the investments being endogenous (chosen by the participants) or exogenous (imposed by the experimenter). Such investments are a cost agents have to incur before deciding whether to cooperate or not, and increase the payoff resulting from the choice to cooperate. Differently from previous studies, we do not ask whether agents would vote for an institution with coercive power that fosters cooperation, and whether this eventually increases cooperation. We ask whether agents themselves are able to create situations that are conducive to cooperation in settings where there is no

[1] Examples of such institutions include peer punishment (Fehr and Gächter [2000], Noussair and Tucker [2005]), competition (Markussen et al. [2014b]), communication (Isaac and Walker [1988]), re-distribution (Sausgruber and Tyran [2007]), group member selection (Gunnthorsdottir et al. [2010]) and advice (Chaudhuri et al. [2006a]), among others.

[2] In Botelho et al. [2005], for instance, most of the experimental subjects voted against the punishment institution, and in Dal Bó et al. [2010], nearly half of the subjects voted against a policy that could foster cooperation.

[3] See for instance Sutter et al. [2010].

enforcement mechanism and cooperation is not easily sustained voluntarily.

The social dilemma situation we consider is an infinitely repeated prisoners' dilemma (PD), which captures the tension at the heart of social dilemmas in a simple form. To test whether the possibility of voluntary upfront investments increases cooperation levels, we compare a condition without investments (NoInv) with a condition where participants can choose how much to invest (Endo). In the treatments with no investment opportunities, subjects just play a two-player repeated PD game for 12 matches, where each match lasts for a randomly determined number of periods. In the investment treatments, subjects decide, at the beginning of each match, how much of a given endowment they want to invest. Then, they learn each others' investment choices and choose between cooperation and defection. To determine whether it matters if investments are chosen or exogenously imposed, we compare the Endo condition with a condition where participants are presented with pre-determined investments (Exo). This also allows us to explore whether participants use investments to signal the intention to cooperate.

Theory and previous empirical work suggest that the discount factor plays an important role in the decision to cooperate. We therefore study whether changes in the discount factor, translated into the probability of continuation of a game, affect cooperation rates in the investigated context. In particular, each of the explored treatments (NoInv, Endo and Exo) is implemented using a low probability of continuation of 0.35 (labeled Short) and a high probability of continuation of 0.75 (labeled Long), which are exogenously imposed. When δ=0.35, cooperation can never be supported as a subgame perfect Nash equilibrium in the NoInv treatment. In Endo and Exo, investments have the potential to transform a game where mutual defection is the only subgame perfect equilibrium into a game in which both mutual defection and mutual cooperation are equilibria, but only when investments are high enough. When δ=0.75, both defection and cooperation are always sustainable in equilibrium.

Recent experiments on infinitely repeated prisoner's dilemma games have shown that individuals cooperate more when the probability of future interactions (i.e., the probability of continuation of the game) is high (Dal Bó [2005], Dal Bó and Fréchette [2011]), when cooperation is risk dominant (Blonski et al. [2011]), and when both continuation probabilities and cooperation payoff are sufficiently high (Dal Bó and Fréchette [2011]). Our experiment is inspired by Dal Bó and Fréchette [2011]. They exogenously vary the payoff from mutual cooperation and the probability of continuation δ of an indefinitely repeated PD to study how cooperation depends on whether mutual cooperation can be supported in a subgame perfect equilibrium, and in a risk dominant equilibrium. Differently from Dal Bó and Fréchette [2011], the (cooperation) payoffs in our repeated PD game are not exogenously given, but endogenously determined by participants' choice of an investment.

Our results can be summarized as follows. Cooperation rarely emerges in treatments where investments are not possible, for both low and high probabilities of continuation. Moreover, we find that when investments are possible but low, cooperation levels are not different from those observed in the no investment condition, but significantly *lower* than when the same investments are exogenous. This result holds both in the Short and in the Long treatments. When high investments are endogenous, cooperation is significantly higher than when investments are not possible, but not significantly different from cooperation in the exogenous conditions. This suggests that low investments signal unwillingness to cooperate, which triggers non-cooperative choices. On the other hand, high investments seem not to serve as signal for willingness to cooperate, as they increase cooperation independent of the mode of implementation.

Even though investments have the potential to foster cooperation, participants in our experiment frequently choose not to invest (in about 40 percent of the cases), or low investments (slightly more than 20 percent of the cases). The investment decision entails a coordination problem, in that individuals would like to invest if others invest as well. One explanation for the observed investment behavior is that our subjects are not able to solve such coordination problem. In most cases, indeed, and especially in the beginning of the experiment, subjects who choose high investments have opponents who choose low investments. This results in the former switching to low investments (especially 0) throughout the experiment, which always guarantees the mutual defection payoff in every period. In our game, not investing and defecting is, in fact, the risk dominant equilibrium. This finding is in line with empirical results on coordination problems, which show a tendency to select the risk-dominant equilibrium (Camerer [2003], Brandts and Cooper [2006a,b], Blume and Ortmann [2007], Chaudhuri et al. [2006b]).

In line with the experimental literature on infinitely repeated PD, we find that higher cooperation payoffs together with a high probability of continuation increase cooperation. In contrast to previous results, we find relatively high levels of cooperation also when δ is rather low, and no significant differences in cooperation rates between Short and Long treatments.

2 Experimental design

The experiment is structured as a 2×3 design and thus consists of six treatments. Two treatments are without investment opportunities (NoInvShort and NoInvLong), in two treatments players could invest before playing an indefinitely repeated PD game (EndoShort and EndoLong) and in two treatments investments were exogenously imposed (ExoShort and ExoLong). The suffixes "Short" and "Long" refer to the probability of continuation used in the corresponding treatment: matches continued from period to period with probability $\delta = 0.35$ in the Short treatments, and with probability $\delta = 0.75$ in the Long treatments.

In all treatments, subjects were randomly paired within matching groups of 8 participants and played a sequence of 12 *matches*. In each match, subjects were initially endowed with $w_i = 8$ Experimental Currency Units (ECU) and played a repeated PD for a randomly determined number of *periods*. In each period, players chose between two actions, either cooperate or defect.[4] The stage PD game is displayed in Table 1.

Table 1: Prisoner's dilemma game payoff matrix

	Cooperate	Defect
Cooperate	$32 + 2r_i, 32 + 2r_j$	$4 + 2r_i, 50$
Defect	$50, 4 + 2r_j$	25, 25

The parameters are calibrated following Dal Bó and Fréchette [2011], who exogenously vary the payoff from mutual cooperation and the probability of continuation δ of an indefinitely repeated PD to study how cooperation depends on whether mutual cooperation can be supported in a subgame perfect equilibrium (SPE).[5] In our PD game, both the payoff from mutual cooperation and the sucker payoff increase with investment levels r_i, r_j, which are integers in $\{0, 1, ..., 8\}$. When $r_i = 0$, the cooperation payoff is 32 and the sucker payoff is 4. When $r_i = 8$, the cooperation payoff is 48, and the sucker payoff is 20. This guarantees the conditions for cooperation to switch from not being sustainable in equilibrium to being supported as SPE as the investments increase. Under $\delta = 0.35$, cooperation is not supported as SPE for $r_i, r_j \leq 4$, while it is for $r_i, r_j > 4$. The equilibrium conditions will be derived and explained in detail in Section 3.

In the treatments with endogenous investments (EndoShort and EndoLong), participants could decide in the beginning of each match how much of their endowment they wish to invest, by choosing a number in $\{0, 1, ..., 8\}$. Players within a pair were informed of the investment decision made by their partner before the PD started. Any non-invested unit produced one unit of direct private benefit, while the invested units were doubled and added to the payoff from cooperation in the subsequent PD

[4]We used a neutral language throughout the experiment, with players choosing between option "A" (cooperate) and option "B" (defect).

[5]Dal Bó and Fréchette [2011] also study whether risk dominance determines cooperation choices. In their experiment, the payoff from mutual cooperation (R) takes one of three possible values: 32, 40, and 48, while the sucker payoff is constant and equal to 12; δ is equal to either 0.5 or 0.75. Different combinations of R and δ determine whether cooperation can be sustained as an SPE. In particular, for $R = 32$ and $\delta = 0.5$ cooperation is never sustainable in equilibrium, while for any other combination of R and δ, cooperation can always be supported in an SPE. Cooperation is risk dominant under $R = 48$ and $\delta = 0.5$, and under $R = 40, 48$ and $\delta = 0.75$.

game. Once a match ended, the new match began with a new investment decision. Hence, the investment decision was made once at the beginning of each match, and subjects were bound by that decision for the duration of that match.[6]

The only difference between the endogenous and the exogenous treatments (ExoShort and ExoLong) is that in the latter investments were not chosen by the participants. For each pair in the endogenous treatments, instead, we created a twin pair in the exogenous treatments, so that the participants in the exogenous condition were presented with the same sequence of investments as chosen by the participants in the endogenous condition. The purpose of the exogenous treatments is to disentangle the effect of the changes in the cooperation payoffs (induced by the investments) and the signaling effect implicit in the active choice of an investment level.

In the treatments without investment opportunity, the endowment of $w_i = 8$ was added to the PD game payoff in every period. The resulting subgame is then the same as the one induced by $r_i, r_j = 0$ in the investment treatments.

In all treatments, pairs remained fixed throughout a match, and subjects were randomly paired with a new partner within their matching group at the end of a match.[7] Since the matching groups consisted of 8 participants playing in 12 matches, subjects met the same partner 1.71 times on average. However, pairs were formed so that each participant would never play with the same partner two matches in a row. At the end of each PD stage game, subjects within a pair received information on their own and their partner's actions and payoffs. In the investment treatments, players were reminded of the investment levels as well. Earnings at the end of a match were the sum of the payoffs realized in each period. At the end of the experimental session, for each matching group one out of the 12 matches was randomly picked. Subjects in a matching group were paid in cash according to the earnings of that match.

2.1 Procedures

The instructions for the experiment were provided on paper, and participants had the opportunity to ask questions at any time during a session. All questions were asked and answered in private. Participants were asked to answer a series of com-

[6]As we are mainly interested in the role of investments in affecting cooperation levels, our primary concern is whether choices in the PD are responsive to investment decisions and, therefore, whether investments are used as a device to trigger future cooperation. If investment choices were to be revised in every period of a match, we could not rule out the possibility of them being used as a punishment device instead. Keeping investment decisions constant within matches, besides making the data more easily tractable, helps their interpretation to be less exposed to this confounding effect.

[7]Rematching within the same group ensures that observations are independent at the matching group level.

prehension questions to verify their full understanding of the game. The experiment started only after all participants had answered correctly all questions. The experiment ended with a questionnaire.

The experiment was conducted at the BEElab of Maastricht University using z-Tree (Fischbacher [2007]). Participants were recruited through ORSEE (Greiner [2015]), and each of them took part in only one session. In total 432 students participated in the experiment. We ran 18 sessions overall, 3 per treatment, with 3 matching groups per session. Each session took approximately 50 minutes for the Short treatments, and 80 minutes for the Long treatments.

Within a treatment, the length of a match differed across matches and matching groups. However, to ease the comparison between treatments with the same probability of continuation, the same random sequence of match lengths was used in treatments with equal δ. That is, match lengths across matching groups in NoInvShort were the same as in EndoShort and ExoShort, and match lengths across matching groups in NoInvLong were the same as in EndoLong and ExoLong.[8]

3 Theoretical background

Table 2 shows a prisoner's dilemma payoff matrix, where: c is the reward from mutual cooperation; d is the payoff from mutual defection; t is the temptation payoff, obtained from defecting when the other cooperates; and s is the sucker payoff, obtained from cooperating when the other defects. The presentation in Table 2 allows for potentially asymmetric payoffs by using indexes i and j. For a game to have the structure of a PD, two conditions have to hold. First, $t_k > c_k > d_k > s_k$ for $k = i, j$. Second, it is also required that $c_i + c_j > \max[t_i + s_j, s_i + t_j]$. This condition guarantees that cooperation is more profitable than alternating between cooperation and defection.

Table 2: Prisoner's dilemma payoff matrix

	C	D
C	c_i, c_j	s_i, t_j
D	t_i, s_j	d_i, d_j

In a PD with asymmetric payoff parameters and common discount factor δ, the critical value δ^{SPE} for which mutual cooperation is sustainable in a SPE is given by (see Blonski and Spagnolo [2015]):

[8]Table 6 in Appendix A presents the sequences of match lengths for the different matching groups that were implemented in the three sets of treatments.

$$\delta^{SPE} = \max\left\{\delta_i^{SPE}, \delta_j^{SPE}\right\} = \max\left\{\frac{t_i - c_i}{t_i - d_i}, \frac{t_j - c_j}{t_j - d_j}\right\}. \tag{1}$$

For our parameters, the critical value δ^{SPE} for which cooperation can be sustained in equilibrium is 0.72 when $r_i, r_j = 0$ (or when investments are not allowed), and it is 0.08 when $r_i, r_j = 8$. For other combinations of r_i and r_j, δ^{SPE} lies within these two extremes, i.e. $0.08 \leq \delta^{SPE} \leq 0.72$, depending on the investment level chosen.

Predictions

In a setting where both mutual cooperation and mutual defection are sustainable as equilibrium outcomes,[9] investments could be 0 or 8 depending on the action expected to be chosen by the other player. Subjects that expect to coordinate on the cooperative equilibrium should invest 8, in order to maximize payoffs. Conversely, subjects that expect defection to be selected as equilibrium outcome should not invest at all. Investing 8 and cooperating in the PD is the payoff dominant equilibrium, while not investing and defecting is the risk dominant one. We formulate the following hypothesis.

H1: *Investment levels r_i, r_j are such that $r_i, r_j \in \{0, 8\}$.*

When $\delta = 0.35$ and investments are not allowed (NoInvShort), defection is the only possible equilibrium outcome. When investment opportunities are introduced while keeping $\delta = 0.35$ (EndoShort), three different cases need to be distinguished. If *a)* both players choose investment levels of 4 or less, or *b)* one player chooses an investment level in the interval $[5, 8]$, while the other chooses to invest less, then cooperation cannot be supported as an equilibrium outcome. If, instead, *c)* both players choose investment levels in the interval $[5, 8]$, trigger strategies can sustain mutual cooperation as part of an SPE, while defection still constitutes an equilibrium outcome. Given these theoretical predictions, we expect no cooperation in NoInvShort. Moreover, we expect behavior in the first two cases of EndoShort (*a)* and *b)*) to be similar to NoInvShort, and cooperation rates to stabilize at a higher level in the last case of EndoShort (*c)*).

The comparison between NoInvShort and EndoShort allows us to study the effect of investments on cooperation, and whether cooperation levels depend on cooperation being sustainable in equilibrium. On the other hand, we do not expect any difference between NoInvLong and EndoLong ($\delta = 0.75$) as in both of these conditions cooperation is supported as equilibrium outcome, regardless of the possibility to invest and the specific investment choices. We hence formulate the following hypothesis.

[9] In the following, "cooperation (not) being sustainable in equilibrium" and "cooperation (not) being sustainable as equilibrium outcome" indicate that there are (no) strategies that support mutual cooperation as equilibrium outcome.

H2: *When $\delta = 0.35$, then*

(i) For $r_i \leq 4, r_j \in [0, 8]$, there is no difference in cooperation rates between NoInvShort and EndoShort.

(ii) For $r_i, r_j > 4$, cooperation rates in EndoShort are larger than in NoInvShort.

When $\delta = 0.75$, then

(i) There is no difference in cooperation rates between NoInvLong and EndoLong, independent of r_i and r_j.

Since the exogenous treatments are an exact replica of the endogenous treatments, SPE predictions do not differ between the Short investment treatments (EndoShort and ExoShort), and between the Long investment treatments (EndoLong and ExoLong).

H3: *For any r_i, r_j, there is no difference in cooperation rates between EndoShort and ExoShort, and between EndoLong and ExoLong.*

However, investments might convey a signal regarding the action that will be chosen in the PD, in which case cooperation levels might vary depending on whether investments have been endogenously chosen or exogenously imposed.[10] Such signal might affect beliefs in two ways. First, investments might signal a player's (un)willingness to cooperate in the subsequent PD. Second, they might signal a player's beliefs on the opponent's (un)willingness to cooperate in the subsequent PD.[11] Therefore, if low investment levels (i.e. below or at the threshold of 4) serve as signal of unwillingness to cooperate, we would expect cooperation in the Endo conditions to be lower than in Exo conditions. Similarly, if high investments (i.e. above the threshold) signal willingness to cooperate, we would expect higher cooperation rates in Endo than in Exo. For the case where investments diverge, signals are contrasting and it is not easy to predict which one will prevail, if any. On the one hand, if a high investment signal willingness to cooperate, the player who chose a low investment might cooperate after seeing the high investment of the opponent. If this effect is strong enough, we would observe higher cooperation in the Endo treatments. On the other hand, if a low investment signal unwillingness to cooperate, the player with high investment might decide to defect after seeing the low investment chosen by the opponent, which could result in lower cooperation rates in Endo than in Exo. These two effects might also offset each other, resulting in no difference in cooperation rates between Endo and Exo. We formulate the following

[10]Selection effects might also play a role in our experiment. Such effects might arise if subjects choose to invest and cooperate because of unobservable characteristics (for example, preferences for cooperative behavior) that differ from those of subjects who choose to not invest and not cooperate. We will address this issue in Section 4.2.2.

[11]Disentangling these two effects goes beyond the scope of this paper. Therefore, we use the term signal to include both effects.

alternative hypothesis.

H4:

(i) For $r_i, r_j \leq 4$, cooperation rates in Endo are smaller than in Exo.

(ii) For $r_i, r_j > 4$, cooperation rates in Endo are larger than in Exo.

By comparing the two NoInv, the two Endo and the two Exo conditions across the two levels of δ, we can assess the impact on cooperation levels of a higher probability of future interactions. Given previous experimental evidence, we expect that the higher probability of continuation leads to higher cooperation rates.[12] For the NoInv conditions, this follows from the theoretical reasoning that cooperation is sustainable as an equilibrium action in NoInvLong but not in NoInvShort. In the investment conditions, we have seen that cooperation is always sustainable for the high probability of continuation, while it is so for the low probability of continuation only when $r_i, r_j > 4$. Hence, if $r_i \leq 4$ in the Short treatments, we expect cooperation rates to be higher in the Long treatments. If δ plays a role in determining cooperation rates, we would expect higher cooperation in the Long conditions also when in the Short treatments investments are such that $r_i, r_j > 4$. This leads to the following hypothesis.

H5: *Cooperation in Long treatments is higher than in Short treatments.*

4 Results

In this section we present the main results. We start with the presentation of the investment choices made in EndoShort and EndoLong. Thereafter, we describe the results on cooperation levels in the six treatments. For each treatment, we collected a sequence of decisions over twelve matches for nine different matching groups. This yields 9 independent observations per treatment. Therefore, for the data analysis we will use matching group averages as the primary unit of observation.

4.1 Investments

In this section we describe the investment choices made by subjects, and compare them across the two treatments with endogenous investment opportunities.

On average, investments do not differ between the EndoShort and EndoLong treatments. When looking at the first match only, the average investment is 4.08 in EndoShort and 4.49 in EndoLong. When aggregating data over all matches,

[12] A number of previous experiments (see for instance Dal Bó [2005], Dal Bó and Fréchette [2011], Blonski et al. [2011]) have provided evidence in favor of people being reactive to changes in the discount rate in laboratory experiments.

average investments are 3.25 and 3.57, respectively. In neither case the difference is statistically significant according to two-sided Mann-Whitney U (MW) tests (Table 3).

Table 3: Average investments

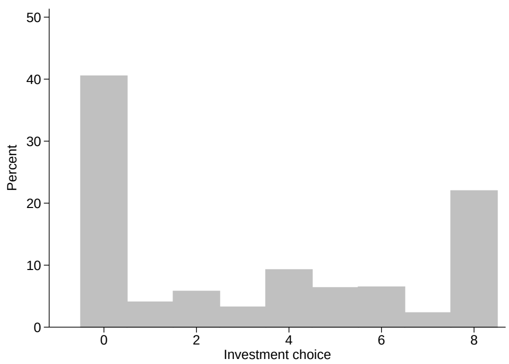
	EndoShort	EndoLong	MW p-values
First match	4.08	4.49	0.2883
All matches	3.25	3.57	0.6267

Averages are taken over matching groups. p-values are from two-sided Mann-Whitney tests which take averages over matching groups as unit of observation.

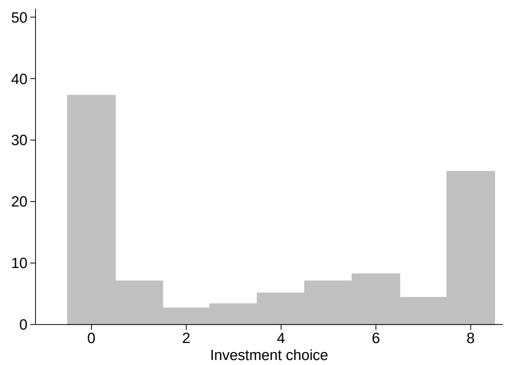
H1 predicts that investments should be either 0 or 8. Figure 1 shows histograms of the investments chosen in the treatments EndoShort (left panel) and EndoLong (right panel). The most frequent investment is 0, which is chosen in both treatments in about 40 percent of the cases. In slightly more than 20 percent of the cases the chosen investments are 8. Investment choices in the middle of the range occur much less frequently, and distribute differently across the two treatments. The two investment distributions are indeed statistically different, according to a Kolmogorov-Smirnov test ($p = 0.017$). While subjects do not exclusively invest either 0 or 8, they largely behave according to the predictions of H1.

Figure 1: Distribution of investments

(a) EndoShort



(b) EndoLong



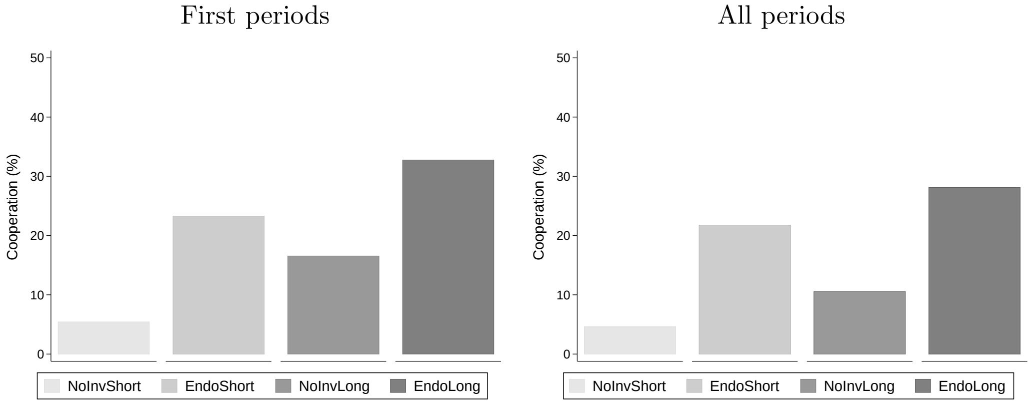
4.2 Cooperation

Introducing an investment possibility gives players the opportunity to influence the payoff received from the cooperation action. We are specifically interested in the changes in cooperation rates that are induced by the introduction of the opportunity to invest and by the actual investment level chosen. We first describe the effects on cooperation of introducing investments, and how the level of investment affects cooperation, by comparing treatments without investment opportunities and treatments with endogenous investment choices. Thereafter, we test whether the endogeneity of the investment choices induces cooperation by comparing treatments with endogenous and exogenous investments. In both cases, we keep the probability of continuation (δ) constant. In the last subsection, we discuss whether and how changes in the probability of future interactions affect cooperation. We will hence compare treatments across the Short and the Long conditions while keeping the investment dimension constant.

4.2.1 The effect of endogenous investments on cooperation

Subjects' cooperation rates in each treatment are shown in Figure 2, averaged over the first period of each match and over all periods.[13] According to MW tests, cooperation rates are significantly higher in treatments with investment opportunities, both in the Short and Long conditions.[14]

Figure 2: Average cooperation by treatment



Next, we analyze how different levels of investment affect cooperation rates. We look at the three following cases (see also Section 3): both players invested at most 4, one player invested at most 4 and the other invested (strictly) more than 4, and both invested (strictly) more than 4. In the Short treatments, cooperation is sustainable in an SPE in the last case, while defection is the only equilibrium in the first two cases. For simplicity and clarity of exposition, the data in the Long

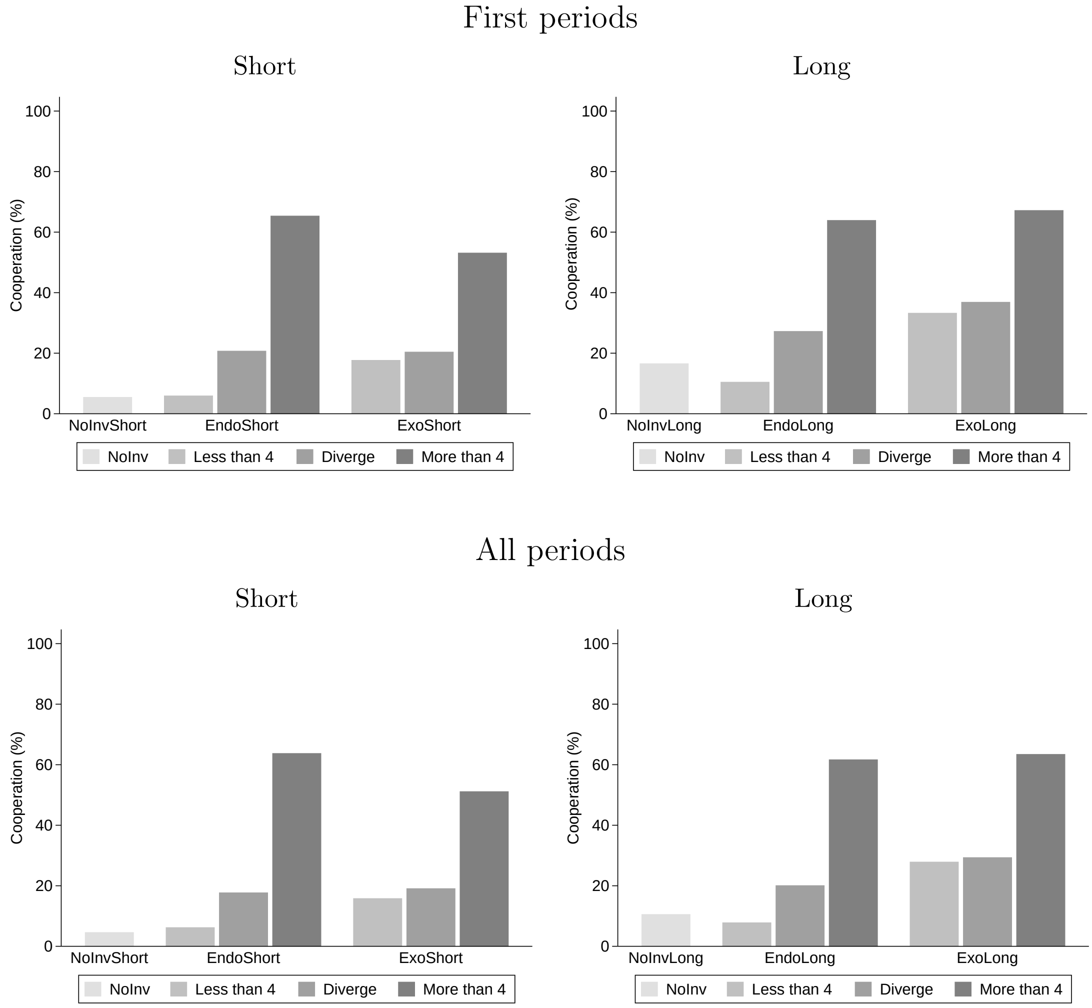
[13]Looking separately at first periods is important since matches have a different number of periods and cooperation rates might vary across periods. Moreover, choices in the first periods indicate how subjects start playing, which potentially affects how they play in the next periods.

[14]MW test results are reported in Table 8 in Appendix C.2, and are consistent with the regression results shown in Table 9.

treatments are organized according to the same categories, even though cooperation is always sustainable in an SPE independent of the investment level.

Figure 3 shows cooperation rates by treatment, and considers the three above-mentioned cases separately for the treatments with investment opportunities. Figure 3 clearly shows that investments do not always trigger high(er) cooperation rates. For instance, first period cooperation rates are about 6 percent both in NoInvShort and in EndoShort when both investments are below 4.

Figure 3: Average cooperation by treatment and investment category



According to H2, we should observe no differences in cooperation rates between NoInvShort and EndoShort when investment levels are such that cooperation cannot be supported in equilibrium ($r_i \leq 4$ for at least one $i \in \{1, 2\}$), while cooperation rates should be larger in EndoShort when investment levels are such that cooperation is sustainable in an SPE ($r_i, r_j > 4$). To test this hypothesis, therefore, we compare average cooperation rates in NoInvShort with those in EndoShort when $r_i \leq 4$

for at least one player, and with those in EndoShort when $r_i, r_j > 4$. According to MW tests, average cooperation is not statistically different between NoInvShort and EndoShort when $r_i, r_j \leq 4$, both when looking at the first period of each match ($p = 0.5623$) and when aggregating data over all periods ($p = 0.2482$). In contrast, when subjects' investments diverge or when both investments are strictly larger than 4, cooperation is higher in EndoShort – this difference is highly significant at 0.1% level for first periods cooperation rates ($p = 0.0009$ for divergent investments, $p = 0.0008$ for investments strictly larger than 4) and for cooperation rates averaged over all periods ($p = 0.0009$ in both cases).[15]

H2 predicts no difference in cooperation rates between NoInvLong and EndoLong, since cooperation is sustainable in an SPE in both treatments. However, we find that in EndoLong investments do have an effect on cooperation. Disaggregating data in the EndoLong treatment in the same way as for EndoShort reveals that behavior is quite similar across the Short and the Long conditions (see Figure 3). In particular, while there are no significant differences in cooperation rates between NoInvLong and EndoLong with $r_i, r_j \leq 4$ (first periods: $p = 0.4013$, all periods: $p = 0.6272$), average cooperation is significantly higher in EndoLong when $r_i, r_j > 4$ (first periods: $p = 0.0013$, all periods: $p = 0.0007$). Cooperation rates when players' investments diverge are higher than when investments are not allowed, but significantly so only when considering data aggregated over all periods (first periods: $p = 0.1022$, all periods: $p = 0.0243$).

We find that investment opportunities have no effect on cooperation rates when both investments are below the threshold level for cooperation to be sustainable in an SPE, while they positively affect cooperation as compared to the no investments condition when investments are above the threshold. This is in line with H2. However, contrary to H2, one player investing above the threshold for cooperation to be an equilibrium action is sufficient for cooperation to significantly increase. When the probability of continuation is high, we find similar results, even though this effect is not predicted by subgame perfection.

4.2.2 Endogenous versus exogenous investments

The comparison NoInv-Endo serves as baseline to examine cooperative behavior with and without the investment institution, but does not permit to pin down the mechanism behind the observed cooperation rates. The comparison between Endo and Exo treatments, instead, allows us to disentangle whether cooperation rates are determined by changes in the PD payoffs, or by the very act of choosing a specific investment level. If payoff is what drives cooperation rates, then we should observe,

[15] See Table 10 for MW test results, and Table 11 for regression results, both in Appendix C.2.

for given investment levels, the same cooperation rates in Endo and Exo treatments. This is what H3 states. If investments provide information on whether a subject is going to defect or cooperate in the PD game, we should instead observe that the same investments induce different cooperation rates in Endo and Exo. As H4 states, cooperation rates in Endo should be lower for investment levels of 4 or less, and larger for investments strictly higher than 4.

Using Figure 3 again, we see that when both players invest at most 4, cooperation is significantly lower in the Endo treatments according to MW tests, both in Long and Short conditions, and both when looking only at first periods (Short: $p = 0.0135$, Long: $p = 0.0080$) and when aggregating data over all periods (Short: $p = 0.0274$, Long: $p = 0.0193$). In contrast, when both investments are above 4, cooperation in EndoShort is around 10 percentage points higher than in ExoShort, while cooperation rates are quite similar in EndoLong and ExoLong. In neither case, however, the difference is statistically significant (MW $p > 0.1$ in all cases).[16] If investments diverge, cooperation tends to be higher in the Exo treatments, both in the Short and in the Long conditions. Also in this case, however, the difference is not statistically significant (MW $p > 0.1$ in all cases).[17]

One interpretation is that choosing low investments signals unwillingness to cooperate, while the increase in cooperation is mostly induced by the high payoffs associated with high investments. A second interpretation might be that selection effects play a role in the endogenous treatments. In this case, cooperation rates might be due not to the investment level chosen, but to some unobservable characteristics (for example, preferences for (un)cooperative behavior) that differ across subjects. For instance, assuming that cooperative subjects choose high investments, if two cooperative subjects are randomly paired, investments and cooperation rates will be high in this pair. High cooperation would then result from selection effects, and not from the investment chosen.

To control for selection effects, we consider separately cooperation rates of subjects who chose investments above 4, and those of subjects who chose investments below or at 4. If selection effects affect results, then subjects who invest $r_i > 4$ ($r_i \leq 4$) would cooperate (not cooperate) irrespective of the investment chosen by their opponents. Table 4 shows that both subjects who choose $r_i > 4$ and subjects who choose $r_i \leq 4$ cooperate more when the opponents choose $r_j > 4$, both in EndoShort and in EndoLong. This difference is statistically significant according to MW tests only for subjects who invest more than 4.[18]

[16]See Tables 12 and 13 in Appendix C.2.

[17]In this case, we further split the data into two sub-categories: one for $r_i \leq 4$ and $r_j > 4$, the other for $r_i > 4$ and $r_j \leq 4$. In both cases, we do not find any differences in cooperation rates between Endo and Exo treatments, according to MW tests.

[18]We find similar patterns in the exogenous treatments. None of the differences in this case is statistically significant.

Table 4: Average cooperation rates by subject's and opponent's investment categories

	EndoShort		EndoLong	
	$r_i \leq 4$	$r_i > 4$	$r_i \leq 4$	$r_i > 4$
$r_j \leq 4$	5.56	24.96	8.50	26.70
$r_j > 4$	11.77	63.27	14.41	61.85
p-value	0.3865	0.0009	0.1711	0.0041

Averages are taken over all periods. p-values are from two-sided Mann-Whitney tests.

We interpret these results as indicating that cooperation rates are not determined by selection effects, but by the signaling effect implied by the choice of an investment level. Investments seem to work as a (negative) signal of willingness to cooperate only when they are low: when both players invest at most 4, we do find lower cooperation rates in the Endo than in the Exo treatments, as H4 predicts. In line with H3, we do not find statistically significant differences between Endo and Exo treatments when investments are high, suggesting that, at least in the Long condition, the increased payoffs are the main driving force behind the higher cooperation levels observed in this case.

4.2.3 The effect of time horizon on cooperation

Early experiments on the infinitely repeated PD have shown that cooperation tends to increase with the probability of continuation, but only marginally, as subjects often fail in fully exploiting the possibility to cooperate (Murnighan and Roth [1978, 1983], Feinberg and Husted [1993]). Recent experiments, by allowing subjects to play more repeated games and gain experience, suggest instead that the effect of repetition on cooperation is substantial (Dal Bó [2005], Dal Bó and Fréchette [2011]; see Dal Bó and Fréchette [forthcoming] for a suvey). Given these results, we expect that subjects cooperate more when the probability of future interactions is high. According to H5, we should then observe higher cooperation rates in the Long treatments than in the Short treatments.

In the NoInv treatments, cooperation averaged over the first period of each match is higher in the Long condition, but this difference is marginally statistically significant only when averaging over the first period of each match.[19] Similarly, in the Endo condition, cooperation rates do not significantly differ between Short and Long treatments. In the Exo condition, cooperation levels are higher in the Long treatments; however, the hypothesis of equality of cooperation rates between Long and

[19]In this section we refer to results from MW tests reported in Table 15 in Appendix C.2. Results from probit regressions are in Tables 16, 17 and 18.

Short treatments is not rejected. Only exceptions are cooperation rates averaged over the first period of each match when investments are less than 4, and when investments diverge: in both cases, cooperation is marginally significantly higher in ExoLong.

In our experiment, increasing the probability of continuation does not substantially affect cooperation rates. This result partly contradicts H5. We will discuss this result further in Section 5.2.

5 Discussion

5.1 Investments as coordination problem

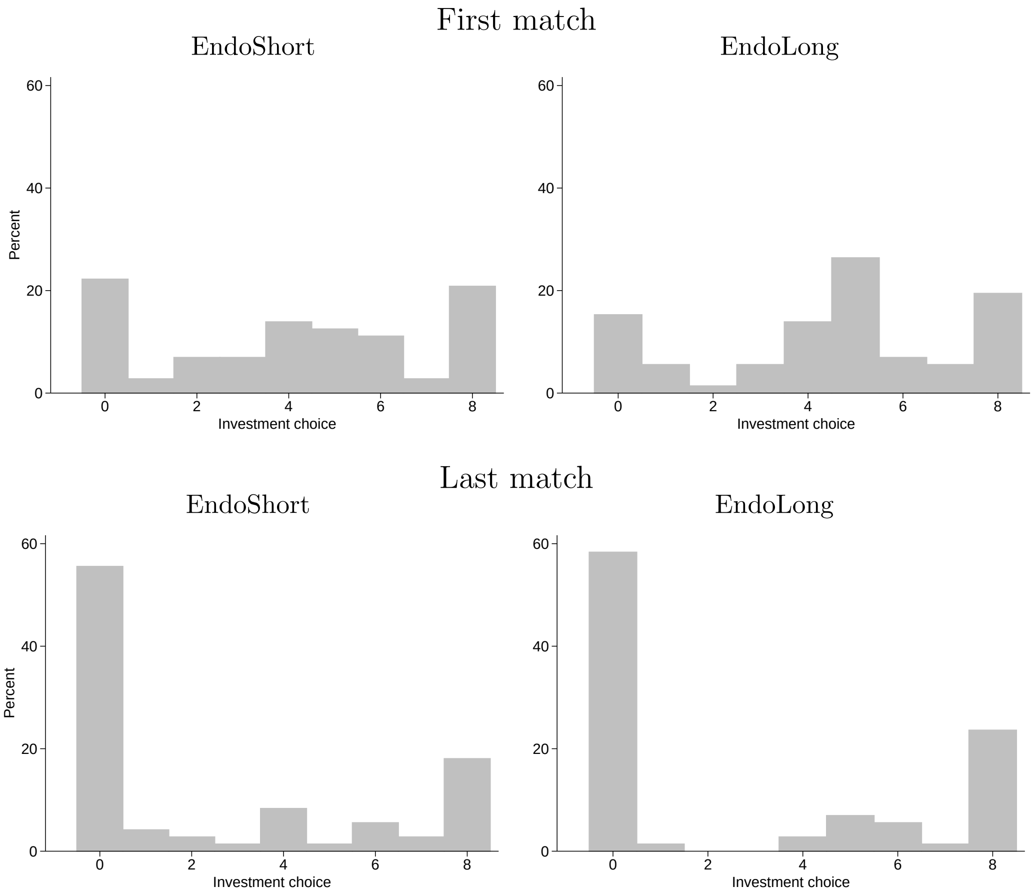
Investments boost overall cooperation levels, independent of whether they are endogenously chosen or exogenously imposed. Yet, in 60 percent of the cases subjects choose low investments, between 0 and 4 (recall Figure 1). In the following, we focus on subjects' investment decisions and discuss a potential explanation for the observed investment behavior. We therefore restrict our attention to the endogenous treatments (EndoShort and EndoLong).

The investment decision entails a coordination problem, in that individuals would like to invest if others invest as well. Figure 4 shows the distribution of investments in the first and in the last match, by treatment. The frequency of investments below or at 4 increases from 53 to 73 percent in EndoShort, and from 42 to 63 percent in EndoLong. This seems to be mostly due to a shift of investment choices from the middle of the range toward 0. Indeed, by comparing first match (upper panels) and last match (lower panels) investment choices, we see that, in both treatments, the percentage of 8 investments does not change much (it remains around 20 percent), the frequency of choices in the middle of the range decreases while the frequency of 0 investments increases substantially (reaching almost 60 percent).

The observed shift toward 0 might be due to the inability of our subjects to solve such coordination problem. Figure 5 shows the proportion of pairs who succeed at coordinating on the same investment category (either both players invest less than 4, or both strictly more than 4) and the proportion of pairs who do not.[20] In the first match, the "miscoordination rate" is relatively high: in roughly 60 percent of the cases in EndoShort and 40 percent of the cases in EndoLong, subjects who chose high investments had opponents who chose low investments. By the end of

[20]Choosing different investment levels, though in the same category, might also lead to the unravelling of investments. However, for the sake of consistency of exposition throughout the paper, and keeping in mind the threshold at 4 for cooperation to be supported in equilibrium in the Short treatments, we focus on investment categories rather than investment levels.

Figure 4: Distribution of investments



the experiment, in match 12, the miscoordination rate is lower in both treatments, while the percentage of pairs that coordinates on low investments rises.[21]

Figure 5: Coordination on the same investment category

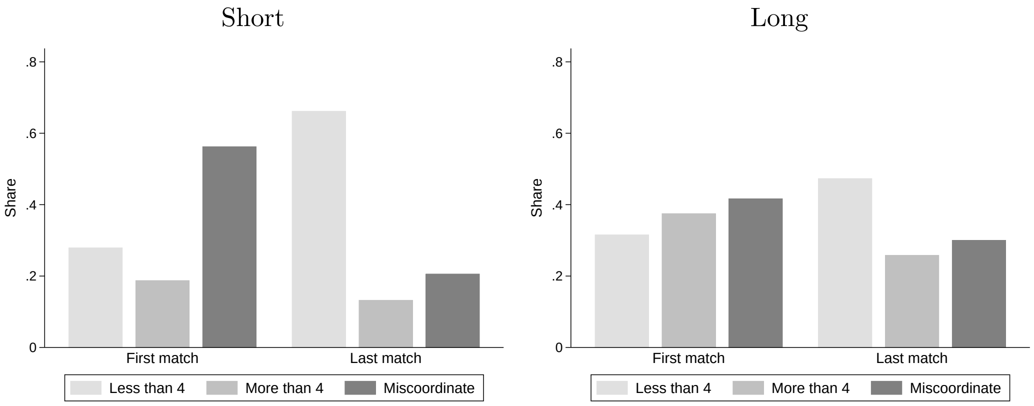
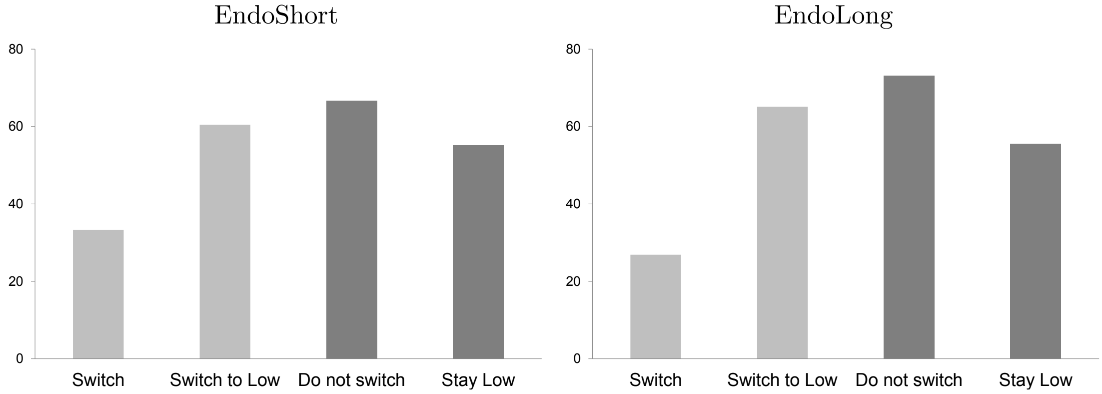


Figure 6 shows the percentage of subjects who, after experiencing miscoordination in the previous match, switch to a different investment category (i.e. shift from investments choices in the Low category ($r_i \leq 4$) to investments in the High category ($r_i > 4$), and vice versa) and the percentage of subjects who do not. It additionally shows, among the subjects who switch, the proportion of subjects who lower their investments (i.e., who switch to the Low category) and, among the subjects who do not switch, the percentage of those who keep choosing investments in Low. In the Short condition, one third of the subjects switch investment category, while in the Long condition this percentage is slightly lower. In most cases, those subjects who switch lower their investments. In both treatments, in more than 60 percent of the cases subjects move to the Low category, where in about 40 percent of the cases they invest nothing. This finding is in line with previous experimental results on coordination games, which show a convergence toward the risk-dominant equilibrium (Camerer [2003], Brandts and Cooper [2006a,b], Blume and Ortmann [2007], Chaudhuri et al. [2006b]).

The highlighted coordination problem explains the shift to lower investments over time, but it only provides a partial explanation for low investments. As mentioned before, only about one third of the subjects decide to switch category. Among the

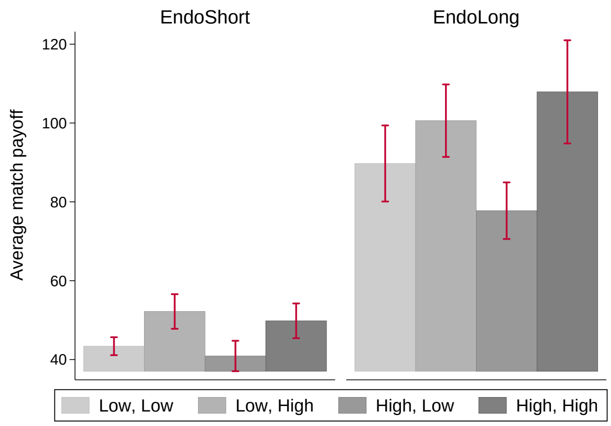
[21] Jonckheere-Terpstra (JT) test results show that in both treatments coordination on investments lower than 4 significantly increases over matches (EndoShort: $p = 0.0010$, EndoLong: $p = 0.0005$), while there is no significant trend for coordination on investments larger than 4 ($p > 0.1$ in both treatments). The miscoordination rate significantly decreases over matches (EndoShort: $p = 0.0006$, EndoLong: $p = 0.0033$). The JT test is a nonparametric test for ordered differences among classes. Here, we test the null hypothesis that average (mis)coordination rates do not differ among matches, against the alternative hypothesis that there is an ordered difference among matches.

Figure 6: Investment choices given miscoordination in previous match



majority of those who do not, the larger percentage (over 55 percent) invest and keep investing in the Low category (Figure 6). Figure 7 provides further insights into why players choose low investments so often. It shows the individual payoff averaged over matches, separately for the following cases: both players invest less than 4 (Low, Low), player i invests less and player j invests strictly more than 4 (Low, High), and vice versa (High, Low), both players invest strictly more than 4 (High, High). Comparing the two darker bars (High, Low and High, High) shows that, in both treatments, choosing investments in the High category yields a relatively high payoff only if both players do so. Given the potential miscoordination, instead, ending up with somebody who chose in Low yields the lowest payoff on average. Moreover, even if both players choose investments in the High category (darkest bars), there is a larger variability in the payoffs than when they both choose investments in the Low category (lightest bars). Therefore, choosing a low investment is the safest option, as it at least guarantees the mutual defection payoff in every period.

Figure 7: Average payoffs



5.2 Cooperation

We find a higher cooperation rate when players can invest than when they cannot. Specifically, when both players choose high investment levels, cooperation rates are highest in the investment treatments.

By comparing endogenous and exogenous investment treatments, we investigated whether the higher cooperation levels are due to a signaling effect, embodied in the choice of an investment, or to greater payoffs, induced by the investments. While low investments seem to be interpreted as signals of unwillingness to cooperate and induce low cooperation rates, high investments are associated with high cooperation levels, independent of whether they are endogenously chosen or exogenously imposed. Payoffs in this case might be large enough to induce as much cooperation in the exogenous as in the endogenous treatments. Differently from previous experiments, we find that a higher probability of continuation does not substantially increases cooperation rates.[22]

In the theoretical and experimental literature on indefinitely repeated PD, Subgame Perfection (SPE), Risk Dominance (RD) and Size of the Basin of attraction of the Always Defect strategy ($SizeBAD$) have been used as possible explanations for cooperation rates. In the following we discuss if these concepts provide an explanation for our results.

Experiments on the indefinitely repeated PD suggest that SPE fails to predict cooperative behavior, mostly because it does not recognize the importance of the risk that cooperating entails. The lower bound δ^{SPE} that equalizes short-run gains and long-run losses from defecting does not take into account that the sucker payoff as well may influence a player's propensity to cooperate. To capture this effect, Blonski and Spagnolo [2015] introduce a measure for the riskiness of cooperation, and use it to define the critical discount factor δ^{RD} for which cooperation is risk dominant.[23] The authors experimentally show that changes in the sucker payoff

[22]For the purpose of providing a benchmark, we compare our results with those in Dal Bó and Fréchette [2011]. The best comparable treatments are our NoInvLong and ExoLong with $r_i = r_j = 0, 4, 8$ and $\delta = 0.75$, and their games with cooperation payoffs of $R = 32, 40$ and 48 and $\delta = 0.75$. Compared to our games, their sucker payoff is higher when $R = 32$, which would suggest lower cooperation in our treatments. We do find substantially lower cooperation rates in our NoInvLong, but similar levels of cooperation in ExoLong (averaged over all periods in all matches). When $R = 48$, our sucker payoff is higher, which would suggest higher cooperation in our games. Indeed, we find greater cooperation rates in ExoLong. We do not have any observations in ExoLong where $r_i = r_j = 4$. When comparing games in EndoLong with the games in Dal Bó and Fréchette [2011], we find lower cooperation in our games when $R = 32$, and higher when $R = 48$.

[23]Blonski and Spagnolo [2015] transpose Harsanyi and Selten [1988]'s concept of RD from symmetric coordination games with two strategies to indefinitely repeated PD by focusing on only two strategies, the Grim (G, that starts by cooperating, and cooperates as long as the other player does so, but defects forever if the other player defects) and the Always Defect (AD). Hence, cooperation is said to be risk dominant if playing G is the best response to the other player choosing G or AD with probability one half.

affect cooperation rates, so that the smaller the sucker payoff, the riskier it is to cooperate (and vice versa), and provide evidence that RD explains cooperation better than SPE alone does.

Dal Bó and Fréchette [2011] show that cooperation is on average higher when it is risk dominant, but they also find that a relatively large number of subjects still fail to coordinate on a cooperative equilibrium when it is risk dominant. They suggest a different index to explain cooperation: $SizeBAD$, defined as the largest set of beliefs that make the Always Defect strategy optimal against Grim. Values of $SizeBAD$ close to one predict that cooperation would hardly emerge, since a player needs to have an extremely strong belief that the partner will cooperate for her to cooperate as well. The opposite holds for values of $SizeBAD$ close to zero.[24] Dal Bó and Fréchette [2011] find that the likelihood of choosing a cooperative action significantly and negatively correlates with $SizeBAD$.[25]

In our experiment, cooperation is not risk dominant in the treatments without investments, NoInvShort and NoInvLong (though it is an SPE in the latter). Moreover, $SizeBAD$ is 1 in NoInvShort, since cooperation is never an equilibrium in this treatment, while $SizeBAD$ is 0.875 in NoInvLong. This might explain why we find low cooperation rates in these treatments, and only a slightly and not statistically significantly higher cooperation in NoInvLong.

Investments, instead, make cooperation choices less risky by increasing the sucker payoff, so that cooperation becomes part of a risk dominant equilibrium for investments beyond a given level.[26] In the Short treatments, cooperation is risk dominant for $r_i, r_j \geq 7$. In the Long condition, the higher r_j, the lower is the investment r_i required for cooperation to be risk dominant.[27] Moreover, investments decrease $SizeBAD$. More precisely, in the Short condition $SizeBAD$ is 1 as long as at least one player invests $r_i \leq 4$, and it decreases with investments when $r_i, r_j > 4$.

[24] The size of the basin of attraction is calculated as follows:

$$SizeBAD = \begin{cases} 1 & \text{if } \delta < \frac{g}{1+g} \\ \frac{(1-\delta)\ell}{(1-(1-\delta)(1+g-\ell))} & \text{otherwise} \end{cases}$$

where $g = \frac{t-c}{c-d}$ and $\ell = -\frac{s-d}{c-d}$. If cooperation cannot be supported as an SPE, $SizeBAD$ is 1.

[25] In Dal Bó and Fréchette [forthcoming] the authors report the results of a meta-study of experiments on infinitely repeated PD games. The analysis shows that, while SPE is not enough to understand cooperation levels, cooperation rates are also relatively low when cooperation can be supported by a risk dominant equilibrium. Cooperation rates decrease with $SizeBAD$, especially when cooperation is risk dominant.

[26] Since different investments imply different cooperation payoffs, the resulting PD might be asymmetric depending on the investment chosen by the players. We take this potential asymmetry into account when determining the critical value δ^{RD} for which cooperation is risk dominant (see Blonski and Spagnolo [2015]). The condition for cooperation to be part of a risk dominant equilibrium is presented in Appendix B.

[27] This implies that cooperation is risk dominant also in cases where, for example, $r_i = 8$ and $r_j = 0$.

In the Long condition, $SizeBAD$ is never 1 (cooperation is always sustainable as equilibrium).[28]

Table 5 presents the results from a linear probability model of the effects of SPE, RD, $SizeBAD$, and their interaction with the investment level, on cooperation. *SPE* is a dummy variable that takes value 1 if cooperation is sustainable in a subgame perfect equilibrium, and 0 otherwise. *RD* takes value 1 if cooperation is sustainable in a risk dominant equilibrium, and 0 otherwise. Table 5 shows that the fact that cooperation is sustainable in an SPE or an RD equilibrium does not increase, per se, the likelihood of choosing the cooperative action. Investments, instead, have a positive and significant effect on cooperation, both when cooperation is an SPE and when it is not. Investments increase cooperation also when cooperation is RD, with this effect being significant only in the Long treatments. This might be due to the fact that in the Short treatments very high investment levels are required for cooperation to be RD. Similarly, investments have a positive and significant effect on cooperation when it is not RD only in the Short treatments. In the Long treatments this effect disappears possibly because cooperation is not RD only for rather low investment levels. We find that cooperation significantly increases when the size of the basin of attraction decreases. Also in this case, investments have a positive impact on cooperation rates, indicating that, for a given $SizeBAD$, the higher the investment the higher the cooperation rates. This suggests that, even when $SizeBAD$ is too large for cooperation to emerge, cooperation would be increasing in the investment level.[29]

Taken together, these results help understand why we observe very similar cooperation patterns in Short and Long treatments. In both cases, investments lower the minimum δ necessary for cooperation to be an SPE and an RD, and decrease the $SizeBAD$, making it easier for cooperation to emerge. This suggests that investments affect and explain cooperation behavior beyond the equilibrium refinement used.

[28]Note that, since the PD might be asymmetric, $SizeBAD$ might differ between players in a pair. We therefore define $SizeBAD = \max\{SizeBAD_i, SizeBAD_j\}$. In the Short treatments, $0.33 \leq SizeBAD \leq 0.91$ for $r_i, r_j > 4$. In the Long treatments, $0.07 \leq SizeBAD \leq 0.88$.

[29]These effects are visible in Figures 8, 9 and 10 in Appendix C.2. Figure 8 shows that cooperation rates increase in the investment level even when cooperation is not RD. Figures 9 and 10 show that, overall, cooperation decreases with $SizeBAD$, but also that, given $SizeBAD$, cooperation might increase with the investment level.

Table 5: Effects on cooperation of SPE, RD, $SizeBAD$ and investments

	Short	Long	Short	Long	Short	Long
SPE	−0.343					
	(0.355)					
Investment×SPE	0.106**	0.052***				
	(0.051)	(0.007)				
Investment×Not_SPE	0.023***					
	(0.004)					
RD			−1.139	−0.011		
			(1.823)	(0.028)		
Investment×RD			0.211	0.052***		
			(0.228)	(0.006)		
Investment×Not_RD			0.029***	−0.015		
			(0.004)	(0.015)		
$SizeBAD$					−0.718***	−0.695***
					(0.131)	(0.090)
Investment×$SizeBAD$					0.024***	0.010**
					(0.004)	(0.005)
Constant	0.079***	0.111***	0.076***	0.123***	0.796***	0.708***
	(0.021)	(0.032)	(0.021)	(0.035)	(0.131)	(0.064)
Nr of obs.	2976	7744	2976	7744	2976	7744

*** Significant at the 1% level. ** Significant at the 5% level. * Significant at the 10% level. All results are from linear probability model regressions. Bootstrapped robust standard errors, clustered over matching groups, in parentheses. SPE takes value 1 if cooperation is sustainable in a subgame perfect equilibrium, and 0 otherwise. RD takes value 1 if cooperation is sustainable in an risk dominant equilibrium, and 0 otherwise.

6 Summary and conclusions

In this paper we ask whether individuals are able to create situations that are conducive to cooperation in settings where there is no enforcement mechanism and cooperation is not easily sustained voluntarily. We introduce upfront investment opportunities and investigate whether they help promoting cooperation in a social dilemma, and whether this effect depends on the investments being endogenous or exogenous. Such investments are a cost that individuals have to incur before deciding whether to cooperate or not, and increase the payoff resulting from the choice to cooperate.

We compare a condition without investments with an endogenous condition where participants can choose their investment level, to test whether investments increase cooperation levels. To determine whether the endogeneity of the investment decision matters for cooperation to increase, we compare the endogenous treatment with a condition where participants are presented with pre-determined investment levels. Finally, we ask how the probability of continuation of the PD game interacts with the investment decision, and study whether changes in this probability affect cooperation rates in this specific context.

We find low cooperation levels in treatments where investments are not allowed, and in treatments where investments are low. When high investments are chosen, cooperation is significantly higher than when investments are not allowed. Moreover, we find that when players choose low investments, cooperation rates are lower in the endogenous than in the exogenous treatments. Cooperation levels are instead not significantly higher in the endogenous treatments when investments are large. This suggests that, while low investments signal unwillingness to cooperate, high investments do not necessarily signal the opposite. In our experiment, a higher probability of continuation is not necessarily associated with higher cooperation rates.

We find that cooperation may not prevail when it is sustainable in a subgame perfect equilibrium, and that it does emerge when it is risk dominant or when the the size of the basin of attraction of AD decreases. However, cooperation increases with the investment level also under unfavorable conditions (for instance, a large $SizeBAD$). This suggests that investments affect and explain cooperation behavior irrespective of the equilibrium refinement used. While investments boost overall cooperation levels, independent of the mode of implementation, we do observe that our participants do not always fully exploit the possibility to create situations favorable to cooperation, and frequently choose low to no investments. We show that this is due to the lack of coordination, which makes choosing a high investment riskier (in terms of earned payoffs) than choosing a low investment.

Our results show that requiring individuals to invest upfront generates cooperative behavior in situations where a functioning enforcement mechanism lacks. Combining endogenous and exogenous elements, such as requiring a minimum investment level, might help overcome the coordination problem embedded in the investment decision. This result seems to provide preliminary support to a theoretical finding in the environmental economics literature. There, the idea is that environmental treaties should focus on investments in green technology rather than on emission limits, arguing that such upfront investments, by reducing a country's temptation to defect, make future cooperation credible and the treaty self-enforcing (Harstad et al. [2016]).

We would like to conclude by pointing out directions for future research. We let the investments increase not only the cooperation payoff, but the sucker payoff as well. Moreover, we focus on selfish investments, i.e. investments that only affect a player's payoff from cooperation. Our intention was to capture the effect of investments per se, isolated from free-riding and other regarding concerns that might play a role if own decisions affect others' payoffs. This obviously does not reflect many real-life situations, where investments are lost once the other party opts for defection, or where investments are directly beneficial to the other party.

References

M. Blonski and G. Spagnolo. Prisoners' other dilemma. *International Journal of Game Theory*, 44:61–81, 2015.

M. Blonski, P. Ockenfels, and G. Spagnolo. Equilibrium selection in the repeated prisoner's dilemma: axiomatic approach and experimental evidence. *American Economic Journal: Microeconomics*, 3:164–192, 2011.

A. Blume and A. Ortmann. The effects of costless pre-play communication: experimental evidence from games with pareto-ranked equilibria. *Journal of Economic Theory*, 132:274–290, 2007.

A. Botelho, G. W. Harrison, L. Costa Pinto, and E. Rutstrom. Social norms and social choice. NIMA Working Papers 30, 2005.

J. Brandts and D. J. Cooper. A change would do you good ... an experimental study on how to overcome coordination failure in organizations. *The American Economic Review*, 96:669–693, 2006a.

J. Brandts and D. J. Cooper. Observability and overcoming coordination failure in organizations: an experimental study. *Experimental Economics*, 9:407–423, 2006b.

C. Camerer. *Behavioral game theory: experiments in strategic interaction.* Princeton University Press, Princeton, 2003.

A. Chaudhuri, S. Graziano, and P. Maitra. Social learning and norms in a public goods experiment with inter-generational advice. *Review of Economic Studies*, 73 (2):357–380, 2006a.

A. Chaudhuri, A. Schotter, and B. Sopher. Talking ourselves to efficiency: coordination in inter-generational minimum effort games with private, almost common and common knowledge of advice. *The Economic Journal*, 119:91–122, 2006b.

P. Dal Bó. Cooperation under the shadow of the future: experimental evidence from infinitely repeated games. *The American Economic Review*, 95:1591–1604, 2005.

P. Dal Bó and G. R. Fréchette. The evolution of cooperation in infinitely repeated games: Experimental evidence. *The American Economic Review*, 101:411–429, 2011.

P. Dal Bó and G. R. Fréchette. On the determinants of cooperation in infinitely repeated games: A survey. *Journal of Economic Literature*, forthcoming.

P. Dal Bó, A. Foster, and L. Putterman. Institutions and behavior: experimental evidence on the effects of democracy. *The American Economic Review*, 100:2205–2229, 2010.

E. Fehr and S. Gächter. Cooperation and punishment in public goods experiments. *The American Economic Review*, 90(4):980–994, 2000.

R. M. Feinberg and T. A. Husted. An experimental test of discount-rate effects on collusive behaviour in duopoly markets. *Journal of Industrial Economics*, 41: 153–160, 1993.

U. Fischbacher. z-tree: Zurich toolbox for ready-made economic experiments. *Experimental Economics*, 10:171–178, 2007.

B. Greiner. Subject pool recruitment procedures: organizing experiments with orsee. *Journal of the Economic Science Association*, 1:114–125, 2015.

A. Gunnthorsdottir, R. Vragov, S. Seifert, and K. McCabe. Near-efficient equilibria in contribution-based competitive grouping. *Journal of Public Economics*, 94(11-12):987–994, 2010.

J. Harsanyi and R. Selten. *A general theory of equilibrium selection in games*. MIT Press, Boston, 1988.

B. Harstad, F. Lancia, and A. Russo. Compliance technology and self-enforcing agreements. CESifo Working Paper Series 5562, 2016.

R. Isaac and J. Walker. Communication and free-riding behavior: the voluntary contribution mechanism. *Economic Inquiry*, 26(4):585–608, 1988.

K. Kamei. Democracy and resilient pro-social behavioral change: an experimental study. *Social Choice and Welfare*, 47:359–378, 2016.

T. Markussen, L. Putterman, and J.-R. Tyran. Self-organization for collective action: an experimental study of voting on sanction regimes. *Review of Economic Studies*, 81:301–324, 2014a.

T. Markussen, E. Reuben, and J.-R. Tyran. Competition, cooperation and collective choice. *The Economic Journal*, 124:F163–F195, 2014b.

J. K. Murnighan and A. E. Roth. Equilibrium behavior and repeated play of the prisoner's dilemma. *Journal of Mathematical Psychology*, 17:189–198, 1978.

J. K. Murnighan and A. E. Roth. Expecting continued play in prisoner's dilemma games: a test of several models. *The Journal of Conflict Resolution*, 27:279–300, 1983.

C. Noussair and S. Tucker. Combining monetary and social sanctions to promote cooperation. *Economic Inquiry*, 43:649–660, 2005.

R. Sausgruber and J.-R. Tyran. Pure redistribution and the provision of public goods. *Economics Letters*, 95:334–338, 2007.

M. Sutter, S. Haigner, and M. Kocher. Choosing the carrot or the stick? endogenous institutional choice in social dilemma situations. *Review of Economic Studies*, 77: 1540–1566, 2010.

J.-R. Tyran and L. Feld. Achieving compliance when legal sanctions are non-deterrent. *Scandinavian Journal of Economics*, 108(1):135–156, 2006.

A Design - number of periods per match

Table 6: Number of periods across matching groups

(a) NoInvShort and InvShort

Matching group	Match 1	2	3	4	5	6	7	8	9	10	11	12	Total
1	1	2	3	2	1	1	1	1	2	1	3	2	20
2	1	2	5	7	1	1	1	2	2	1	1	2	26
3	3	1	1	1	1	1	1	1	4	1	4	3	22
4	1	6	1	2	1	2	1	1	1	2	2	2	22
5	2	2	1	1	2	1	1	3	1	1	4	1	20
6	1	1	2	2	1	2	1	1	2	1	2	1	17
7	1	1	1	1	1	2	2	1	1	3	2	1	17
8	1	1	5	1	2	1	2	2	1	2	1	1	20
9	1	1	2	5	1	2	1	1	1	1	2	4	22

(b) NoInvLong and InvLong

Matching group	Match 1	2	3	4	5	6	7	8	9	10	11	12	Total
1	1	2	1	1	7	7	1	5	4	1	2	1	33
2	1	11	7	3	8	7	3	6	2	2	2	5	57
3	1	1	8	7	6	5	15	9	7	2	5	3	69
4	3	1	4	1	7	5	1	4	2	10	4	3	45
5	6	1	8	4	2	8	14	10	4	1	6	5	69
6	8	8	17	3	1	2	5	1	2	2	1	3	53
7	7	4	2	4	3	1	2	1	9	9	2	3	47
8	11	7	1	1	9	2	5	1	9	12	3	2	63
9	4	5	2	1	3	2	8	6	3	1	8	5	48

B Theoretical background

For a PD with asymmetric payoff parameters and symmetric discount factor δ, the critical values δ^{RD} for which cooperation is part of a risk dominant equilibrium is given by (see Blonski and Spagnolo [2015]):

$$\delta^{RD} = \frac{Y+Z}{2W} + \sqrt{\left(\frac{Y+Z}{2W}\right)^2 - \frac{X}{W}} \tag{2}$$

where

$$\begin{aligned}
X &= (d_i - s_i)(d_j - s_j) - (t_i - c_i)(t_j - c_j), \\
Y &= (d_i - s_i)(d_j - s_j) - (t_i - d_i)(t_j - c_j), \\
Z &= (d_i - s_i)(d_j - s_j) - (t_i - c_i)(t_j - d_j) \quad \text{and} \\
W &= (d_i - s_i)(d_j - s_j) - (t_i - d_i)(t_j - d_j).
\end{aligned}$$

C Additional material

C.1 Investments

Table 7: Treatment effects, investments

	Investment	
	First periods	All periods
Long	0.321	0.288
	(0.88)	(0.90)
Constant	3.252***	3.219***
	(0.69)	(0.72)
Nr of obs.	1728	5360

Results are from OLS regressions. *** Significant at the 0.1% level. Bootstrapped standard errors, clustered over matching groups, in parentheses. Long takes value 1 if the observation comes from the EndoLong treatment and 0 otherwise.

C.2 Cooperation

The effect of endogenous investments on cooperation

Table 8: Percentage of cooperation by treatment

	NoInvShort	EndoShort	p-value	NoInvLong	EndoLong	p-value
First periods	5.44	23.26	0.0115	16.55	32.75	0.0301
All periods	4.58	21.75	0.0091	10.55	28.08	0.0092
Nr of obs.		18			18	

Averages are taken over matching groups. p-values are from two-sided Mann-Whitney tests which take averages over matching groups as unit of observation.

A probit regression of the probability of choosing the cooperative action is used to assess the impact of introducing the opportunity to invest.[30] Table 9 reports the results for both the treatments with $\delta = 0.35$ and the treatments with $\delta = 0.75$. The reference group in both cases is the treatment NoInv.

Table 9: Effects of investment treatment on the probability to cooperate

	$\delta = 0.35$		$\delta = 0.75$	
	First periods	All periods	First periods	All periods
Investment	0.873^{***}	0.913^{***}	0.525^{*}	0.728^{**}
	(0.22)	(0.24)	(0.24)	(0.24)
Constant	-1.604^{***}	-1.771^{***}	-0.972^{***}	-1.389^{***}
	(0.10)	(0.08)	(0.19)	(0.19)
Nr of obs.	1728	2976	1728	7744

*** Significant at the 0.1% level. ** Significant at the 1% level. * Significant at the 5% level. Bootstrapped standard errors, clustered over matching groups, in parentheses. Investment takes value 1 if the observation comes from EndoShort or EndoLong, and 0 otherwise. In each regression, the reference group is the treatment without investments.

[30] All reported regressions use cluster-robust bootstrapped standard errors, corrected for potential correlations at the matching group level.

Table 10: Differences in cooperation between NoInv and Endo

	NoInv	(1) $r_i, r_j \leq 4$	(2) $r_i \leq 4, r_j > 4$	(3) $r_i, r_j > 4$	NoInv vs (1)	NoInv vs (2)	NoInv vs (3)
Short							
First periods	5.44	5.93	20.71	65.34	0.5623	0.0009	0.0008
All periods	4.58	6.21	17.71	63.74	0.2482	0.0009	0.0009
Nr of obs.					17	18	16
Long							
First periods	16.55	10.45	27.22	63.89	0.4013	0.1022	0.0013
All periods	10.55	7.81	20.08	61.67	0.6272	0.0243	0.0007
Nr of obs.					18	18	18

Averages are taken over matching groups. p-values are from two-sided Mann-Whitney tests which take averages over matching groups as unit of observation.

Table 11: Effects of investments on the probability to cooperate, by investment category

	$\delta = 0.35$ First periods	$\delta = 0.35$ All periods	$\delta = 0.75$ First periods	$\delta = 0.75$ All periods
$r_i, r_j \leq 4$	-0.048	0.019	-0.186	0.032
	(0.14)	(0.12)	(0.28)	(0.29)
$r_i \leq 4, r_j > 4$	0.865^{***}	0.854^{***}	0.383	0.337
	(0.16)	(0.16)	(0.23)	(0.21)
$r_i, r_j > 4$	1.966^{***}	1.977^{***}	1.499^{***}	1.848^{***}
	(0.21)	(0.21)	(0.25)	(0.26)
Constant	-1.604^{***}	-1.771^{***}	-0.972^{***}	-1.389^{***}
	(0.10)	(0.08)	(0.19)	(0.19)
Nr of obs.	1728	2976	1728	7744

*** Significant at the 0.1% level. Bootstrapped standard errors, clustered over matching groups, in parentheses. In each regression, the reference group is the treatment without investments.

Endogenous versus exogenous investments

Table 12: Differences in cooperation between Endo and Exo

	$r_i, r_j \leq 4$			$r_i \leq 4, r_j > 4$			$r_i, r_j > 4$		
	Endo	Exo	p-value	Endo	Exo	p-value	Endo	Exo	p-value
Short									
First periods	5.93	17.67	0.0135	20.71	20.40	0.8945	65.34	53.12	0.4428
All periods	6.21	15.80	0.0274	17.71	19.08	0.7573	63.74	51.13	0.3706
Nr of obs.		16			18			14	
Long									
First periods	10.45	33.25	0.0080	27.22	36.87	0.2888	63.89	67.17	0.6272
All periods	7.81	27.87	0.0193	20.08	29.33	0.4529	61.67	63.44	0.6272
Nr of obs.		18			18			18	

Averages are taken over matching groups. p-values are from two-sided Mann-Whitney tests which take averages over matching groups as unit of observation.

In addition, a probit regression of the probability of choosing the cooperative action is used to assess treatment differences between Endo and Exo. Table 13 reports the results for the treatments with $\delta = 0.35$ and $\delta = 0.75$, both for the first period of each match and all periods. The reference groups in each specification are the corresponding investment category in the Exo treatment.

Table 13: Endo versus Exo

	$\delta = 0.35$					
	1st periods	All periods	1st periods	All periods	1st periods	All periods
$r_i, r_j \leq 4 \times$Endo	-0.736***	-0.667***				
	(0.17)	(0.16)				
$r_i, r_j > 4 \times$Endo			0.403	0.334		
			(0.34)	(0.32)		
$r_i \leq 4, r_j > 4 \times$Endo					0.062	-0.007
					(0.18)	(0.17)
Constant	-0.916***	-1.085***	-0.041	-0.128	-0.801***	-0.910***
	(0.14)	(0.13)	(0.28)	(0.26)	(0.13)	(0.09)
Nr of obs.	812	1352	368	588	548	1036

	$\delta = 0.75$					
	1st periods	All periods	1st periods	All periods	1st periods	All periods
$r_i, r_j \leq 4 \times$Endo	-0.583*	-0.348				
	(0.28)	(0.32)				
$r_i, r_j > 4 \times$Endo			-0.215	0.006		
			(0.33)	(0.33)		
$r_i \leq 4, r_j > 4 \times$Endo					-0.300	-0.460*
					(0.23)	(0.23)
Constant	-0.576**	-1.009***	0.742*	0.453	-0.290	-0.593**
	(0.20)	(0.21)	(0.30)	(0.29)	(0.19)	(0.21)
Nr of obs.	616	2724	428	1876	684	3144

*** Significant at the 0.1% level. ** Significant at the 1% level. * Significant at the 5% level. Bootstrapped standard errors, clustered over matching groups, in parentheses. In each regression, the reference group is the corresponding category in the exogenous treatment.

Table 14: Within treatment differences in cooperation rates, across investment category

	$\delta = 0.35$			
	Endo		Exo	
	1st periods	All periods	1st periods	All periods
$r_i, r_j \leq 4$	-0.913^{***}	-0.834^{***}	-0.116	-0.175
	(0.10)	(0.13)	(0.09)	(0.14)
$r_i, r_j > 4$	1.101^{***}	1.123^{***}	0.760^{***}	0.782^{***}
	(0.22)	(0.18)	(0.18)	(0.20)
Constant	-0.739^{***}	-0.917^{***}	-0.801^{***}	-0.910^{***}
	(0.12)	(0.14)	(0.13)	(0.09)
Nr of obs.	864	1488	864	1488

	$\delta = 0.75$			
	Endo		Exo	
	1st periods	All periods	1st periods	All periods
$r_i, r_j \leq 4$	-0.569^{**}	-0.305	-0.286	-0.417^{*}
	(0.20)	(0.22)	(0.20)	(0.17)
$r_i, r_j > 4$	1.117^{***}	1.512^{***}	1.032^{***}	1.046^{***}
	(0.11)	(0.17)	(0.26)	(0.29)
Constant	-0.589^{***}	-1.052^{***}	-0.290	-0.593^{**}
	(0.12)	(0.08)	(0.20)	(0.22)
Nr of obs.	864	3872	864	3872

*** Significant at the 0.1% level. ** Significant at the 1% level. * Significant at the 5% level. Bootstrapped standard errors, clustered over matching groups, in parentheses. In each regression, the reference group is the category $r_i > 4, r_j \leq 4$.

The effect of time horizon on cooperation

Table 15: Differences in cooperation between Short and Long

No Investments	Short	Long	p-value						
First periods	5.44	16.55	0.0687						
All periods	4.58	10.55	0.1575						
Nr of obs.		18							
	$r_i, r_j \leq 4$			$r_i \leq 4, r_j > 4$			$r_i, r_j > 4$		
	Short	Long	p-value	Short	Long	p-value	Short	Long	p-value
Endo									
First periods	5.93	10.45	0.3862	20.71	27.22	0.1709	65.34	63.89	1.0000
All periods	6.21	7.81	0.9233	17.71	20.08	0.4529	63.74	61.67	1.0000
Nr of obs.		17			18			16	
Exo									
First periods	17.67	33.25	0.0675	20.40	36.87	0.0636	53.12	67.17	0.4584
All periods	15.80	27.87	0.2482	19.08	29.33	0.3538	51.13	63.44	0.3404
Nr of obs.		17			18			16	

Averages are taken over matching groups. p-values are from two-sided Mann-Whitney tests which take averages over matching groups as unit of observation.

Additionally, we regress the probability to cooperate over a dummy for δ being high (see Table 16). Results confirm that, in our experiment, increasing the probability of continuation does not necessarily increase the probability of a cooperative outcome.

Table 16: Effects of δ on the probability to cooperate

	No Investments	
	First periods	All periods
Long	0.632**	0.381
	(0.22)	(0.21)
Constant	-1.604***	-1.771***
	(0.10)	(0.08)
Nr of obs.	1728	5360

*** Significant at the 0.1% level. ** Significant at the 1% level. * Significant at the 5% level. Robust standard errors, clustered over matching groups, in parentheses. Long takes value 1 if the observation comes from a treatment with $\delta = 0.75$ and 0 otherwise. In each regression, the reference category is the Short treatment.

Table 17: Effects of δ on the probability to cooperate

	Endogenous					
	First periods			All periods		
	$r_i, r_j \leq 4$	$r_i \leq 4, r_j > 4$	$r_i, r_j > 4$	$r_i, r_j \leq 4$	$r_i \leq 4, r_j > 4$	$r_i, r_j > 4$
Long	0.494*	0.150	0.165	0.394	-0.135	0.253
	(0.21)	(0.18)	(0.24)	(0.25)	(0.16)	(0.26)
Constant	-1.652***	-0.739***	0.362	-1.751***	-0.917***	0.206
	(0.10)	(0.12)	(0.19)	(0.09)	(0.14)	(0.19)
Nr of obs.	714	616	398	2038	2090	1232

*** Significant at the 0.1% level. ** Significant at the 1% level. * Significant at the 5% level. Robust standard errors, clustered over matching groups, in parentheses. Long takes value 1 if the observation comes from a treatment with $\delta = 0.75$ and 0 otherwise. In each regression, the reference category is the Short treatment.

Table 18: Effects of δ on the probability to cooperate

	Exogenous					
	First periods			All periods		
	$r_i, r_j \leq 4$	$r_i \leq 4, r_j > 4$	$r_i, r_j > 4$	$r_i, r_j \leq 4$	$r_i \leq 4, r_j > 4$	$r_i, r_j > 4$
Long	0.341	0.511*	0.165	0.075	0.317	0.582
	(0.24)	(0.23)	(0.24)	(0.26)	(0.23)	(0.37)
Constant	-0.916***	-0.801***	0.362	-1.085***	-0.910***	-0.128
	(0.14)	(0.13)	(0.19)	(0.14)	(0.09)	(0.23)
Nr of obs.	714	616	398	2038	2090	1232

*** Significant at the 0.1% level. ** Significant at the 1% level. * Significant at the 5% level. Robust standard errors, clustered over matching groups, in parentheses. Long takes value 1 if the observation comes from a treatment with $\delta = 0.75$ and 0 otherwise. In each regression, the reference category is the Short treatment.

Discussion

Figure 8: Risk dominance and cooperation, by investment level

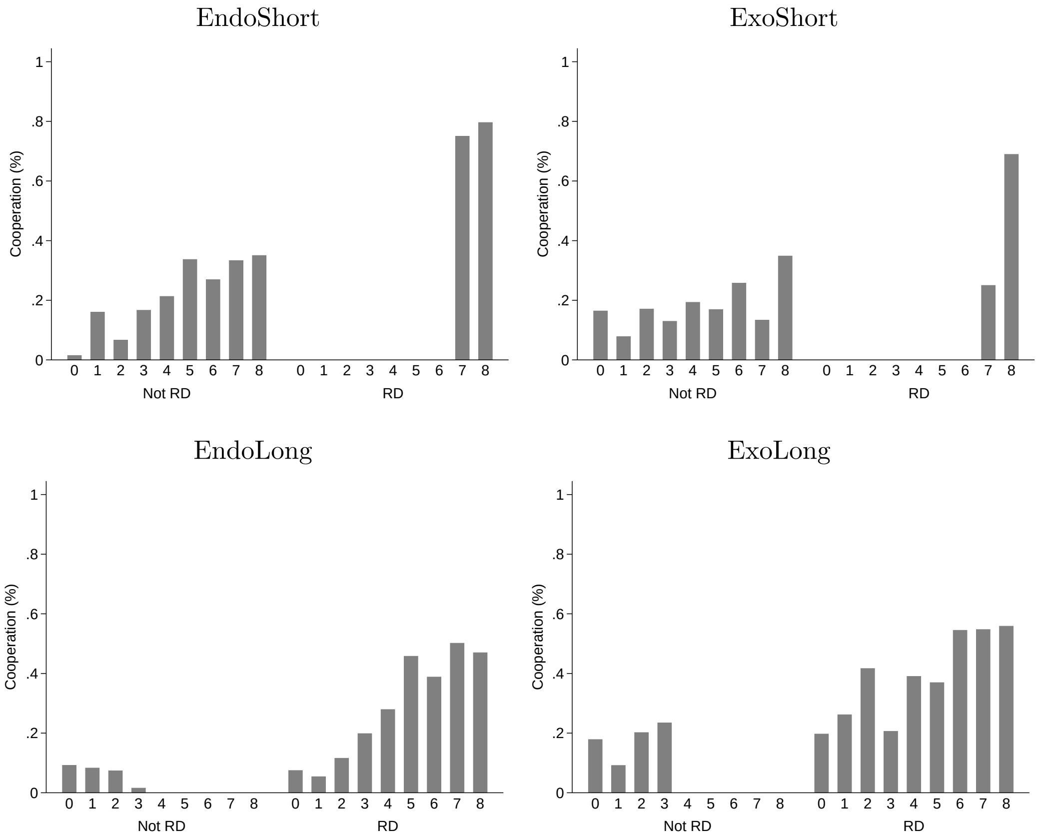


Figure 9: Cooperation and $SizeBAD$

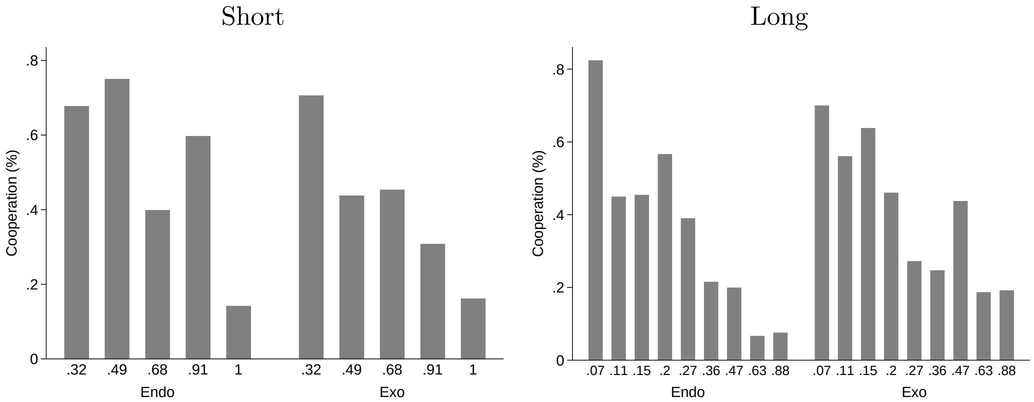


Figure 10: Cooperation, investments and *SizeBAD*