Indirect Reciprocity in Cyclical Networks

- An Experimental Study -

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June 30, 2003

Abstract

A cyclical network of indirect reciprocity is derived organizing 3- or 6-person groups into rings of social interaction where the first individual can help the second, the second the third, and so on till the last, who in return can help the first. Mutual cooperation is triggered by assuming that what one passes on to the next is multiplied by a factor of 3. Participants play repeatedly either in a partner or in a stranger condition, and take their decisions first simultaneously and then sequentially. We find that pure indirect reciprocity enables mutual cooperation although strategic considerations and group size are important too.

Keywords:

JEL Classification: C91, C72, D3

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1 Introduction

According to Alexander (1987), networks of indirect reciprocity are crucial for understanding the evolution of large-scale cooperation among humans. Such networks arise whenever individuals help and receive help from different persons: A helps B, who helps C, who helps D, who finally helps A. Alexander calls this kind of interaction "indirect reciprocity" and considers, among others, two possibilities. First, A helps B only if B helps C. Second, A helps B only if A receives help from D. In both cases, conditional behavior is based on local information. Each agent knows the behavior of the individuals with whom she interacts, but does not know what happens along the entire chain of indirect reciprocity.

So far the literature has focused to a large extent on direct reciprocity, i.e. a direct reaction to the act of an individual one has interacted with before.[1] Less attention has been paid to indirect reciprocity, usually interpreted as rewarding (punishing) people who were kind (hostile) towards others. In most experiments, the social status of the potential receiver affects the donor's decision, where the term social status normally refers to an image score, i.e. a record of the individual's past level of cooperation. Recent experimental studies of this form of indirect reciprocity include Wedekind & Milinski (2000) and Seinen & Schram (2001), who examine behavior in a 2-person repeated helping game[2] where donors can observe recipients' image score. They conclude that indirect reciprocity is important since many donors base their helping decision on the image score of the recipient. Dufwenberg, Gneezy, Güth & Van Damme (2001)

[1]Many experimental studies have observed direct reciprocal behavior, which can be either positive (rewarding kind actions) or negative (punishing unkind actions). Relevant studies include public goods games (Croson 2000, Brandts & Schram 2001), prisoner's dilemmas (Andreoni & Miller 1993, Cooper, DeJong, Forsythe & Ross 1996), ultimatum games (Güth, Schmittberger & Schwarze 1982, Camerer & Thaler 1995), investment games (Berg, Dickhaut & McCabe 1995, Gneezy, Güth & Verboven 2000), and gift exchange games (Fehr, Kirchsteiger & Riedl 1993, 1998, Gächter & Falk forthcoming).

[2]The helping game is a degenerate game in which a donor has the choice of either "helping" a recipient at a cost smaller than the recipient's benefit, or "passing", in which case both individuals receive zero.

and Güth, Königstein, Marchand & Nehring (2001) find as well evidence of indirect reciprocity in an investment game where instead of repaying their own donor, receivers repay a different donor whose attitude to cooperate is commonly known.

In this paper, we investigate experimentally the second type of indirect reciprocity envisioned by Alexander. In our experiment, participants know only what is done to themselves and have no information about the cooperative attitudes (i.e., the image score) of the person whom they can help or of any other individual in their group.[3] We believe that this form of indirect reciprocity captures better real-world situations than that requiring knowledge about the receivers' image score. In general, one would expect that individuals have much better information about what others did to them than about others' interactions with third parties.

To implement networks of indirect reciprocity, we use a variant of the investment game introduced by Berg et al. (1995). We arrange individuals into a ring of n players. Each individual i can receive an investment from her left hand-neighbor $i-1$ and, after learning only about how much she receives, she can send an investment to her right hand-neighbor $i+1$. We close the ring by allowing individual n to return the investment to individual 1.[4] Cooperation is beneficial because individual $i+1$ (for all $i = 1, ..., n$) receives three times the investment of i, i.e. the social cost of giving is smaller than its social benefits.

The hypothesis tested in this paper claims that people are nicer to others if third parties were nice to them. Boyd & Richerson (1989) view this as a generalization of tit-for-tat to the case of indirect reciprocity. Their model also suggests that the conditions necessary for the evolution of indirect reciprocity become more restrictive as group size increases. We test the effect of group size

[3] This type of indirect reciprocity has been studied theoretically by Boyd & Richerson (1989) who investigated its evolutionary properties.

[4] On the word of Boyd & Richerson (1989, p. 232), "... Real social networks are made up of many interconnected loops of varying lengths. Individuals are at the center of a web of potentially cooperative interactions."

on indirect reciprocity by comparing 3- to 6-person cyclical networks.

Note that we explicitly define reciprocity as (conditional) behavior and do not refer to reciprocity as a motivation or a preference. In this paper, we do not intend to contribute to the discussions on the motivation underlying reciprocal behavior.[5] Instead, we focus on the consequences that indirect reciprocal behavior has for the repeated interaction among individuals in a (closed) loop.

It is widely acknowledged that indirect reciprocity works throughout reputation and status, and that the interaction of indirect reciprocity and strategic reputation building can have substantial impact on cooperation.[6] Based on Seinen & Schram (2001)'s design, Engelmann & Fischbacher (2002) conducted an experimental helping game where in any period only half of the players had a public image score and hence a strategic incentive to help. In this way, they study pure indirect reciprocity uncontaminated by strategic concerns. They find clear evidence for pure indirect reciprocity, but they also find very strong effects of strategic reputation building: The average helping rate of donors with a public score is more than twice the average helping rate of donors without.

To assess the interplay of indirect reciprocity and strategic reputation building, we repeat the game a finite number of times and vary the rematching procedure. In particular, we distinguish between a partners condition (where the same group interacts for 10 periods) and a strangers condition (where groups are randomly re-assembled after each period). While partners may have an incentive to play strategically in the sense of Kreps, Milgrom, Roberts & Wilson (1982), strangers cannot be motivated by strategic reasoning. By comparing the decisions made by "partners" with those made by "strangers", we can evaluate the impact of strategic reputation on investment rates.

Can indirect reciprocity play a role also when decisions are simultaneous

[5]The motivation underlying reciprocity can be related to other regarding preferences, such as fairness (e.g., Rabin 1993, Fehr & Schmidt 1999, Bolton & Ockenfels 2000) or altruism (e.g., Trivers 1971, Levine 1998), or to the pursuit of efficiency gains throughout cooperation (e.g., Brandts & Schram 2001).

[6]Cf., Alexander (1987). See also Harbaugh (1998) and Milinski, Semmann & Krambeck (2002).

and independent? To explore this issue, we enable all n players in the ring to decide simultaneously rather than successively. Though differently framed, both decision protocols can trigger mutual cooperation based on indirect reciprocity: Players can always condition their behavior on the amount that they receive.

In Section 2 we describe our experimental procedures and formulate our hypotheses. In Section 3 we present and discuss the results. We find that the average amounts sent are positive for both partners and strangers. The latter provides evidence for pure indirect reciprocity. The average amount sent by partners is, however, significantly higher than the average amount sent by strangers. Hence strategic reputation building plays an important role as well. Furthermore, we find that small groups are more cooperative than large ones. Our results are therefore consistent with the argument by Boyd & Richerson (1989) that indirect reciprocity is likely to be more effective for relatively small, close, long-lasting loops. We conclude in Section 4 by summarizing our main findings.

2 Experimental procedures and hypotheses

Let $N = \{1, 2, ..., n\}$ be an ordered group of players, each endowed with $e = 5$ ECU.[7] The only decision of player i (for all $i \in N$) is how much of e she wants to send to $i+1$, where $n+1 = 1$. Let x_i denote the integer amount sent, with $x_i \in \{0, 1, 2, 3, 4, 5\}$. As in the investment game of Berg et al. (1995), $i+1$ receives from i not just x_i but $3x_i$. Thus, the final earning, U_i, of each player i depends on her own choice x_i, and the choice x_{i-1} of the left neighbor $i-1$ via

$$U_i = e - x_i + 3x_{i-1}, \quad \text{where } i{-}1 = n \text{ for } i = 1.$$

The game theoretic solution, assuming opportunistically rational players and common knowledge of opportunism,[8] is to send zero, i.e. $x_i^* = 0$ for all

[7] ECU stands for Experimental Currency Unit.

[8] Opportunism means that individuals are only interested in their own monetary reward.

$i \in N$.[9] On the other hand, symmetric efficiency requires full cooperation in the sense that $x_i^+ = e$ for all $i \in N$.

Within this basic experimental setting, three aspects were varied in a systematic manner:

i) the group size ($n = 3$ versus $n = 6$),

ii) the rematching procedure (partners versus strangers condition), and

iii) the protocol specifying how decisions could be taken (I-protocol versus S-protocol).

Under the I-protocol, all players $i \in N$ decide independently and simultaneously how much they want to send, being informed of $3x_{i-1}$ from period 2 onward. Under the S-protocol, players decide sequentially, i.e. player 1 chooses x_1; then, being informed of $3x_1$, player 2 chooses x_2; and so on till finally, being informed of $3x_{n-1}$, player n chooses x_n. In both decision protocols, players get to know only how much they receive; they never learn the investment decisions of the other group members. Participants encountered successively both decision protocols (within-subjects factor) with the group size and the rematching procedure as between-subjects factors.

The computerized experiment was conducted at the experimental laboratory of the Max Planck Institute in Jena, Germany.[10] Participants, mainly students of business administration and economics, were volunteers recruited by mail-shot invitations. After being seated at a computer terminal, participants received written instructions (see Appendix A for an English translation). Questions to clarify the rules were answered privately. Once the understanding of the instructions was ensured, the experiment started. Each session took about $1\frac{1}{2}$ hour. We implemented an exchange rate of 100 ECU = €4.00. The average earnings per subject was €16.42 (including a show-up fee of €2.50). At the end of the experiment, subjects were asked to fill in a questionnaire

[9] Formally, this solution behavior can be derived by repeated elimination of (weakly) dominated strategies.

[10] The software was produced by means of Fischbacher (1999)'s *z-Tree*.

concerning the rationale for their choices in the game (see Appendix B).

In total, we ran nine sessions. Each session involved 24 participants, and consisted of four subsequent phases of 10 periods each. The first two phases employed the I-protocol and the last two phases the S-protocol.[11] Participants in the S-protocol had the same player number in both phases.

There were two partners sessions with group of size $n = 3$, four partners sessions with $n = 6$, and three strangers sessions with $n = 3$. Hence, only partners interacted in large groups.[12] In the partners sessions, subjects stayed in the same groups throughout an entire phase (i.e., groups were randomly rematched every 10 periods). In the strangers sessions, new groups were randomly formed in each of the 40 repetitions.

In the partners (strangers) sessions we distinguished matching groups of size $2n$ ($4n$), thus guaranteeing 8 independent observations per each group size for the partners condition, and 6 independent observations for the strangers conditions. Participants were not informed that random rematching of the groups had been restricted in such a way.

As pointed out above, (common knowledge of) rationality requires $x_i^* = 0$ for all $i \in N$. Applying the backward induction argument, this is the unique subgame perfect equilibrium outcome of the repeated game. Nevertheless, the multiplication of the amount sent by a factor of 3 provides a strong incentive to rely on indirect reciprocity and engage in mutually beneficial cooperation. Several studies suggest that behavior is guided to some extent by reciprocity. Although the literature has mainly focused on direct reciprocity, several authors have stressed that the concept does not need to be restricted to two individuals,[13] and experimental evidence has demonstrated that indirect reciprocity is

[11] We decided for the ordering $I-S$ because, due to the asymmetry of the players, the S-protocol seems more complex than the I-protocol.

[12] As stated in the Introduction, our main reason for varying the rematching procedure is to separate strategic play by partners from non-strategic play by strangers. In our view, comparisons based on one group size suffice to this purpose.

[13] See, e.g., Trivers (1971), Sugden (1986), Alexander (1987), Binmore (1992).

an important phenomenon in the laboratory.[14] Consequently, we expect indirect reciprocity to be equally important in our context, and test the following hypothesis:

Hypothesis 1 *Regardless of the decision protocol, subjects in both the partners and the strangers conditions send on average positive amounts.*

Experimental evidence suggests that cooperation is higher when strategic reputation building interacts with indirect reciprocity than when the latter is uncontaminated by strategic concerns.[15] In our setting this means that partners, who have a strategic incentive to build up the reputation for being cooperative, send higher amounts than strangers. Previous public goods experiments provide mixed evidence regarding the (dis)similarity in behavior between partners and strangers.[16] Yet, using a larger number of independent observations than other similar experiments, Keser & van Winden (2000) observe that partners, on average, contribute significantly more than strangers. In our view, non parametric test statistics based on a high number of independent observations are more reliable than studies with only few independent observations. Thus, in line with Keser and van Winden and with the evidence concerning the enforcement of indirect reciprocity by strategic reasoning, we expect less cooperation in case of the strangers condition and test:

Hypothesis 2 *In both the I- and the S-protocols, strangers send on average lower amounts than partners.*

Our last hypothesis concerns the effects of group size variation. In Boyd & Richerson's (1989) model, increasing group size reduces the extend of coop-

[14] Cf., Kahneman, Knetsch & Thaler (1986), Dufwenberg et al. (2001), Güth et al. (2001), Wedekind & Milinski (2000), Seinen & Schram (2001), and Engelmann & Fischbacher (2002).

[15] Cf., Engelmann & Fischbacher (2002).

[16] In his seminal article, Andreoni (1988) observes that strangers contribute more to the public good than partners. A similar result is reported by Palfrey & Prisbey (1996). Weimann (1994), on the other hand, finds no difference in the contribution levels of the two conditions. More recently, Croson (1996) reports a replication of Andreoni's experiment but obtains the opposite results: In her experiment, partners contribute significantly more than strangers.

eration. Here this implies that the larger the group, the smaller the players' investment.[17] Thus, we claim:

Hypothesis 3 *Regardless of the decision protocol, groups of size 6 send on average lower amounts than groups of size 3.*

3 Experimental results

In reporting our results we proceed as follows. First, we present a general overview and analysis of investment behavior both over periods and across treatments. This part of the analysis is based on data for the independent groups.[18] Then, we try to identify some features of individual behavior by studying participants' strategies in more depth.

3.1 General results

Figure 1 displays the time paths of the average amounts sent in the strangers and the partners conditions, the I- (first 20 periods) and the S-protocols (last 20 periods), and 3- and 6-person groups.

Insert Figure 1 about here.

The predictions of the subgame perfect equilibrium are clearly rejected. On average all players, independently of the decision protocol, the group size and the rematching procedure, send positive amounts. Partners in 3-person groups send on average 3.68 (3.35) ECU in the first (second) 10-period phase of the I-protocol and 3.62 (3.61) ECU in the first (second) phase of the S-protocol. The respective averages for groups of size 6 are 2.12 (1.98) and 2.46 (2.00). Concerning the strangers, they invest on average 2.87 (2.65) in the first (second) phase of the I-protocol and 2.32 (2.38) in the first (second) phase of the S-protocol. Hence, we report the following result:

[17] On this issue, see also Olson (1971) and Selten (1973).

[18] Due to our rematching system, the numbers of statistically independent groups are 8 for each n in the partners condition and 6 in the strangers condition.

Result 1 *Regardless of the decision protocol, the group size and the rematching procedure, average amounts sent are positive.*

This finding provides immediate support for the hypothesis that players are indirectly reciprocal and, in particular, for the existence of pure indirect reciprocity uncontaminated by strategic concerns.

Figure 1 shows various things. First of all, there is a clear order in investment decisions: Partners invest on average more than strangers, and groups of size 3 invest more than groups of size 6. Second, partners (especially in groups of size 3) exhibit a sharp end-effect in each of the four 10-period phases, with average donations dropping drastically in the final period of each phase. No end-effect seems to be present in the strangers condition. Finally, the figure reveals a "restart effect" in all treatments: Regardless of the decision protocol, the group size and the rematching procedure, cooperation regains in strength when a new phase starts.[19]

Using the independent matching group averages per treatment as independent observations, we conducted non parametric Wilcoxon rank sum tests (one-tailed) for comparing the two between-subjects treatments. The results indicate that groups of size 3 invest significantly more than groups of size 6 ($p < 0.01\%$ for both the I- and the S-protocol) and that, within 3-person groups, partners invest significantly more than strangers ($p < 0.05\%$ for both decision protocols). Therefore (even with a conservative non parametric test) we find treatment effects in the sense that both the group size and the rematching procedure affect choices. This influence is in the direction conjectured by Hypotheses 2 and 3, implying that partners try indeed to strategically build a reputation.

Result 2 *Independently of the decision protocol, players are significantly more cooperative when $n = 3$ than when $n = 6$, and when they interact in a partners, rather than strangers, condition.*

[19]Andreoni (1988) introduced and studied restart effects in public goods experiments. On this issue see also Croson (1996).

Statistical corroboration of the final round effect for the partners condition comes from a series of Wilcoxon signed-rank tests (one-tailed) comparing the independent group averages in the first nine periods and in the last (i.e., tenth) period for each of the four phases. The tests show that, whatever phase and group size, partners send significantly higher amounts in the first nine periods than in the final period ($p < 0.05\%$). On the contrary, for the strangers we can reject the null hypothesis that they donate the same or less during the first nine periods than in the final period only for the first phase of the S-protocol ($p = 0.03$). This confirms that positive amounts sent by the partners in earlier periods were mainly attempts to establish the reputation for being cooperative; namely, by sending positive amounts, partners invest in the reputation for cooperativeness towards their group members, whom they try to exploit strategically by defecting at the very end.

Concerning the restart-effect, for each decision protocol, group size and rematching procedure we applied a one-tailed Wilcoxon signed-rank test (based on independent group averages) to compare the average amount sent in period 10 to the average amount sent in period 11. For the partners, whatever group size and decision protocol, we can reject the hypothesis that they send the same or more in period 10 than in period 11 at the 1% significance level. For the strangers the restart effect is significant under the S-protocol ($p = 0.038$) and insignificant (but present) under the I-protocol ($p = 0.076$). These results are inconsistent with the learning hypothesis (according to which subjects learn the incentives of the game, and thus the equilibrium, throughout the experiment) and consistent with the hypothesis of strategic behavior by the partners, who have a strategic incentive to send more in early periods of phase 2.

To provide another summary of the data, we regressed the independent group averages separately for partners and strangers on the variable *Period* (which takes values 1 to 10 for each of the four phases), and on the dummies *DProt*, *Phase* and *GrSize*. *DProt* takes value 0 for the I-protocol and 1 for the S-protocol. For each decision protocol, the dummy variable $Phase$ is 0 for the first phase and 1 for the second phase. $GrSize$ is 0 if $n = 6$ and 1 if $n = 3$.[20] Table 1 lists the estimates for the standardized and unstandardized coefficients, standard errors, t-statistics and p-values.

Insert Table 1 about here

While for the partners there are no decision-protocol effects, quite unexpectedly, $DProt$ is significantly negative for the strangers, meaning that they send higher amounts under the I-protocol. $Phase$ has only a very small influence on the data for both partners and strangers. The coefficient on $GrSize$ is significantly positive, which implies (as already summarized by Result 2) that partners invest more if they are in small groups. Finally, the coefficient on $Period$ is significantly negative for both partners and strangers, indicating that average amounts sent decrease over time regardless of the rematching procedure. We cannot reject that the regression residuals are normally distributed (one sample Kolmogorov-Smirnov-Test, $p = 0.696$ for the partners and $p = 0.146$ for the strangers), which supports the reliability of the linear regressions. The decline of cooperation over periods in the strangers condition may be seen as learning the dominant strategy. Nevertheless, the finding of a restart effect opposes the learning hypothesis. A detailed analysis of individual strategies will help to shed more light on what drives strangers' decisions.

3.2 Individuals' strategies

In this section, we will study the participants' strategies in more detail. We will allow these strategies to depend on the relationship between the amount received and the amount sent.

In the post-experimental questionnaire, most subjects declared that their strategy was "to pass on an amount equal to that received". Following Boyd

[20] Of course, this dummy was excluded from the regression concerning the strangers.

& Richerson (1989), we refer to such strategy as "indirect tit-for-tat".[21] To investigate whether indirect tit-for-tat is present in our data, Table 2 shows the proportion of decisions following the strategy for each decision protocol, group size and 10-period phase.[22] We report the values separately for partners and strangers, to be able to detect whether (and how) the rematching procedure affects people's willingness to follow indirect tit-for-tat.

Insert Table 2 about here

Between 41% ($n = 6$, I-protocol) and 69% ($n = 3$, S-protocol) of the partners followed the described strategy, which compare to rates between 27% (I-protocol) and 41% (S-protocol) for the strangers. This already indicates that partners comply with the indirect tit-for-tat more than strangers. Although the reported proportions convey no information about the actual (absolute) amounts sent, the table reveals a clear group size effect for the partners and a remarkable difference between the two decision protocols both for partners and strangers. To corroborate statistically these findings, we apply Wilcoxon rank-sum tests (one-tailed) to compare partners to strangers and groups of size 3 to groups of size 6, and Wilcoxon signed-rank tests (one-tailed) to compare the S-protocol to the I-protocol and phase 1 to phase 2. The tests confirm that the analyzed strategy is followed more when subjects interact in the partners, rather than strangers, condition ($p < 0.001$ for both the I- and the S-protocol), when they play sequentially rather than simultaneously (for the partners $p = 0.027$ if $n = 3$ and $p = 0.004$ if $n = 6$; for the strangers $p = 0.015$) and when n equals 3 instead of 6 ($p = 0.007$ and 0.032 for the I- and the S-protocol, respectively). On the contrary, for each decision protocol, and both for partners and

[21] Actually, the strategy space in Boyd & Richerson's model is smaller than ours. In their model, individuals have to choose only between cooperation and defection. However, we can think of indirect tit-for-tat as requiring player i to act exactly like player $i - 1$, which in our context means to pass on an amount identical to that received.

[22] To calculate this variable we have to exclude the decisions that cannot be conditioned on the others' behavior, i.e. the amount sent in period 1 by all n players (player 1) for the I- (S-) protocol.

strangers, the proportion of subjects following the indirect tit-for-tat strategy in the first 10-period phase is not significantly different from that in the second 10-period phase. The S-protocol seems, hence, to trigger more indirect tit-for-tat reasoning. Nevertheless, since "sending 0 in response to 0" is considered as an indirect tit-for-tat strategy, the higher compliance with this strategy under the S-protocol compared to the I-protocol may be due to more opportunistic behavior in case of sequential decisions.

Besides indirect tit-for-tat, our design allows us to provide a complete categorization of individuals' strategies based on the comparison between x_i (i.e., i's investment choice) and x_{i-1} (i.e., i's received amount).[23] Dufwenberg & Kirchsteiger (2002) define the reference point of zero kindness of player i to player j as the average between the minimum and maximum payoff of j that is compatible with the space of i's efficient strategies.[24] Applying this definition to our game, an amount sent of at least 3 ECU is kind while an amount inferior to 3 ECU is unkind. Using this definition, we can distinguish the following strategies:

I: *Pure altruism (or warm-glow)*[25]: Acting kindly towards the downward individual despite the unkindness of the upward individual (i.e., $x_i \geq 3$ in response to $x_{i-1} < 3$).

II: *Positive indirect reciprocity*: Acting kindly towards the downward individual when the upward individual was kind (i.e., $x_i \geq 3$ in response to $x_{i-1} \geq 3$).

[23]Note that, in the I-protocol, x_i and x_{i-1} refer respectively to periods t and $t-1$, with $t = 2, \cdots, 10$. That is, i can react in t to the amount sent by $i-1$ in the previous period. The same holds, in the S-protocol, for player 1, who decides about x_1 in t after observing the nth player's decision in $t-1$. Instead, for all the other players i ($i = 2, \cdots, n$) in the S-protocol x_i and x_{i-1} refer to the same period; i.e., decisions can be conditioned within the same period.

[24]In Dufwenberg and Kirchsteiger's model, kindness relates to beliefs so that intentions and possibilities define the kindness of an action. Differently from them, we focus exclusively on reciprocity as behavior. We disregard the motivations behind reciprocal behavior or reciprocity as a motive itself. In our game, i's kindness is measured only in terms of i's behavior. Since i knows how much $i-1$ has sent to him, no belief-dependent motivations are involved in our game.

[25]See Andreoni (1990) for a definition of warm-glow.

III: *Negative indirect reciprocity*: This is the counterpart to II, where an unkind action by the upward individual is answered by an unkind action towards the downward individual (i.e., $x_i < 3$ in response to $x_{i-1} < 3$)

IV: *Defection*: Acting unkindly though the upward individual was kind (i.e., $x_i < 3$ in response to $x_{i-1} \geq 3$).

Of course, we need to distinguish between positive indirect reciprocity by partners and positive indirect reciprocity by strangers as the former is contaminated by incentives for strategic reputation building. In particular, assuming that strangers are not motivated at all by strategic concerns, we can attribute the observed difference in indirect reciprocity between partners and strangers to strategic behavior.

We are aware that our categorization may be somewhat artificial.[26] However it facilitates the descriptive analysis of the distribution of average amounts sent for all possible amounts received as described in Tables 3 and 4 for, respectively, partners and strangers.[27] The tables are split in different sub-tables, which refer to the different experimental treatments (I versus S-protocol and, for the partners, $n = 3$ versus $n = 6$). Each sub-table is in turn divided in four symmetric panels, which are defined by the kindness of the amount sent (i.e., by whether the amount sent is smaller or greater than 3) compared with the kindness of the amount received. Hence, each panel corresponds to one of the four aforementioned strategies. The cases lying on the main diagonal of each sub-table represent the numbers of subjects complying with the indirect tit-for-tat strategy.

<u>Insert Tables 3 and 4 about here</u>

[26]For instance, according to our categorization, a person who sends zero in response to zero is a negative indirect reciprocal. Nevertheless, she may be an (unconditional) defector who always maximizes her monetary payoff.

[27]We report averages across all the 20 periods of a decision protocol. A more detailed analysis separating the two 10-period phases does not yield any statistically significant difference for any possible experimental treatment.

The data reveal that most subjects, regardless of the decision protocol, the group size and the rematching procedure, are indirect reciprocal, and that sending 0 in response to 0 is in general more frequent under the S-protocol than under the I-protocol. The latter finding explains why indirect tit-for-tat behavior is more frequent in case of sequential decisions. It may be argued that this is a consequence of the asymmetric position of player 1 with respect to players 2 to n in the S-protocol. Such asymmetry may be perceived as unfair by the player who must decide first, without being able to condition her choice on the others' behavior. Unfair procedures are assumed to trigger negative feelings which could induce players to act opportunistically.[28] To test for this conjecture, we compared the percentages of players 1 sending zero in the two decision protocols using Wilcoxon signed-rank tests (one-tailed). However, we cannot reject the hypothesis that players 1 send more or equal often zero amounts in the S-protocol than in the I-protocol ($p > 0.05$ for both group sizes).

The percentage of participants in the various treatments estimated to use a specific strategy is summarized in Table 5 (which also includes in parentheses positive and negative indirect tit-for-tat). Figure 2 visualizes the performance of the different strategies in the different treatments.

Insert Table 5 and Figure 2 about here

The table and the figure make it clear that the distribution of individuals across the four strategies depends on both rematching procedure and group size. In particular, under both decision protocols, indirect reciprocity fares better in partners than in strangers groups (where we observe higher shares of defectors and pure altruists), and when partners interact in 3- instead of 6-person groups. Between the two indirect reciprocity categories, positive indirect reciprocity performs better than negative indirect reciprocity for the partners in groups of size 3 under both protocols and for the strangers under the I-protocol.

[28]See, e.g., Lind & Tyler (1988) for the notion (and evidence) of procedural fairness.

If we concentrate only on positive indirect reciprocity (so as to exclude the ambiguous case "sending 0 in response to 0"), we have that, on average, 39% (32%) of the strangers (indirectly) reciprocates the kindness of the upward individual in the I-(S-)protocol. This percentage increases by 26 (35) percentage points for the strategic partners. If we accept the assumption that strangers cannot be motivated to cooperate out of strategic considerations (since cooperative decisions cannot be carried over different groups), these results imply that indirect reciprocity is behaviorally important although cooperative choices are also influenced by strategic reasoning. The interaction of indirect reciprocity and strategic play appears thus to have substantial impact on cooperation.[29]

Studying the participants' behavioral patterns reveals a huge amount of dynamics. In this sense, it is interesting to look at the evolution of the different strategies over time. Figure 3 displays the average proportion of participants following each of the four strategies across the 40 periods separately for partners and strangers, and 3- and 6-person groups.

<u>Insert Figure 3 about here</u>

The total amount of positive and negative reciprocity stays rather constant over time for the partners as well as for the strangers. Yet, in the last (tenth) period of each phase, the partners (but not the strangers) exhibit a king in the proportion of negative reciprocators. Noticing that the proportion of defection starts increasing in the second to the last period, we have a further corroboration of the partners' strategic play.

In the first two periods of every phase, the share of indirect positive reciprocity is higher than the share of the other strategies, especially for the partners in 3-person groups. However, the dominance of defection over warm-glow drives the amount of positive reciprocity down and increases the share of negative reciprocity, what is reflected in the observed sending behavior.

[29]Seinen & Schram (2001) and Engelmann & Fischbacher (2002) report results quite similar to ours. The numbers are however not directly comparable because we investigate experimentally a different type of indirect reciprocity and use different classifications.

4 Conclusions

We have conducted an experimental investment game where each player is located at a different position into a ring of n players and must decide how much to send to her right neighbor after learning about how much she receives by her left neighbor. By this means, we aimed to study whether n-person cyclical networks of indirect reciprocity can sustain cooperation.

There exists an abundance of evidence showing that direct reciprocity (where a person who is affected by the choice of another person can directly reward or punish the latter) is behaviorally important. There are also experimental studies showing that individuals act kindly (hostile) towards those who were kind (hostile) towards others. This paper has shown that individuals act kindly (hostile) towards others if someone else has been kind (hostile) to themselves.

In our experiment, indirect reciprocity shows up in the sensitivity of the amount sent by a player to the amount that she receives. Both when analyzing responses to the post-experimental questionnaire and when estimating strategies, we observed that many subjects decide how much to send on the basis of how much they received.

We found, however, significant treatment effects. Namely, small groups are more cooperative than large ones and partners are more cooperative than strangers. We find therefore support for the hypothesis that cooperation rates are higher when individuals have strategic incentives to send positive amounts. This is in line with earlier experiments indicating that, in helping games, the interplay of indirect reciprocity and strategic reasoning favors cooperation (see, e.g., Seinen & Schram 2001, and Engelmann & Fischbacher 2002).

To conclude, this paper intended to contribute to the recently growing literature maintaining that mutually beneficial cooperation does not require bilateral exchanges but that it can be sustained also in situations where reciprocity has to be indirect.

Appendix A

Sample instructions (originally in German)

In this appendix we report the instructions that we used for 3-person groups. The instructions for the partners in 6-person groups were adapted accordingly.

A.1 Instructions in the I-protocol

The following instructions were distributed at the beginning of the experiment.

Welcome and thanks for participating in this experiment. Please read the following instructions carefully. From now on any communication with the other participants is forbidden. If you have any questions, please raise your hand, and one of the experimenters will come to help you.

During the experiment you will be able to earn money. How much you will earn depends on your decisions and the decisions of the other participants. Your experimental income will be calculated in ECU (Experimental Currency Unit), where 25 ECU = 1 euro. At the end of the experiment, the ECU you have earned will be converted to euros, and the obtained amount will be immediately paid to you in cash.

The experiment consists of several phases, each lasting for 10 rounds. In each round, the participants are divided in groups of three. The group composition will be randomly determined at the beginning of each phase, and then kept constant over the entire phase. That is, you will be interacting with the same two persons in all 10 rounds of a phase. [*In the strangers session, the last two paragraphs were replaced by*: The group composition will be randomly determined after each round. That is, your group members will be different from one round to the next.]

The three group members will be identified by numbers from 1 to 3. At the beginning of each round, each group member receives 5 ECU. Your task is to decide how many ECU you want to give

- to the group member with the number following yours, if you are member 1 or 2;
- to member 1, if you are member 3.

Therefore, if you are member 1, you have to decide how many ECU you want to give to member 2. If you are member 2, you have to decide how many ECU you want to give to member 3. If you are member 3, you have to decide how many ECU you want to give to member 1.

You can give your group member either 0 or 1 or 2 or 3 or 4 or 5 ECU.

For any amount you decide to give, your group member actually receives the triple. For instance, if you give 1 ECU, your group member receives 3 ECU; if you give 3 ECU, (s)he receives 9 ECU; if you give 5 ECU, (s)he receives 15 ECU.

Likewise, you receive three times the amount that your group member gives you. Your round income consists, therefore, of two parts:

(1) the amount you keep for yourself (i.e., 5 ECU − ECU you give);

(2) three times the amount that your group member gives you.

Your round income = *ECU you keep for yourself* + *3 × ECU you receive from your group member*

In each round, all three group members choose *at the same time* how many ECU they want to give.

At the end of each round, you will be informed about the amount that you receive from your group member, and about your round income.

A.2 Instructions in the S-protocol

The following instructions were distributed at the end of phase 2.

The only change with respect to the previous phases is that now the three group members must make their round-decision in *an ordered sequence* with member 1 deciding first and member 3 deciding last.

Specifically, in each round, the sequence will be as follows:

- First member 1 decides how much (s)he wants to give to member 2, where the amount to be given can be either 0 or 1 or 2 or 3 or 4 or 5 ECU.
- Then member 2, after being informed about the amount (s)he receives from member 1, decides how much (s)he wants to give to member 3. Also member 2 can only give either 0 or 1 or 2 or 3 or 4 or 5 ECU.
- Finally member 3, after being informed about the amount (s)he receives from member 2, decides how much (s)he wants to give to member 1. Also member 3 can only

give either 0 or 1 or 2 or 3 or 4 or 5 ECU.

This ends a round. All group members will be informed about their round income, and a new round will start.

Besides this modification, the following will remain as before:

(1) You will be interacting in groups of 3 individuals.

(2) The composition of your group will remain constant throughout the 10 rounds of each phase whereas it will randomly change after each phase. [*In the strangers session, this paragraph was replaced by*: The composition of your group will randomly change after each round.]

(3) At the beginning of each round, you will receive 5 ECU.

(4) Your round income will be:

ECU you keep for yourself
+
3 × ECU you receive from your group member

Appendix B

Questionnaire (originally in German)

The following questionnaire was handed out at the end of the experiment.

Number of cabin:

Please, describe briefly and with your own words the procedures of the experiment.

Please, explain briefly how you made your decisions.

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Table 1: OLS regression for the (independent) average amounts sent

	Independent variables	**Unstandardized Coefficients**		**Standardized Coefficients**		
		B	Std. Error	Beta	t	Sig.
Partners	*Constant*	3.280	0.104		31.656	0.000
	DProt	0.143	0.075	0.054	1.914	0.056
	Phase	-0.231	0.075	-0.088	-3.090	0.002
	GrSize	1.429	0.075	0.541	19.092	0.000
	Period	-0.199	0.013	-0.433	-15.275	0.000
		$R = 0.70$	$R^2 = 0.49$	Adj. $R^2 = 0.48$	Std. Error = 0.95	
Strangers	*Constant*	3.182	0.135		23.645	0.000
	Dprot	-0.408	0.104	-0.240	-3.910	0.000
	Phase	-0.083	0.104	-0.049	-0.793	0.429
	Period	-0.069	0.018	-0.234	-3.819	0.000
		$R = 0.34$	$R^2 = 0.11$	Adj. $R^2 = 0.10$	Std. Error = 0.81	

Table 2: Proportion of players following the indirect tit-for-tat strategy

	Partners		**Strangers**
	$n = 3$	$n = 6$	$n = 3$
***I*-Protocol**	0.54	0.41	0.27
Phase 1	0.50	0.37	0.27
Phase 2	0.58	0.45	0.27
***S*-Protocol**	0.69	0.55	0.41
Phase 1	0.68	0.55	0.40
Phase 2	0.70	0.55	0.41

Table 3: Empirical distribution of average amounts sent for each possible amount received; partners condition

***I*-protocol**

$n = 3$

Amount received	Amount sent 0	1	2	3	4	5	N*	Mean	Mode
0	0.54	0.08	0.10	0.05	0.02	0.22	105	1.58	0
1	0.38	0.16	0.13	0.19	0.03	0.13	32	1.72	0
2	0.25	0.13	0.09	0.22	0.25	0.05	55	2.25	0
3	0.13	0.03	0.08	0.31	0.26	0.19	104	3.11	3
4	0.09	0.04	0.08	0.17	0.24	0.39	105	3.61	5
5	0.09	0.01	0.04	0.05	0.07	0.74	463	4.21	5

$n = 6$

Amount received	Amount sent 0	1	2	3	4	5	N	Mean	Mode
0	0.61	0.16	0.09	0.04	0.03	0.06	491	0.89	0
1	0.33	0.30	0.19	0.08	0.02	0.08	271	1.43	0
2	0.24	0.18	0.25	0.17	0.06	0.10	272	1.90	2
3	0.16	0.08	0.18	0.27	0.14	0.16	216	2.63	3
4	0.13	0.14	0.16	0.12	0.23	0.23	136	2.87	4
5	0.20	0.06	0.06	0.08	0.10	0.49	342	3.30	5

***S*-protocol**

$n = 3$

Amount received	Amount sent 0	1	2	3	4	5	N	Mean	Mode
0	0.65	0.06	0.05	0.05	0.03	0.16	154	1.24	0
1	0.46	0.18	0.21	0.04	0.00	0.11	28	1.25	0
2	0.27	0.14	0.30	0.20	0.07	0.02	44	1.73	2
3	0.17	0.04	0.19	0.23	0.25	0.13	48	2.73	4
4	0.06	0.03	0.05	0.09	0.31	0.46	80	3.95	5
5	0.07	0.01	0.01	0.02	0.05	0.84	574	4.52	5

$n = 6$

Amount received	Amount sent 0	1	2	3	4	5	N	Mean	Mode
0	0.71	0.09	0.06	0.04	0.02	0.08	612	0.82	0
1	0.31	0.37	0.19	0.06	0.02	0.04	214	1.23	1
2	0.18	0.18	0.30	0.18	0.08	0.09	210	2.05	2
3	0.11	0.09	0.13	0.40	0.17	0.11	217	2.76	3
4	0.09	0.08	0.12	0.16	0.38	0.17	186	3.16	4
5	0.10	0.03	0.05	0.06	0.09	0.67	449	4.03	5

Note: The four symmetric panels in each sub-table correspond to our four individual strategies. Starting from the upper left panel and moving round, we have: negative indirect reciprocity, altruism, positive indirect reciprocity, and defection.

* N denotes the number of times in which each possible amount received was observed. The total numbers of observations are 960 for $n = 3$ and 1920 for $n = 6$. We do not report the cases in which the amount sent does not depend on the others' behavior. The unconditioned choices are 32 for the S-protocol, and 96 or 192 for the I-protocol depending on whether n equals 3 or 6.

Table 4: Empirical distribution of average amounts sent for each possible amount received; strangers condition

***I*-protocol**

Amount received	Amount sent 0	1	2	3	4	5	N	Mean	Mode
0	0.28	0.08	0.16	0.21	0.09	0.17	241	2.27	0
1	0.28	0.14	0.15	0.17	0.05	0.20	113	2.18	0
2	0.18	0.08	0.22	0.21	0.11	0.19	168	2.57	2
3	0.19	0.08	0.17	0.25	0.11	0.21	253	2.66	3
4	0.22	0.09	0.07	0.16	0.22	0.25	187	2.82	5
5	0.11	0.07	0.08	0.16	0.20	0.37	334	3.38	5

***S*-protocol**

Amount received	Amount sent 0	1	2	3	4	5	N	Mean	Mode
0	0.54	0.09	0.11	0.06	0.09	0.11	417	1.40	0
1	0.31	0.28	0.18	0.11	0.06	0.06	127	1.54	0
2	0.22	0.12	0.27	0.15	0.10	0.14	175	2.19	2
3	0.23	0.09	0.07	0.33	0.13	0.14	178	2.47	3
4	0.18	0.06	0.13	0.17	0.20	0.26	163	2.93	5
5	0.20	0.04	0.05	0.08	0.12	0.51	332	3.41	5

Note: As in Table 3, the four panels in each sub-table correspond to our four strategies. N has the same interpretation as in Table 3.

Table 5: Percentages of participants complying with each strategy (I: altruism, II: positive indirect reciprocity, III: negative indirect reciprocity, IV: defection)

	Partners				**Strangers**	
	I-protocol		*S*-protocol		*I*-protocol	*S*-protocol
Strategy	$n = 3$	$n = 6$	$n = 3$	$n = 6$	$n = 3$	$n = 3$
I	0.08	0.12	0.06	0.10	0.19	0.15
II	0.65	0.25	0.67	0.34	0.39	0.32
	(0.59)	(0.20)	(0.65)	(0.31)	(0.18)	(0.19)
III	0.14	0.48	0.19	0.45	0.21	0.37
	(0.10)	(0.36)	(0.15)	(0.39)	(0.09)	(0.22)
IV	0.13	0.15	0.08	0.11	0.21	0.16

Note: Numbers in parentheses refer to the respective (i.e., positive or negative) indirect tit-for-tat strategy.

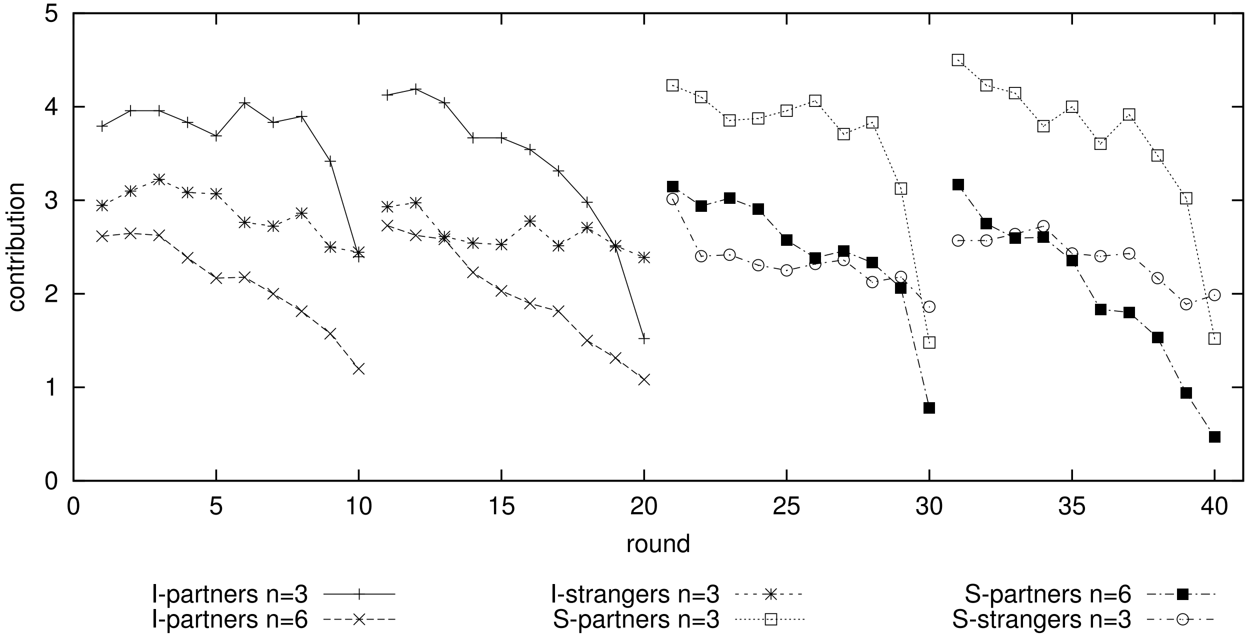


Figure 1: Average amounts sent in each period of the I- and S-protocols separately for strangers and partners, and for $n = 3$ and $n = 6$

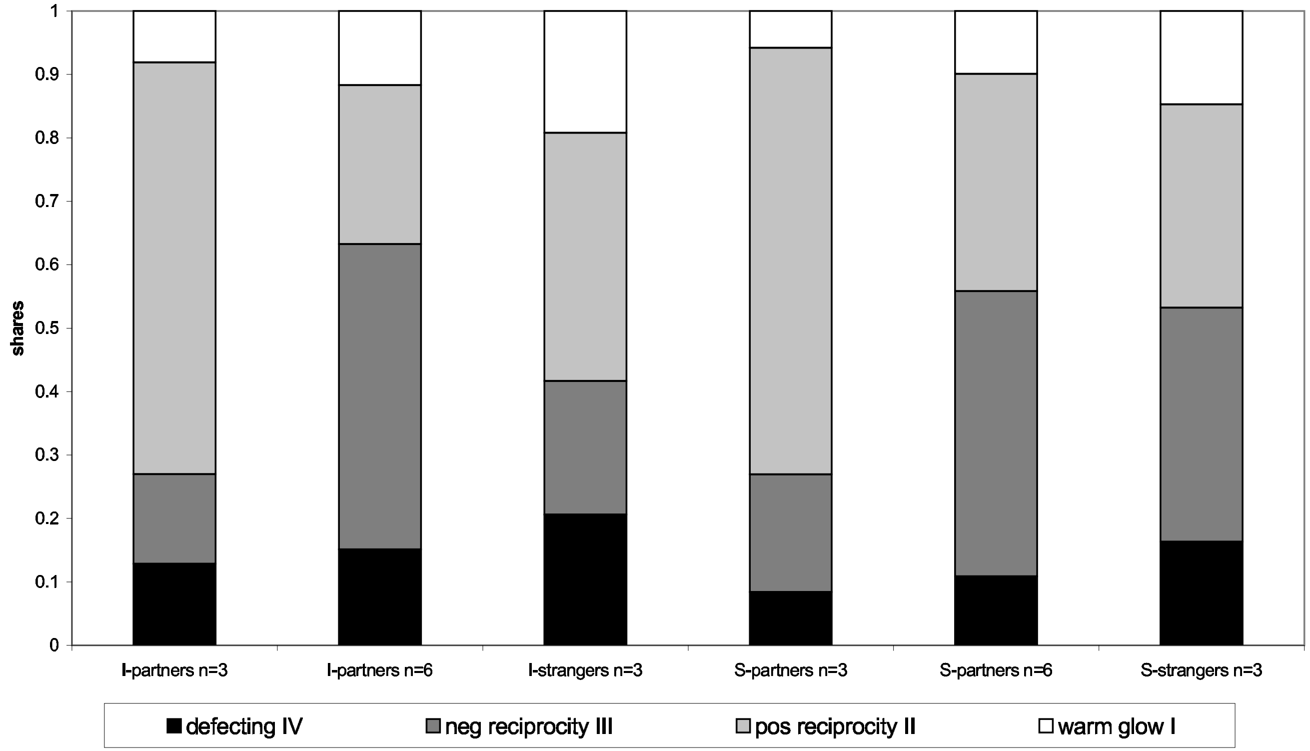
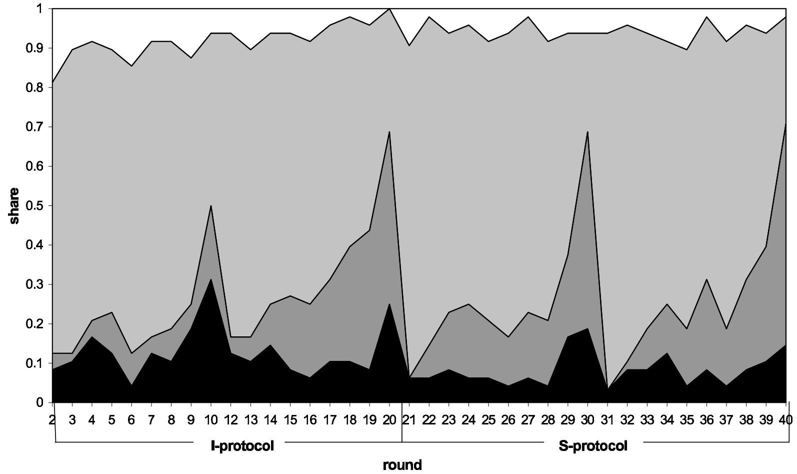


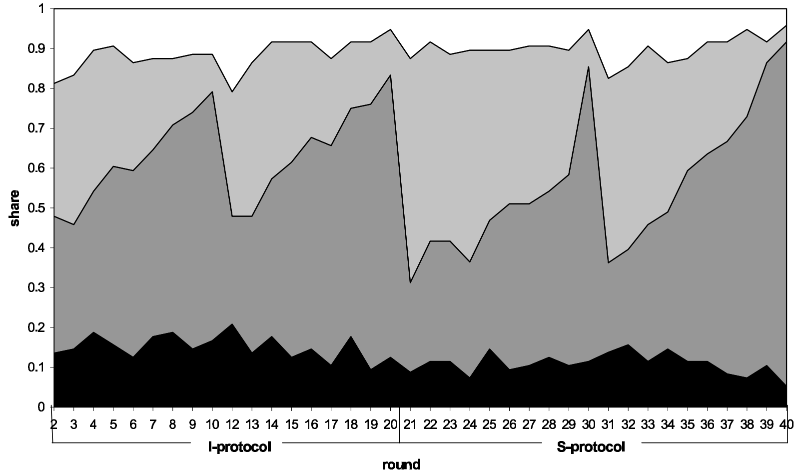
Figure 2: Relative performance of the four individual strategies in the different experimental treatments

Partners

$n = 3$



$n = 6$



Strangers

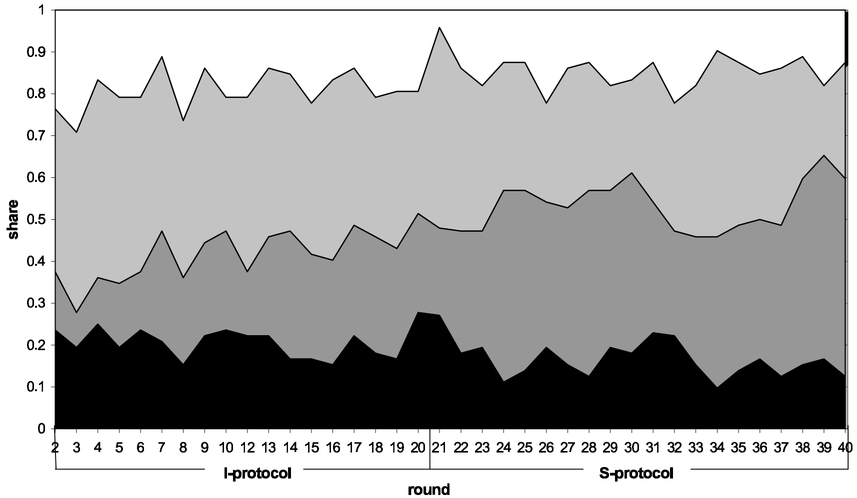


Figure 3: Average relative shares of the four individual strategies over periods separately for partners and strangers, $n = 3$ and $n = 6$ (colors as in Figure 2)