“An Experimental Study of Finitely and Infinitely Repeated Linear Public Goods Games”

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Abstract*

A growing literature in experimental economics examines the conditions under which cooperation can be sustained in social dilemma settings. In particular, several recent studies contrast cooperation levels in games in which the number of decision rounds is probabilistic to games in which the number of decision rounds is finite. We contribute to this literature by contrasting the evolution of cooperation in probabilistically and finitely repeated linear voluntary contribution public goods games (VCM). Consistent with past results, cooperation increases in MPCR, and in group size, holding MPCR constant. We also find, as the number of decision sequences increase, there is a pronounced decrease in cooperation in the final round of finite sequences compared to those with a probabilistic end round. We do not, however, find strong evidence that overall cooperation rates are affected by whether the number of decision rounds is finite or determined probabilistically.

Keywords: Social Dilemmas, Public Goods Games, Experimental Economics, Repeated Games.  
*JEL codes: C72, C92, D83, E40.

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1 Introduction

The linear voluntary contribution public goods game (VCM) has been the cornerstone for examining factors that facilitate cooperation in public goods settings. The vast majority of this research has focused on the role of game parameters and institutional settings in influencing cooperation. In this regard, much of this research has not focused on VCM settings in which cooperation at the social optimum can be supported as an equilibrium outcome. In particular, most of this research has examined one-shot or finitely repeated decision settings in which the final decision round was common knowledge (see Ledyard (1995) for a review). In our daily lives, however, we also face interactions of uncertain duration. This uncertainty, and the shadow of the future, has the potential to change incentives regarding cooperation relative to situations that are perceived as one-shot or finite in duration. Indeed, repeated interactions may give rise to implicit or explicit punishment schemes that, in turn, may help discipline opportunistic behavior and support cooperation.

The research we report here is motivated by the limited evidence in VCM settings regarding repeated play in the context of uncertain duration, as well as the recent study of Dal Bó (2005). In this study the author examines decision making in 2-person PD games in which subjects participate in sequences of decisions with the same partner and then are re-matched according to a Turnpike matching protocol. The experimental design contrasts conditions in which sequences are one shot, repeated with a known end round, or repeated with the end round being determined probabilistically. Our experimental design was created to parallel many of the attributes of the methodology used by Dal Bó (2005), but in the setting of a VCM game structure with varying number of subjects. Our experiment was conducted in several phases, including several treatment conditions motivated by results from earlier phases of the experimental study.

In summary, the study began with an investigation of behavior in a VCM game setting where N=4 and MPCR=0.3 or MPCR=0.6. The first is a setting that has been shown to lead to low cooperation rates in settings in which the decision setting is repeated a publicly announced finite number of times. The second, N=4 and MPCR=0.6, was chosen based on prior evidence that in groups of size N=4, cooperation levels are higher holding group size constant and increasing MPCR (see, Isaac, et al., 1994). This result is found to hold although the game theoretic equilibrium of zero contributions to the public good is the same in both settings when individuals are assumed to make decisions based only on own income maximization and this is common information. Based on the initial results, and motivated by the 2-person PD game setting of Dal Bó (2005), we extended our study to include a linear VCM setting with N=2, and MPCR=0.6, with and without limiting subjects to binary choices. In the binary choice linear VCM games, decisions were either a contribution of zero or one’s full endowment to the public good.

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1 MPCR is defined as the ratio of the marginal value of contributions to the public good to individual i relative to the opportunity cost to individual i of contributing to the public good.
The experiments reported here follow the methodology of Dal Bó (2005) where subjects make decisions in the context of repeated sequences of decisions, where groups are fixed within a sequence but not across sequences. The number of decision rounds in a sequence is either finite with a known end round or probabilistic. Thus, in addition to allowing us to contrast the effects of sequences with finite or probabilistic termination rounds, our study also allows us to examine the evolution of contributions in VCM decisions settings in which there are a large number of repeated decision sequences and under different parameters. This is especially important since, as in Dal Bó (2005) and Dal Bó and Fréchette (2011), there are multiple equilibria in indefinitely repeated games, and thus it is important to explore parameter changes that may affect cooperation levels.

In summary, we do not find strong evidence that overall cooperation rates are increased in the probabilistic setting compared to the finite. We do observe, however, that there is a more pronounced decrease in cooperation in the final round of sequences in the finite setting than in the probabilistic setting. In addition, our results for both the finite and probabilistic decision settings support several of the findings from previous studies examining VCM in finite decision settings. In particular, holding group size constant, we find that contributions increase with increases in MPCR. We also provide evidence that, holding MPCR constant, contributions increase as group size increases from N=2 to N=4.

The paper is organized as follows. In section 2, we summarize related literature. Section 3 provides a theoretical discussion. Section 4 describes the decision setting, parameters of the games investigated and hypotheses. Section 5 presents the experimental results and Section 6 provides a discussion of results and conclusions.

2 Related Literature

Here we discuss laboratory experiments that focus on indefinitely repeated social dilemma games where the majority of studies explore indefinitely repeated Prisoner’s Dilemma games. Dal Bó (2005) finds that cooperation increases as the probability of continuation increases and that cooperation is higher in games with indefinite duration than in finite games with the same expected length. In addition, Dal Bó and Fréchette (2011) find that experience plays an important role for the emergence of cooperation in indefinitely repeated Prisoner’s Dilemma games. In particular, they find that, with experience, subjects converge to very low levels of cooperation when cooperation is not an equilibrium outcome, while they achieve higher levels of cooperation when both the probability of continuation and the payoff from

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2 The study of behavior in indefinitely repeated games in laboratory settings goes beyond the Prisoner’s Dilemma game and includes (weak or strict) dominance solvable finite games, oligopoly games, trust games and monetary theory (e.g., Duffy and Puzzello (2014), Engle-Warnick and Slonim (2006)), Holt (1985), Van Huyck, Wildenthal and Battalio (2002))

3 Roth and Murnighan (1978) and Murnighan and Roth (1983) find mixed evidence for the effect of the probability of continuation on cooperation rates. See Dal Bó (2005) for some methodological weakness of these studies that may have affected the results.
cooperation are sufficiently high. Blonski et al. (2011) also study cooperation in Prisoner’s Dilemma games under different game parameters with the purpose of improving the understanding of determinants of cooperation. Duffy and Ochs (2009) explore the effect of matching protocols on the frequency of cooperation in indefinitely repeated Prisoner’s Dilemma games and find that the frequency of cooperation is higher when subjects are matched in fixed pairings in comparison to when subjects are randomly paired across games.

To the best of our knowledge, there are only three papers exploring contributions in indefinitely repeated voluntary contribution games. Palfrey and Rosenthal (1994) study an indefinitely repeated provision point voluntary contribution game, where subjects make a binary choice as whether to contribute to the public good. The public good is provided if the number of subjects contributing meets or exceeds a known threshold. In addition, their game setting includes incomplete information as subjects have different (privately known) marginal rates of substitution between the public good and the private good. Unlike the classic linear voluntary contribution game, the one-shot version of their game has multiple equilibria with some involving positive contributions. Also, some equilibrium outcomes in the repeated game are associated with higher levels of contribution than equilibrium outcomes of the one-shot games. They find that contributions are higher in the indefinitely repeated game than in the one-shot games, but the differences are small. They observe that this result may be due to the structure of the game, which requires overcoming a difficult coordination problem associated with cut-point contribution strategies and private information.

Sell and Wilson (1999) study an indefinitely repeated $n$-person Prisoner’s Dilemma version of a public good game. In particular, in the binary choice stage game subjects are shown a payoff matrix where payoffs depend on whether they choose to cooperate or defect and on the number of group members who cooperate. The payoffs, however, cannot be mapped into a linear VCM game. They study the effect of different probabilities of continuation (0.7, 0.8 and 0.95) and the effect of imposing the grim trigger strategy, finding that higher probabilities of continuation are associated with a higher frequency of cooperation, but only in treatments where subjects are required to play the grim trigger strategy. Thus, a higher expected length of playing the game is not sufficient to induce significantly higher levels of cooperation.

More recently, Tan and Wei (2014) examine cooperation rates in a linear VCM game setting where subjects make decisions across two sequences, finite (10 decision rounds) and indefinitely repeated (0.9 probability of continuation). They find that average contributions do not differ between finitely and

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4Their parametrization also implies higher returns from cooperation than in our study. For example, the fraction of the social optimum that is achieved under the Nash equilibrium is 0.3, while in our study that fraction is 0.8333 (when the MPCR is 0.3) or 0.416 (when the MPCR is 0.6).

5Their parameterization (with $N=5$, $E=100$ and MPCR=0.5) implies that the fraction of the social optimum which is achieved under the Nash equilibrium is 0.4.
indefinitely repeated games. However, while contributions decrease in finitely repeated games, they are found to exhibit cycles in indefinitely repeated games. In addition, they find evidence of a restart effect at the beginning of the second sequence only in finitely repeated games.

Relative to Dal Bó (2005) and Dal Bó and Fréchette (2011), our \( N=2 \) treatment where choices are not binary consists of a somewhat more complex environment since subjects have more than two choices available, and thus more degrees of cooperation are possible at the individual level. This aspect of our design led us to conduct the last treatment condition in our study in which subjects were limited to the binary choices of full contribution or no contribution to the public good. Relative to Tan and Wei (2014), in addition to the effect of changing group size, we also explore the impact of experience in the selection of equilibria. In both of our known end-round and probabilistic end-round decision environments subjects participate in a large number of decision sequences, which allows us to more completely explore whether experience plays a role in the selection of equilibria and the evolution of cooperation. There are multiple equilibria in the probabilistic end-round environment, including zero contributions and up to full cooperation. Thus our design allows us to examine to what extent equilibrium selection is affected by game parameters within the context of the linear VCM game, as well as the role of experience.\(^6\)

In terms of findings, as in Tan and Wei (2014), we do not find strong evidence that contribution levels are higher in indefinitely repeated games than in finitely repeated games. Unlike Tan and Wei (2014), we find that restart effects are present in indefinitely repeated games, but they are smaller than in finitely repeated games.

Finally, Arifovic and Ledyard (2012) and Holt and Laury (2008) consider models that could rationalize some of the empirical regularities observed in finitely repeated public goods experiments, including models with evolutionary learning and heterogeneous agents with other-regarding preferences, noisy decision making, noisy evolutionary adjustment, expectations evolving based on past observed behavior and forward-looking behavior (see Chaudhuri (2011) for more references). Our approach captures some of the features of the latter type of models, as initially proposed by Isaac, Walker and Williams (1994), in that agents in our model are forward-looking. However, in the indefinitely repeated framework we consider, forward-looking incentives are motivated by the uncertainty of the length of the interaction rather than by myopic behavioral biases.

3 Theoretical Predictions

In this section we show that it is possible to support full cooperation as a subgame perfect equilibrium in infinitely repeated voluntary contribution public goods games. We start by describing the stage game.

\(^6\)As in Dal Bó and Fréchette (2011), we also randomly re-match subjects across sequences, to limit the extent of repeated game effects across sequences. We do not have any unanticipated restart games.
Let $N$ be the number of agents in the group. Each agent $i$ is endowed with $Z$ tokens. We denote the action set of agent $i$ by $A_i = \{0,1,...,Z\}$, i.e., an agent decides how many tokens, $m_i \in A_i$ to contribute to a group account, and keeps the rest of his endowment in a private account, with a per token payoff equal to 1. Let $c \in R$ be such that $\frac{1}{N} < \frac{c}{N} < 1$. Agent $i$’s payoff in tokens is determined as follows:

$$
\Pi_i(m_1,m_2,...,m_N) = Z - m_i + c \left( \frac{m_i + \sum_{j \neq i} m_j}{N} \right).
$$

That is, the total amount contributed to the group account is multiplied by a factor $c > 1$, and then divided equally among the group members. In this context where the return from private account is 1, the term $\frac{c}{N}$ is the Marginal Per Capita Return (MPCR) from the group account and the restriction $\frac{1}{N} < \frac{c}{N} < 1$ implies that this game is a social dilemma. That is, assuming own income maximization across all players and that this is common knowledge, because $\frac{c}{N} < 1$, not contributing to the group account is a strictly dominant strategy in the stage game. However, because $\frac{c}{N} > \frac{1}{N}$, the social optimum is for every agent to contribute their full endowment of tokens to the group account. Thus, the unique Nash equilibrium for this stage game is $(m_1,m_2,...,m_N) = (0,0,...,0)$, which is not Pareto optimal. Furthermore, backward induction implies that contributing zero in each period is also the unique subgame perfect equilibrium of the finitely repeated game.

The game with a probabilistically determined ending can be viewed as an infinite repetition of the stage game. As agents interact repeatedly over time, they can now condition their actions in each period on their group members’ past actions. Clearly, not to contribute in every period remains a subgame perfect Nash equilibrium outcome of the infinitely repeated game. Suppose now that the total group endowment, $NZ=K$, is common knowledge. Then, other cooperative outcomes, associated with positive contributions to the group account, can be supported as subgame perfect Nash equilibria of the repeated game. In particular, it is possible to show that, if agents are sufficiently patient, full cooperation (i.e., to contribute all tokens to the group account) can be supported as a subgame perfect Nash equilibrium outcome in the infinitely repeated voluntary contribution public goods provision game.

Let $t=1,2,...$ denote the time period and $\delta<1$ the discount factor. Payoffs in the infinitely repeated game are determined by the discounted sum of stage payoffs. Recall that the total sum of individual endowments is common knowledge and equal to $K$. Now consider the following grim-trigger strategy:
"Start by contributing all of your tokens to the group account. Contribute all of your tokens to the group account as long as you observe that the total contribution to the group account is equal to K. If you observe that the total contribution is less than K, contribute 0 to the group account forever after." 

This strategy prescribes agents to begin playing cooperatively and to continue doing so until a defection is observed. As soon as a defection is observed, the grim strategy prescribes that no one should contribute to the group account forever after, which can be interpreted as “punishment” of the defector in retaliation for his deviation.

Next we show that if agents are sufficiently patient (and thus they care enough about future payoffs), this strategy is a subgame perfect Nash equilibrium of the infinitely repeated public goods game. Note also that the equilibrium outcome associated with this strategy is full cooperation and it is supported by the threat of completely shutting down any contribution to the group account. To prove that this strategy is a subgame perfect Nash equilibrium, we need to show that no agent has an incentive to deviate on and off the equilibrium path.

On the equilibrium path, if agent $i$ follows the strategy, his payoff is given by:

$$\frac{1}{1-\delta} \left( \frac{c}{N} \sum_{j=1}^{N} Z \right)$$

while if he deviates, he receives a one-shot gain followed by lower future payoffs:

$$\left( Z + \frac{c}{N} \sum_{j \neq i} Z \right) + \frac{\delta}{1-\delta} Z.$$

Thus, an agent has no incentive to deviate on the equilibrium path when

$$\frac{1}{1-\delta} \left( \frac{c}{N} \sum_{j=1}^{N} Z \right) \geq \left( Z + \frac{c}{N} \sum_{j \neq i} Z \right) + \frac{\delta}{1-\delta} Z$$

or

$$\delta \geq \frac{(1-c/N)Z}{1-c/N} = \frac{(1-c/N)}{N^{(N-1)}} \Delta \delta$$

It is easy to see that off the equilibrium path no agent has the incentive to deviate from the grim-trigger strategy of zero contributions in the current and future periods. The intuition for the sustainability of full cooperation.

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*Further, we notice that the grim-trigger strategy can support less than full cooperation as a subgame perfect equilibrium and that there are other strategies that support full cooperation.*
cooperation is simple: the threat of punishment that reduces agents’ long-term payoffs may be sufficient to deter them from exploiting their short-term advantage, if they care enough about the long term (i.e., if $\delta$ is large enough).

In addition, note that parameter changes which decrease $\delta$ imply that cooperation can be supported with agents that are “less patient,” as the returns from cooperation are constant. In particular, we examine three such changes in our study: 1) increases in the MPCR, holding group size constant, 2) increasing N while holding the group account return ($c$) constant, and 3) increasing N while changing $c$ as to hold the MPCR constant. In summary, whether cooperation is easier or more difficult to support in larger groups depends on how the return to the group account is adjusted in response to a group size increase. These observations will guide our Hypotheses presented in the next section.

4. Experimental Design, Procedures, and Hypotheses

4.1 Design and Procedures

This study occurred over a two year time frame, 2013 to 2015, with stages of the experiment being motivated by the results from the previous experiments. Table 1 summarizes the complete design. All experimental sessions consisted of 15 sequences of decision rounds, where after each sequence, subjects were randomly regrouped. Each treatment condition consisted of sessions in which the number of decision rounds in a sequence was fixed and publicly known (Finite) and sessions in which the number of decision rounds in a sequence was determined by a random draw with a 80% chance of continuation (Probabilistic). The expected number of rounds in sequences in Probabilistic treatments equaled the number of rounds in the Finite sessions. As in Dal Bó (2005), this design feature is incorporated to examine whether cooperation may be affected by the “shadow of the future” rather than just sequence length.

The initial experiments were conducted utilizing the NovaNet system that had been the “workhorse” for a large number of experimental projects. While conducting these experiments, however, it became apparent that further study of this issue would be facilitated by utilizing a Z-tree program designed explicitly for this purpose. (Appendix A has the instructions for the N=4, MPCR=.03, Finite and Probabilistic conditions.) In particular, the Z-tree program was designed to more efficiently accommodate the reassignment of subjects into new groups after each decision sequence.8 The treatment

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8 A NovaNet system problem in some initial sessions resulted in a few sequences having groups of size 3 and 5, instead of 4. These odd-sized groups account for 8% of the observations in the N=4, MPCR=0.3 condition and 3% in the N=4, MPCR=0.6 condition. It can be shown that the 80% continuation probability used in this study is sufficient to support cooperation with group sizes of N=3 and 5, so we have chosen to include the odd-sized groups in the graphs and statistical analysis. This does not affect the qualitative conclusions from our analysis. Our first sessions with Z-tree used the same parameters as our NovaNet N=4, MPCR=0.3 sessions, and we found no systematic differences in contribution behavior between the Z-tree sessions and the NovaNet sessions.
conditions with \( N=2 \) were conducted to move to decision settings that more closely paralleled those of Dal Bó (2005).\(^9\)

### Table 1: Design Parameters

<table>
<thead>
<tr>
<th>Decision Environment</th>
<th>Group Size</th>
<th>Binary Choice</th>
<th>Group Account Return</th>
<th>MPCR</th>
<th>Number of Sessions</th>
<th>Number of Subjects</th>
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<tbody>
<tr>
<td>Finite</td>
<td>4</td>
<td>No</td>
<td>$.024</td>
<td>.6</td>
<td>1</td>
<td>12</td>
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<tr>
<td>Probabilistic</td>
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<td>No</td>
<td>$.024</td>
<td>.6</td>
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<td>16</td>
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<tr>
<td>Finite</td>
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<td>No</td>
<td>$.012</td>
<td>.3</td>
<td>3</td>
<td>48</td>
</tr>
<tr>
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<td>No</td>
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<td>.3</td>
<td>2</td>
<td>32</td>
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<tr>
<td>Finite</td>
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<td>No</td>
<td>$.012</td>
<td>.6</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>Probabilistic</td>
<td>2</td>
<td>No</td>
<td>$.012</td>
<td>.6</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
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<td>Yes</td>
<td>$.012</td>
<td>.6</td>
<td>2</td>
<td>24</td>
</tr>
<tr>
<td>Probabilistic</td>
<td>2</td>
<td>Yes</td>
<td>$.012</td>
<td>.6</td>
<td>2</td>
<td>26</td>
</tr>
</tbody>
</table>

Includes NovaNet sessions where 48 subjects participated in sessions with Group Account Return = .012 and 28 with Group Account Return = .024. All remaining sessions used Z-tree software designed to facilitate conducting the large number of multiple sequences.

This study includes data from experimental sessions conducted at Indiana University-Bloomington (U.S.). In each session, 8 to 16 subjects were recruited from a subject database that included undergraduates from a wide range of disciplines.\(^10\) Subjects made decisions sitting at workstations that included side-blinders for privacy. At the beginning of each session, subjects privately read a set of instructions, which were then summarized publicly by a member of the research team. Subjects made all decisions privately. The experimental design is an across-subject design. That is, each subject participated in only one session.\(^11\)

Each decision round was a linear VCM game. In each decision round, each subject was endowed with 25 tokens to be allocated between a private account and a group account. For each token placed in his or her private account a subject received $.01 in payment. For each token placed in the group account, each group of 4 received $.012 in sessions with MPCR=0.3 and $.024 in sessions with MPCR=0.6. While

\(^9\) Subjects were recruited using ORSEE (Greiner 2003).

\(^10\) The largest \( N=4 \) session was 16 subjects, and the smallest was 12. The largest \( N=2 \) session was 16 subjects, and the smallest was 8.

\(^11\) In the experiments conducted by Dal Bó (2005), within a session, subjects experienced sequences with different probabilities of continuation in the probabilistic sessions and different numbers of decision rounds in the sequences with a known fixed number of rounds.
each group of 2 received $.012 with MPCR=0.6. After all subjects had made their decisions in each decision round, they were informed of the aggregate allocations to the group account, as well as their earnings in that round. The sessions in which subjects were limited to a binary decision were conducted exactly as the other sessions, except that each subject was allowed only two choices; all tokens placed in the group account or all tokens placed in their private account.

Subjects were informed that across decision sequences they would be randomly grouped with other group members, 4 or 2 depending on the relevant research condition. In sessions with Probabilistic treatments, the subjects were informed that “The number of decision rounds in each sequence is determined by a computerized random draw. At the end of each decision round in a sequence, there is an 80% chance that the sequence of decision rounds will continue and a 20% chance that the sequence will end.” Subjects were not informed of the number of sequences: they were told that “the experiment may consist of numerous sequences”. In sessions with Finite treatments, the information subjects were given varied somewhat between the initial NovaNet sessions and the sessions conducted with Z-tree. In the NovaNet session, subjects were simply told that the experiment would consist of numerous sequences. After deliberation over this point, in the Z-tree sessions, subjects were explicitly informed that there would be 15 sequences of 5 rounds each. The subjects earned an average of $26.72, with a maximum of $44.25 and a minimum of $18.75. In the Probabilistic treatments, the average number of rounds per sequence was 5.33, the minimum was 1 and the maximum was 14.

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12 As is the standard in public goods experiments, the language used was neutral, the terms “contributions” and “public goods” were not used. For brevity, however, in the discussion of results we will use these terms when discussing tokens allocated to the group account.

13 As discussed in Dal Bó and Fréchette (2011), there is no evidence that this random matching protocol delivers different results than turnpike protocols. Furthermore, this design choice allows us to run more sequences (repeated games) in a session than turnpike matching protocols would allow. This is an important advantage for our study, especially given that, in part, we focus on groups of 4 subjects.

14 The number of rounds in the sequences of the Probabilistic sessions was determined in advance using a random number generator for each sequence, with replacement. The NovaNet sessions utilized different sets of draws for each Probabilistic session. (For the MPCR=0.3 session, the sequence lengths were: 3, 4, 3, 7, 5, 4, 8, 13, 6, 3, 11, 2, 4, 2, 5. For the MPCR=.6 session, the sequence lengths were: 9, 3, 5, 4, 13, 2, 1, 3, 4, 6, 3, 2, 5, 1, 14.) For further experimental control, the first set of draws from the NovaNet sessions was then used in all Probabilistic sessions using Z-tree. This particular sequence was chosen because of our plan to compare the robustness of the NovaNet MPCR=.3 behavior to the Z-tree MPCR=.3 behavior. Dal Bó and Fréchette (2011) and Engle-Warnick and Slonim (2006) document that different sequence lengths can have an impact on cooperative behavior. For this reason, we chose to hold constant the sequence lengths across Probabilistic sessions. See also Fréchette and Yuksel (2013) and Duffy and Puzzello (2014) for other studies following this approach.

15 The decision to inform the subjects of the number of sequences in the Finite sessions using Z-tree was to reinforce the “finiteness” of the experimental session. We chose 15 sequences based on our prior experience in the NovaNet sessions. This number allowed us to have a sufficient number of sequences in the Finite sessions to compare to the Probabilistic sequences. Also, note that the number of rounds in the sequences in the Finite sessions is equal to the expected number of rounds in the sequences of the Probabilistic sessions.
4.2 Hypotheses

Based on the game parameters chosen for this study and assuming subjects’ choices of contributions to the group account are motivated only by maximizing their own earnings and that this is common information among subjects, positive contribution levels, up to full contribution of endowment, can be supported as equilibrium outcomes in the infinitely repeated games.\textsuperscript{16} Thus, because in infinitely repeated games positive contributions are part of equilibria that Pareto dominate zero contribution outcomes, we conjecture that subjects are more likely to contribute positive amounts to the group account in the Probabilistic condition.

\textit{Hypothesis 1.} Group account contributions in repeated games with sequences that have probabilistic end rounds will be greater than or equal to those in repeated games with sequences that have known end rounds.

Based on the theoretical discussions of Section 3 and previous experimental evidence, we present the following hypotheses concerning behavior in Probabilistic treatments.\textsuperscript{17}

\textit{Hypothesis 2.} In games with probabilistic end rounds, group account contribution levels will be higher with MPCR=0.6 than MPCR=0.3 for groups with N=4.

\textit{Hypothesis 3a.} For a fixed group account return, group account contribution levels in games with probabilistic end rounds will be higher with N=2 than N=4.

\textit{Hypothesis 3b.} In games with probabilistic end rounds, group account contribution levels will be higher in groups with N=4 than in groups with N=2, if the group account return is adjusted to keep the MPCR constant across groups.

\textsuperscript{16} Our parameterization with probability of continuation $\delta=4/5$ exceeds both $\delta_{0.3}^{0.4} \approx 0.778$, $\delta_{0.6}^{0.4} \approx 0.222$ and $\delta_{0.6}^{0.2} \approx 0.67$, so that full cooperation can be supported as a subgame perfect equilibrium of the indefinitely repeated games.

\textsuperscript{17} Note, the continuation probability in our design is above the threshold discount factor implied by the parameterizations we study. The theoretical predictions only have implications for the threshold. However, as discussed in Blonski et al. (2011), several studies in applied theory are based on the interpretation that the lower is the threshold discount factor, the more likely cooperation is. Furthermore, prior experimental evidence, suggests that in indefinitely repeated Prisoner’s Dilemma games, cooperation rates are positively correlated with the difference between the probability of continuation and the threshold probability of continuation obtained under subgame perfection (see Dal Bó and Fréchette (2014)).
In addition to these hypotheses related to contributions in the Probabilistic treatments, prior evidence from VCM games (Isaac, et al., 1994) also suggests that in the Finite treatments we examine, support may be found for Hypotheses 2, 3a and 3b. Thus, our design allows us to examine the robustness of the earlier findings in settings with a large number of repeated decision sequences, with random matching of subjects across sequences.

5. Results

5.1 Descriptive statistics and trends

The presentation of results is organized around an overview that focuses on group account contributions. Table 2 presents average group account contribution levels for each treatment condition, allowing for comparisons of: a) the average of the first round of sequence 1 and the average of the first round pooling across all sequences, b) the average of the last round of sequence 1 and the average of the last round pooling across all sequences, and c) the average across all rounds of Sequence 1 and the average across all rounds. Thus, in addition to examining all rounds, we also examine first round and last round decisions. As discussed in Dal Bó and Fréchette (2014), an advantage of examining first round behavior is that the number of rounds in the Probabilistic setting varies due to the probabilistic termination rule, potentially affecting the group contribution dynamics within sequences. Examining last round behavior allows for a clear contrast between behavior in Finite and Probabilistic settings, since in the last round of Finite settings there is no shadow of the future within a particular sequence.

As one can see from the data presented in Table 2, there is no systematic evidence to support Hypotheses 1 that group account contributions will be greater in Probabilistic treatments relative to Finite treatments. The results presented in Table 2, however, do provide preliminary support for Hypotheses 2, 3a and 3b. In the Probabilistic treatments, average contributions are found to be consistently higher for N=4, MPCR=0.6 compared to N=4, MPCR=0.3, N=2, MPCR=0.6 compared to N=4, MPCR=0.3 (group account function is held constant), as well as for N=4, MPCR=0.6 compared to N=2, MPCR=0.6, when decisions are not binary. These results are also found to be supported in the Finite treatments, providing evidence of the robustness of results reported in Isaac, et al. (1994) and Isaac and Walker (1988).

Table 2 provides a “snap-shot” of overall average tendencies in the data. The averages, however, mask differences in time trends that may exist across treatment conditions, both within and across sequences. To gain insight into such differences, Figure 1 presents average first round and last round contributions decisions (as a percentage of maximum) across sequences for each of the treatment conditions. Generally, the results displayed in Figure 1 support the conclusions drawn from Table 1. As one can observe, there is also evidence of a restart effect at the beginning of each sequence that persists.
over time, in both Probabilistic and Finite settings (see Andreoni, 1988 and Norton, 2015 for previous evidence in finite settings). When N=2, this restart effect is more pronounced in the Finite settings. Finally, the data suggest a fairly strong pattern in which average contributions decrease from the first round to the last round within sequences. This pattern is more pronounced in Finite than in Probabilistic settings, particularly in later sequences.  

Table 2: Average group account contributions: Percentage of maximum possible

<table>
<thead>
<tr>
<th>Decision Environment</th>
<th>First Round Sequence 1</th>
<th>First Round All Sequences</th>
<th>Last Round Sequence 1</th>
<th>Last Round All Sequences</th>
<th>All Rounds Sequence 1</th>
<th>All Rounds All Sequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=4, Finite MPCR=0.3</td>
<td>36.1</td>
<td>22.7</td>
<td>15.8</td>
<td>6.8</td>
<td>25.4</td>
<td>13.1</td>
</tr>
<tr>
<td>N=4, Probabilistic</td>
<td>39.5</td>
<td>23.2</td>
<td>30.9</td>
<td>10.4</td>
<td>22.3</td>
<td>12.9</td>
</tr>
<tr>
<td>MPCR=0.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=4, Finite MPCR=0.6</td>
<td>51.3</td>
<td>59.4</td>
<td>64.3</td>
<td>43.9</td>
<td>59.9</td>
<td>52.6</td>
</tr>
<tr>
<td>N=4, Probabilistic</td>
<td>64.8</td>
<td>58.4</td>
<td>47.3</td>
<td>45.2</td>
<td>59.6</td>
<td>45.8</td>
</tr>
<tr>
<td>MPCR=0.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=2, Finite MPCR=0.6</td>
<td>52.3</td>
<td>55.9</td>
<td>39.0</td>
<td>13.8</td>
<td>46.5</td>
<td>41</td>
</tr>
<tr>
<td>N=2, Probabilistic</td>
<td>54.6</td>
<td>53</td>
<td>57.3</td>
<td>39.2</td>
<td>57</td>
<td>41.7</td>
</tr>
<tr>
<td>MPCR=0.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=2, Finite MPCR=0.6, Binary</td>
<td>66.7</td>
<td>78.9</td>
<td>54.2</td>
<td>25</td>
<td>65</td>
<td>57.5</td>
</tr>
<tr>
<td>N=2, Probabilistic</td>
<td>54.5</td>
<td>57.6</td>
<td>46.2</td>
<td>28.2</td>
<td>57.3</td>
<td>38.4</td>
</tr>
<tr>
<td>MPCR=0.6, Binary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

18 In the last five sequences, for each parameter condition, this result is statistically significant (p<.05) in all pairwise comparisons of Finite versus Probabilistic setting.
Figure 1: Average group account contributions: Percentage of maximum possible across sequences
5.2 Formal Statistical Tests

In the discussion which follows, we turn to a more formal testing of differences in contribution decisions in the Finite and Probabilistic conditions for each of the treatments. More specifically, the data set for each treatment was constructed as a panel, with subjects as the cross sectional dimension that was associated with a contribution decision in each round of each sequence. For example, for the Finite condition, there are 75 decision rounds, where rounds 6, 11, 16, …, 71 denote the first decision made in sequences 2, 3, 4, …, 15, respectively. The model regression specification below was then conducted for each treatment, comparing behavior in the the Finite and Probabilistic conditions (except for the N=2, MPCR=0.6 binary treatment, which we discuss below).

\[ \text{Contr}_t = \beta_{tF} t_{F} + \beta_{tP} t_{P} + \sum_{r=1}^{4}\beta_{r_i} r_i + \epsilon_i \]

where \( t_{F} \) and \( t_{P} \) are dummy variables for the Finite and Random conditions, respectively, while \( r_1-r_4 \) are dummy variables for rounds 1-4 in each sequence, which we use to control for restart effects and path dependencies which may occur within sequences.

Recall that in our experiment, subjects are randomly regrouped in each sequence. As a result, in addition to serial correlation, we can expect spatial (cross-sectional) correlation within a session. The typical way of dealing with this problem would be clustering the standard errors. The number of sessions, however, is too small (typically 2 or less per treatment) for clustering the standard errors at the session level.\(^{19}\) Further, we cannot cluster at the subject level, since these clusters are not independent due to the rematching of groups in each sequence. For these reasons, instead of clustering, we estimate using Driscoll and Kraay (1998) standard errors, which are robust to arbitrary spatial and serial correlation. Importantly, Vogelsgang (2012) shows that for large T and finite N (as is the case in our samples), the Driscoll and Kraay (1998) standard errors are consistent even in specifications with time fixed effects. For estimation, the procedure is implemented in STATA as xstcc, developed by Hoechle (2007). After estimating the values of \( \beta_{tF} \) and \( \beta_{tP} \), conditional on restart effects and path dependencies within sequences, we test the hypotheses that for each treatment condition.

As noted above, these procedures were used for all treatment conditions except for when decisions were binary (zero contribution to the group account or full contribution to the group account). For this case, we calculate the average contribution for each sequence of a given session, and use these averages to formally compare means across treatments.\(^{20} \) The advantage of this approach is obtaining a left-hand side variable which can be treated as a continuous variable due to aggregation. This allows us to

---

\(^{19}\) Typically, it is recommended to have at least 30-40 clusters.

\(^{20}\) If we tried to test the equality of the means using the same level of aggregation as for non-binary cases, we could use the probit. However, in that case we would not be able to control for the restarting effects with round dummies, since as argued by Wooldridge (2002, 483-84), probit estimator with fixed effects is not a consistent estimator of \( \beta_{tF} \) and \( \beta_{tP} \).
apply a similar methodology to the approach above, except for eliminating the need for round-specific
dummy variables since we aggregate over decision rounds within sequences:

\[ \text{Contr}_t' = \beta_0 + \beta_1 t + \varepsilon_t' \]

Table 3 presents the results for all rounds in a given sequence. The model is also estimated using
observations from only first round decisions (Table 4), and observations from only last round decisions
(Table 5). In each table, results are reported from all sequences (1-15), as well for only the first 5
sequences (1-5) and the last five sequences (11-15).

Focusing first on the model results from examining data from all periods and all sequences (the
first 4 rows of Table 3) we observe that the average group account contributions are significantly and
consistently higher in Probabilistic games than in Finite games only in the treatment conditions where
N=2 with MPCR=0.6. For the other treatments, the differences are either not significantly different, or
significantly different in a direction that is opposite the hypothesized direction (group account average
contributions higher in Finite games than in Probabilistic games). If we focus only on sequences 1-5 or
11-15, the primary observation remains the same.

Tables 4 and 5 examine the same model specifications as in Table 3, with the exception that
observations are pooled only from first round decisions of each sequence (Table 4) and last round
decisions of each sequence (Table 5). The results reported in Table 4 from examining only first round
decisions from sequences provide even weaker support for Hypotheses 1. The results reported in Table 5,
however, suggest a different conclusion. As one can see, the data examining last round decisions from
sequences provides strong support for Hypotheses 1 that contributions in the Probabilistic treatments
exceed those in the Finite treatments.

We now turn to formal tests regarding Hypotheses 2, 3a, and 3b. The same methodology
discussed above is used for comparing contributions in Finite versus Probabilistic conditions for the
treatment conditions relevant to these hypotheses. Recall, Hypothesis 2 states that in the Probabilistic
condition, group account contribution levels will be higher with MPCR=0.6 than MPCR=0.3 for groups
with N= 4. The model results for this test are presented in Table 6. Hypothesis 3a states that in the
Probabilistic condition, group account contribution levels will be higher with N=2 than N=4, when the
group account function (c) is held constant. The model results for this test are presented in Table 8.
Finally, Hypothesis 3b states that group account contribution levels will be higher in groups with N=4
than in groups with N=2, if the group account return is adjusted to keep the MPCR constant across groups.
The model results for this test are presented in Table 9.

There is strong evidence in support of Hypotheses 2, 3a, 3b, and the results are generally robust to
whether all sequences are considered, only the first 5 sequences are considered, or the last 5 sequences are
considered. Also, all three hypotheses are supported when we examine the same treatment comparisons in
the Finite condition, providing evidence of the robustness of results reported in Isaac, et al. (1994) and Isaac and Walker (1988).

Table 3: Model results using all decision rounds

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Sequences</th>
<th>Finite</th>
<th>Sign</th>
<th>Probabilistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N. Obs</td>
<td>Average</td>
<td>Comparison</td>
</tr>
<tr>
<td>N=4, MPCR=0.3</td>
<td>1-15</td>
<td>3600</td>
<td>13.1</td>
<td>&gt;</td>
</tr>
<tr>
<td>N=4, MPCR=0.6</td>
<td>1-15</td>
<td>900</td>
<td>52.6</td>
<td>&gt;**</td>
</tr>
<tr>
<td>N=2, MPCR=0.6</td>
<td>1-15</td>
<td>2100</td>
<td>41.0</td>
<td>&lt; ***</td>
</tr>
<tr>
<td>N=2, MPCR=0.6, Binary</td>
<td>1-15</td>
<td>30</td>
<td>57.5</td>
<td>&gt; ***</td>
</tr>
<tr>
<td>N=4, MPCR=0.3</td>
<td>1-5</td>
<td>1200</td>
<td>20.5</td>
<td>&gt;</td>
</tr>
<tr>
<td>N=4, MPCR=0.6</td>
<td>1-5</td>
<td>300</td>
<td>53.0</td>
<td>&lt;</td>
</tr>
<tr>
<td>N=2, MPCR=0.6</td>
<td>1-5</td>
<td>700</td>
<td>40.3</td>
<td>&lt; ***</td>
</tr>
<tr>
<td>N=2, MPCR=0.6, Binary</td>
<td>1-5</td>
<td>10</td>
<td>63.8</td>
<td>&gt; ***</td>
</tr>
<tr>
<td>N=4, MPCR=0.3</td>
<td>11-15</td>
<td>1200</td>
<td>9.2</td>
<td>&gt;</td>
</tr>
<tr>
<td>N=4, MPCR=0.6</td>
<td>11-15</td>
<td>300</td>
<td>51.8</td>
<td>&gt; ***</td>
</tr>
<tr>
<td>N=2, MPCR=0.6</td>
<td>11-15</td>
<td>700</td>
<td>40.6</td>
<td>&lt; ***</td>
</tr>
<tr>
<td>MPCR=0.6, Binary</td>
<td>11-15</td>
<td>10</td>
<td>52.5</td>
<td>&gt;*</td>
</tr>
</tbody>
</table>

Note: The table presents sample averages, while the tests of significance are conditional, controlling for restart and path dependency effects. Sign comparisons consistent with the hypotheses are noted in bold.
Table 4: Model results using only first round decisions

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Sequences</th>
<th>Finite</th>
<th>Sign Comparison</th>
<th>Probabilistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N. Obs.</td>
<td>Average</td>
<td></td>
</tr>
<tr>
<td>N=4, MPCR=0.3</td>
<td>1-15</td>
<td>720</td>
<td>22.7</td>
<td>&lt;</td>
</tr>
<tr>
<td>N=4, MPCR=0.6</td>
<td>1-15</td>
<td>180</td>
<td>59.4</td>
<td>&gt;</td>
</tr>
<tr>
<td>N=2, MPCR=0.6</td>
<td>1-15</td>
<td>420</td>
<td>55.9</td>
<td>&gt;</td>
</tr>
<tr>
<td>N=2, MPCR=0.6, Binary</td>
<td>1-15</td>
<td>30</td>
<td>78.9</td>
<td>&gt; ***</td>
</tr>
<tr>
<td>N=4, MPCR=0.3</td>
<td>1-5</td>
<td>240</td>
<td>31.9</td>
<td>&lt;</td>
</tr>
<tr>
<td>N=4, MPCR=0.6</td>
<td>1-5</td>
<td>60</td>
<td>57.0</td>
<td>&lt;</td>
</tr>
<tr>
<td>N=2, MPCR=0.6</td>
<td>1-5</td>
<td>140</td>
<td>51.0</td>
<td>&lt; *</td>
</tr>
<tr>
<td>N=2, MPCR=0.6, Binary</td>
<td>1-5</td>
<td>10</td>
<td>77.5</td>
<td>&gt; ***</td>
</tr>
<tr>
<td>N=4, MPCR=0.3</td>
<td>11-15</td>
<td>240</td>
<td>17.1</td>
<td>&gt; **</td>
</tr>
<tr>
<td>N=4, MPCR=0.6</td>
<td>11-15</td>
<td>60</td>
<td>59.7</td>
<td>&gt; *</td>
</tr>
<tr>
<td>N=2, MPCR=0.6</td>
<td>11-15</td>
<td>140</td>
<td>62.1</td>
<td>&gt; ***</td>
</tr>
<tr>
<td>MPCR=0.6, Binary</td>
<td>11-15</td>
<td>10</td>
<td>80.0</td>
<td>&gt; ***</td>
</tr>
</tbody>
</table>

Note: The table presents sample averages, while the tests of significance are conditional, controlling for restart and path dependency effects. Sign comparisons consistent with the hypotheses are noted in bold.
Table 5: Model results using only last round decisions

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Sequences</th>
<th>Finite</th>
<th>Sign Comparison</th>
<th>Probabilistic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N. Obs.</td>
<td>Average</td>
<td>Average</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=4, MPCR=0.3</td>
<td>1-15</td>
<td>720</td>
<td>6.8</td>
<td>&lt; *</td>
</tr>
<tr>
<td>N=4, MPCR=0.6</td>
<td>1-15</td>
<td>180</td>
<td>43.9</td>
<td>&lt;</td>
</tr>
<tr>
<td>N=2, MPCR=0.6</td>
<td>1-15</td>
<td>420</td>
<td>13.8</td>
<td>&lt; ***</td>
</tr>
<tr>
<td>N=2, MPCR=0.6, Binary</td>
<td>1-15</td>
<td>30</td>
<td>25.0</td>
<td>&lt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=4, MPCR=0.3</td>
<td>1-5</td>
<td>240</td>
<td>11.5</td>
<td>&lt;</td>
</tr>
<tr>
<td>N=4, MPCR=0.6</td>
<td>1-5</td>
<td>60</td>
<td>48.5</td>
<td>&gt;</td>
</tr>
<tr>
<td>N=2, MPCR=0.6</td>
<td>1-5</td>
<td>140</td>
<td>20.5</td>
<td>&lt; ***</td>
</tr>
<tr>
<td>N=2, MPCR=0.6, Binary</td>
<td>1-5</td>
<td>10</td>
<td>37.5</td>
<td>&gt;</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>N=4, MPCR=0.3</td>
<td>11-15</td>
<td>240</td>
<td>3.8</td>
<td>&lt; **</td>
</tr>
<tr>
<td>N=4, MPCR=0.6</td>
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<td>60</td>
<td>40.2</td>
<td>&lt;</td>
</tr>
<tr>
<td>N=2, MPCR=0.6</td>
<td>11-15</td>
<td>140</td>
<td>6.0</td>
<td>&lt; ***</td>
</tr>
<tr>
<td>MPCR=0.6, Binary</td>
<td>11-15</td>
<td>10</td>
<td>16.7</td>
<td>&lt; ***</td>
</tr>
</tbody>
</table>

Note: The table presents sample averages, while the tests of significance are conditional, controlling for restart and path dependency effects. Sign comparisons consistent with the hypotheses are noted in bold.
Table 6: Model results, MPCR=0.3 vs MPCR=0.6 with N=4

<table>
<thead>
<tr>
<th>Treatments</th>
<th>MPCR=0.3</th>
<th>Sign Comparison</th>
<th>MPCR=0.6</th>
<th>Sequences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N. Obs</td>
<td>Average</td>
<td>N. Obs.</td>
<td></td>
</tr>
<tr>
<td>N=4, MPCR=0.3 vs. N=4, MPCR=0.6</td>
<td>2560</td>
<td>12.0</td>
<td>&lt; ***</td>
<td>45.8</td>
</tr>
<tr>
<td>N=4, MPCR=0.3 vs. N=4, MPCR=0.6</td>
<td>704</td>
<td>20.0</td>
<td>&lt; ***</td>
<td>48.4</td>
</tr>
<tr>
<td>N=4, MPCR=0.3 vs. N=4, MPCR=0.6</td>
<td>768</td>
<td>8.5</td>
<td>&lt; ***</td>
<td>40.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatments</th>
<th>MPCR=0.3</th>
<th>Sign Comparison</th>
<th>MPCR=0.6</th>
<th>Sequences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N. Obs</td>
<td>Average</td>
<td>N. Obs.</td>
<td></td>
</tr>
<tr>
<td>N=4, MPCR=0.3 vs. N=4, MPCR=0.6</td>
<td>3600</td>
<td>13.1</td>
<td>&lt; ***</td>
<td>41.7</td>
</tr>
<tr>
<td>N=4, MPCR=0.3 vs. N=4, MPCR=0.6</td>
<td>1200</td>
<td>20.5</td>
<td>&lt; ***</td>
<td>49.5</td>
</tr>
<tr>
<td>N=4, MPCR=0.3 vs. N=4, MPCR=0.6</td>
<td>1200</td>
<td>9.2</td>
<td>&lt; ***</td>
<td>43.1</td>
</tr>
</tbody>
</table>

Note: The table presents sample averages, while the tests of significance are conditional, controlling for restart and path dependency effects. Sign comparisons consistent with the hypotheses are noted in bold.
Table 7: Model results, N=4 vs N=2, Fixed Group Account Function (c)

<table>
<thead>
<tr>
<th>Treatments</th>
<th>N. Obs</th>
<th>Average</th>
<th>MPCR=0.3 Sign Comparison</th>
<th>MPCR=0.6 Average</th>
<th>N. Obs.</th>
<th>Sequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=4, MPCR=0.3 vs. N=2, MPCR=0.6</td>
<td>2560</td>
<td>12.0</td>
<td>&lt; ***</td>
<td>41.7</td>
<td>2240</td>
<td>1-15</td>
</tr>
<tr>
<td>N=4, MPCR=0.3 vs. N=2, MPCR=0.6</td>
<td>704</td>
<td>20.0</td>
<td>&lt; ***</td>
<td>49.5</td>
<td>616</td>
<td>1-5</td>
</tr>
<tr>
<td>N=4, MPCR=0.3 vs. N=2, MPCR=0.6</td>
<td>768</td>
<td>8.5</td>
<td>&lt; ***</td>
<td>43.1</td>
<td>600</td>
<td>11-15</td>
</tr>
</tbody>
</table>

Finite

<table>
<thead>
<tr>
<th>Treatments</th>
<th>N. Obs</th>
<th>Average</th>
<th>MPCR=0.3 Sign Comparison</th>
<th>MPCR=0.6 Average</th>
<th>N. Obs.</th>
<th>Sequences</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=4, MPCR=0.3 vs. N=2, MPCR=0.6</td>
<td>3600</td>
<td>13.1</td>
<td>&lt; ***</td>
<td>52.6</td>
<td>2100</td>
<td>1-15</td>
</tr>
<tr>
<td>N=4, MPCR=0.3 vs. N=2, MPCR=0.6</td>
<td>1200</td>
<td>20.5</td>
<td>&lt; ***</td>
<td>53.0</td>
<td>700</td>
<td>1-5</td>
</tr>
<tr>
<td>N=4, MPCR=0.3 vs. N=2, MPCR=0.6</td>
<td>1200</td>
<td>9.2</td>
<td>&lt; ***</td>
<td>51.8</td>
<td>700</td>
<td>11-15</td>
</tr>
</tbody>
</table>

Note: The table presents sample averages, while the tests of significance are conditional, controlling for restart and path dependency effects. Sign comparisons consistent with the hypotheses are noted in bold.
Table 8: Model results, N=4 vs N=2, MPCR=0.6

<table>
<thead>
<tr>
<th>Treatments</th>
<th>N=2</th>
<th>Sign Comparison</th>
<th>N=4</th>
<th>Sequences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N. Obs.</td>
<td>Average</td>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>N=4, MPCR=0.6 vs. N=2, MPCR=0.6</td>
<td>2240</td>
<td>41.7</td>
<td>**</td>
<td>45.8</td>
</tr>
<tr>
<td>N=4, MPCR=0.6 vs. N=2, MPCR=0.6</td>
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<td>49.5</td>
<td></td>
<td>48.4</td>
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<tr>
<td>N=4, MPCR=0.6 vs. N=2, MPCR=0.6</td>
<td>600</td>
<td>43.1</td>
<td>&gt;</td>
<td>40.5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Treatments</th>
<th>N=2</th>
<th>Sign Comparison</th>
<th>N=4</th>
<th>Sequences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N. Obs.</td>
<td>Average</td>
<td></td>
<td>Average</td>
</tr>
<tr>
<td>N=4, MPCR=0.6 vs. N=2, MPCR=0.6</td>
<td>2100</td>
<td>41.0</td>
<td>***</td>
<td>52.6</td>
</tr>
<tr>
<td>N=4, MPCR=0.6 vs. N=2, MPCR=0.6</td>
<td>700</td>
<td>40.3</td>
<td>***</td>
<td>53.0</td>
</tr>
<tr>
<td>N=4, MPCR=0.6 vs. N=2, MPCR=0.6</td>
<td>700</td>
<td>40.6</td>
<td>***</td>
<td>51.8</td>
</tr>
</tbody>
</table>

Note: The table presents sample averages, while the tests of significance are conditional, controlling for restart and path dependency effects. Sign comparisons consistent with the hypotheses are noted in bold.

Our interpretation of the results from this study is that in both the probabilistic and finitely repeated settings, the shadow of the future may be a part of the decision process. This argument is consistent with the forward-looking modeling approach developed by Isaac et al. (1994), where subjects’ behavior was interpreted as a willingness to cooperate in repeated VCM decision settings as long as their cooperative behavior was sufficiently rewarded by reciprocal behavior by others.

6 Conclusions and Suggestions for Further Research

This study contributes to the literature contrasting the evolution of cooperation in probabilistically and finitely repeated social dilemma games by examining contribution decisions in linear voluntary contribution public goods games. The experimental design was motivated by that of Dal Bó (2005), where subjects make decisions in the context of repeated sequences of decisions, and
groups are fixed within a sequence but not across sequences. The number of decision rounds in a sequence is either finite with a known end round or probabilistic.

In summary, we do not find strong evidence that overall cooperation rates are affected by whether the number of decision rounds is finite or determined probabilistically. We do observe, however, that there is a more pronounced decrease in cooperation in the final round of repeated sequences with a commonly known end round compared to those in which the end round is determined probabilistically. In addition, our results for both the finite and probabilistic decision settings support several of the findings from previous studies examining VCM in finite decision settings. In particular, holding group size constant, we find that contributions increase with increases in MPCR. We also provide evidence that, holding MPCR constant, contributions increase as group size increases from N=2 to N=4. To our knowledge, this is the first study to examine a VCM setting with a large number of decision sequences, where groups are re-matched after each sequence. In this setting, in both the probabilistic and finite settings we find evidence of a restart effect at the beginning of each decision round.

We interpret the results from this study as providing further evidence that, in both the probabilistic and finitely repeated settings, the shadow of the future may be a part of the decision process. In this sense, the results reported above and those from prior studies suggest at least two directions for future research involving VCM in both probabilistic and finitely repeated decision settings. The first is gaining a better understanding of the relationship between changes in MPCR, the resulting effect on δ, and how subjects respond to these changes. In addition, both Dal Bó (2005) and Isaac et al. (1994) provide evidence that the level of cooperation increases with the number of rounds in the decision sequence. These results suggest that examining subjects’ responses to a systematic change in the number of decision rounds in repeated-decision sequences may prove fruitful in creating a better understanding of how subjects respond to changes in the shadow of the future.
References


Appendix A: Instructions, N =4, MPCR=0.3, Finite and Probabilistic

Instructions for the Finite Decision Settings

Summary Instructions

• Individuals are randomly placed in groups of 4. Each decision round, each person receives an endowment of 25 tokens. Each person must decide how to divide their tokens between a Private Account and a Group Account. Each person has a Private Account. However, each group of 4 persons has only one Group Account.

• Each individual earns $.01 for each token they retain in their Private Account. Each token placed in the Group Account earns $.003 for each person in the group, earning the group $.012 per token.

• The experiment will consist of 15 sequences. Each sequence consists of 5 decision rounds.

• Each group of 4 remains together during a sequence. However, at the beginning of each sequence, individuals are randomly placed in new groups of 4.
Now that the experiment has begun, please make sure that your cell phone is switched off.

We ask that you do not talk with one another.

If you have a question after reading the instructions, please raise your hand and the experimenter will answer your question in private.

Also, please do not turn around or peer onto the screens of other participants.

You will receive $5 for showing up to the experiment and you will have additional earnings for every round of the experiment. The entire experiment will last about 1 hour.

Please read the instructions carefully, as the amount of money you earn depends on your decisions during this experiment as well as the decisions of your group members.

Please note: You will not be able to return to this page once you hit the 'Continue' button.
Instructions: 3 out of 8

Individuals are randomly placed into groups of 4. The experiment will consist of 15 sequences. Each sequence consists of 5 decision making rounds. Each group of 4 remains together during a sequence. However, at the beginning of each sequence, individuals are randomly placed into new groups of 4.

Starting Balances

Everyone in your group has an Private Account and your group of four has a Group Account. Both the Private Account and the Group Account begin with $0 balance in them. Each person receives 25 tokens at the beginning of each round and decides how to divide the tokens between the two accounts.

At the end of each round, your earnings for the round (explanations on a following screen) will be recorded and the number of tokens in each account will reset to 0. Your final earnings will be the sum of the amounts that you earn in each round.

Please note: You will not be able to return to this page once you hit the "Continue" button.

Instructions: 4 out of 8

Decision Tasks

At the start of each round, each individual will be endowed with 25 tokens. In each round, each individual must decide how to divide their tokens between their Private Account and a Group Account. Each person in the group has a Private Account, however, there is only one Group Account for the entire group.

Each individual will earn $0.01 for each token that they retain in their Private Account in any decision making round. Thus, if an individual chooses to retain all of their 25 tokens in their Private Account, they will earn $0.25 in that round from their Private Account.

Each token in the Group Account yields a total return of $0.012. Everyone in the group will receive the same portion of earnings from the Group Account. Thus if 4 people are in a group, each individual will receive 144-15% of the group earnings from the Group Account, regardless of the number of tokens that they themselves place in the Group Account.

It is important to realize that EVERYONE in the group receives a 1/4 share of the earnings from the Group Account. This is true for each individual regardless of the number of tokens that the individual places in the Group Account.

Please note: You will not be able to return to this page once you hit the "Continue" button.
Instructions: 5 out of 8

Exercises
Let us now explain how your earnings are calculated. In each group of four, an individual's earnings per round will be:

$$0.01 \times \text{Number of tokens in that person's Private Account} + 0.003 \times \text{Number of tokens in the Group Account}$$

On the next two screens you will see some examples of how earnings are calculated.

Please note: You will not be able to return to this page once you hit the 'Continue' button.

Instructions: 6 out of 8

Example 1: Every person in the group moves 20 tokens to the Group Account.

There are 5 tokens in the Group Account.
Every individual receives $0.20 (this round, because:

$$0.01 \times 20 \text{ tokens in Private Account} + 0.003 \times 0 \text{ tokens in Group Account} = 0.20$$

The total amount earned in the group this round is $1.00.

Example 2: Every person in the group moves 25 tokens to the Group Account.

There are 100 tokens in the Group Account.
Every individual receives $0.38 (this round, because:

$$0.01 \times 6 \text{ tokens in Private Account} + 0.003 \times 100 \text{ tokens in Group Account} = 0.38$$

The total amount earned in the group this round is $1.90.
We will now randomly select some Group Account contributions for each person and calculate the corresponding earnings.

**Example 1:**
- Person 1 moves 6 tokens to the Group Account.
- Person 2 moves 21 tokens to the Group Account.
- Person 3 moves 3 tokens to the Group Account.
- Person 4 moves 18 tokens to the Group Account.

There are 61 tokens in the Group Account:
- Person 1 receives $0.255/this round:
  \[ \frac{6 \times 0.35}{18 \text{ tokens in Private Account}} + \frac{6 \times 0.35}{6 \text{ tokens in Group Account}} \approx 0.255 \]
- Person 2 receives $0.176/this round:
  \[ \frac{21 \times 0.35}{12 \text{ tokens in Private Account}} + \frac{21 \times 0.35}{4 \text{ tokens in Group Account}} \approx 0.176 \]
- Person 3 receives $0.335/this round:
  \[ \frac{3 \times 0.35}{4 \text{ tokens in Private Account}} + \frac{3 \times 0.35}{1 \text{ token in Group Account}} \approx 0.335 \]
- Person 4 receives $0.205/this round:
  \[ \frac{18 \times 0.35}{12 \text{ tokens in Private Account}} + \frac{18 \times 0.35}{3 \text{ tokens in Group Account}} \approx 0.205 \]

The total amount earned in the group this round is $1.095.

---

**Instructions:**

Information
Prior to entering your decisions for future rounds, you will be shown the results from the previous round. You will also be able to review the results from ANY previous round in the sequence.

Before making actual decisions that effect your earnings, you will answer a short quiz designed to make sure you understood the decision task.

Please note: You will not be able to return to this page once you hit the ‘Start Quiz’ button.
Quiz: 1 out of 2

Question 1

a) How many people are in your group (you included)?

b) How much is added to your per round earnings for every token that you place in your Private Account? (Give your answer in dollars, omitting the "$" sign.)

c) How much is added to your per round earnings for every token that you place in the Group Account? (Give your answer in dollars, omitting the "$" sign.)

d) How much is added to each of your group members' per round earnings for every token that you place in the Group Account? (Give your answer in dollars, omitting the "$" sign.)

Quiz: 2 out of 2

As a reminder, this is how earnings are calculated:

\[ \frac{0.01 \times \text{Number of tokens in that person's Private Account}}{0.06 \times \text{Number of tokens in the Group Account}} \]

If you would like to use a calculator to answer this question, click the button in the bottom right corner of the screen.

Question 2

Consider the following scenario: Every person in your group (you included) places 10 tokens into the Group Account.

a) How many tokens are in the Group Account?

b) After moving 10 tokens to the Group Account, how many tokens are in your Private Account?

c) How much do you earn this round? (Give your answer in dollars, omitting the "$" sign.)
Your tokens divide between your private account and the group account:

Tokens you choose to move to the Group Account: 25

Summary Information for current round:

The number of tokens you choose to move to the Group Account: 25
Total number of tokens moved to the Group Account by the group: 25
Every group member’s earnings from the Group Account: $0.003 x 25 = $0.075

Your earnings from your Private Account: $0.01 x 0 = $0.000
Your total earnings in this period: $0.075
Your tokens to divide between your private account and the group account:

Token you choose to move to the Group Account:

<table>
<thead>
<tr>
<th>Period</th>
<th>Tokens willing to move to the Group Account</th>
<th>Total number of tokens you (as DP) moved to the Group Account</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

**End of Sequence**

You have now completed the decision sequence.

In this sequence you have earned $0.020
You will now be randomly *regrouped* into a new group of 4.
Summary Instructions

- Individuals are randomly placed in groups of 4. Each decision round, each person receives an endowment of 25 tokens. Each person must decide how to divide their tokens between a Private Account and a Group Account. Each person has a Private Account. However, each group of 4 persons has only one Group Account.

- Each individual earns $.01 for each token they retain in their Private Account. Each token placed in the Group Account earns $.003 for each person in the group, earning the group $.012 per token.

- The experiment may consist of numerous sequences. The number of decision rounds in each sequence is determined by a computerized random draw. At the end of each decision round in a sequence, there is an 80% chance that the sequence of decision rounds will continue and a 20% chance that the sequence will end.

- Each group of 4 remains together during a sequence. However, at the beginning of each sequence, individuals are randomly placed in new groups of 4.
Instructions: 1 out of 8

Now that the experiment has begun, please make sure that your cell phone is switched off.

We ask that you do not talk with one another.

If you have a question after reading the instructions, please raise your hand and the experimenter will answer your question in private.

Also, please do not turn around or peer onto the screens of other participants.

Continue

Instructions: 2 out of 8

You will receive $5 for showing up to this experiment and you will have additional earnings for every round of the experiment.

Please read the instructions carefully, as the amount of money you earn depends on your decisions during this experiment as well as the decisions of your group members.

Please note: You will not be able to return to this page once you hit the 'Continue' button.

Continue
Individuals are randomly placed into groups of 4. The experiment will consist of one or more sequences. The number of decision rounds in each sequence is determined by a computerized random draw. At the end of each decision round in a sequence, there is an 80% chance that the sequence of decision rounds will continue and a 20% chance that the sequence will end. Each group of 4 remains together during a sequence. However, at the beginning of each sequence, individuals are randomly placed into new groups of 4.

Starting Procedures:
Everyone in your group has a Private Account and your group of four has a Group Account. Both the Private Account and the Group Account begin with 0 tokens in them. Each person receives 25 tokens at the beginning of each round and decides how to divide the tokens between the two accounts.

At the end of each round, your earnings for the round (explained on the following screen) will be recorded and the number of tokens in each account will reset to 0. Your final earnings will be the sum of the amounts that you earn in each round.

Please note: You will not be able to return to this page once you hit the ‘Continue’ button.

Instructions: 4 out of 8

Decision Task:
At the start of each round, each individual will be endowed with 25 tokens. In each round, each individual must decide how to divide their tokens between their Private Account and a Group Account. Each person in the group has a Private Account, however, there is only one Group Account for the entire group.

Each individual will earn $0.01 for each token that they retain in their Private Account in any decision-making round. Thus, if an individual chooses to retain all of their 25 tokens in their Private Account, they will earn $0.25 in that round from their Private Account.

Each token in the Group Account yields a total return of $0.012. Everyone in the group will receive the same portion of earnings from the Group Account. Thus if 4 people are in a group, each individual will receive 1/4 or 25% of the group earnings from the Group Account, regardless of the number of tokens that they themselves place in the Group Account.

It is important to realize that EVERYONE in the group receives a 1/4 share of the earnings from the Group Account. This is true for each individual regardless of the number of tokens that the individual places in the Group Account.

Please note: You will not be able to return to this page once you hit the ‘Continue’ button.
Example 1: Every person in the group moves 6 tokens to the Group Account.

There are 9 tokens in the Group Account.
Every individual receives $0.25 this round, because:

$0.25 x 9 tokens in Private Account
+ $3.00 x 1 token in Group Account
= $3.25

The total amount earned in the group this round is $3.25.

Example 2: Every person in the group moves 25 tokens to the Group Account.

There are 100 tokens in the Group Account.
Every individual receives $0.30 this round, because:

$0.30 x 9 tokens in Private Account
+ $9.00 x 1 token in Group Account
= $9.30

The total amount earned in the group this round is $9.30.

Earnings:

Let us now explain how your earnings are calculated. In each group of four, an individual’s earnings per round will be:

$0.61 \times \text{Number of tokens in that person’s Private Account} +$0.003 \times \text{Number of tokens in the Group Account}$

On the next two screens you will see some examples of how earnings are calculated.

Please note: You will not be able to return to this page once you hit the ‘Continue’ button.
We will now randomly select some Group Account contributions for each person and calculate the corresponding earnings.

**Example 3**

Person 1 moves 2 tokens to the Group Account.
Person 2 moves 25 tokens to the Group Account.
Person 3 moves 10 tokens to the Group Account.
Person 4 moves 1 tokens to the Group Account.

There are 42 tokens in the Group Account.
Person 1 receives $8.250 this round

- $0.25 x 5 tokens in Private Account
- $8.00 x 42 tokens in Group Account
  = $8.250

Person 2 receives $8.195 this round

- $0.19 x 9 tokens in Private Account
- $8.00 x 42 tokens in Group Account
  = $8.195

Person 3 receives $8.200 this round

- $0.20 x 9 tokens in Private Account
- $8.00 x 42 tokens in Group Account
  = $8.200

Person 4 receives $8.420 this round

- $0.42 x 9 tokens in Private Account
- $8.00 x 42 tokens in Group Account
  = $8.420

The total amount earned in the group this round is $31.405.

---

**Instructions: 8 out of 8**

How the final decision-making round will be determined:
At the end of each decision round there is an 80% chance that there will be another decision round, and thus a 20% chance that the decision sequence will end.
To determine whether the sequence will continue or end, the computer will draw a random integer between 1 and 100, where each integer has a 1% chance of occurring. If the randomly drawn integer is between 1 and 80, the sequence will continue with another decision round. If the randomly drawn integer is greater than 80, the sequence will end.
You will be informed of this continue-or-end decision when all participants have entered a decision for the current round.

Information:
Prior to entering your decisions for future rounds, you will be shown the results from the previous round. You will also be able to review the results from all previous rounds in the sequence.

Before making actual decisions that affect your earnings, you will answer a short quiz designed to make sure you understand the decision task.

Please note: You will not be able to return to this page once you hit the "Start Quiz" button.
Question 1

a) How many people are in your group (you included)?

b) How much is added to your per round earnings for every token that you place in your Private Account? (Give your answer in decimals.)

c) How much is added to your per round earnings for every token that you place in the Group Account? (Give your answer in decimals.)

d) How much is added to each of your group members’ per round earnings for every token that you place in the Group Account? (Give your answer in decimals.)

Question 2

As a reminder, this is how earnings are calculated:

\[ \$0.01 \times \text{Number of tokens in that person’s Private Account} + \$0.002 \times \text{Number of tokens in the Group Account} \]

If you would like to use a calculator to answer this question, click the button in the bottom right corner of the screen.

Consider the following scenario: Every person in your group (you included) places 10 tokens into the Group Account:

a) How many tokens are in the Group Account?

b) After moving 10 tokens to the Group Account, how many tokens are in your Private Account?

c) How much do you earn this round? (Give your answer in decimals.)
Your tokens are divided between your private account and the group account.

Tokens you chose to move to the Group Account: 12

<table>
<thead>
<tr>
<th>Rank</th>
<th>Tokens 1st round to the Group Account</th>
<th>Total number of tokens moved to the Group Account by the group</th>
<th>Every group member's earnings from the Group Account</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>$0.003 \times 12 = $0.036</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Summary Information for round 1:

- The number of tokens you chose to move to the Group Account: 12
- Total number of tokens moved to the Group Account by the group: 12
- Every group member's earnings from the Group Account: $0.003 \times 12 = $0.036

Your earnings from your Private Account: $0.01 \times 13 = $0.130

Your total earnings in this round: $0.156

Next: Continue
To determine whether this sequence will continue or end the computer has drawn a random integer between 1 and 100, where each integer has a 1% chance of occurring. If the randomly drawn integer is between 1 and 80, the sequence will continue with another decision round. If the randomly drawn integer is between 81 and 100, the sequence will end.

The random integer is 12 which is not greater than 80, so the sequence continues.

End of Sequence
You have now completed the decision sequence.

In this sequence you have earned $0.494
You will now be randomly regrouped into a new group of 4.