Relatives Versus Neighbors

- An Experiment Studying Spontaneous Social Exchange -

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September 16, 2004

Abstract

Social institutions regulating group conduct have been regarded as necessary for human cooperation to transcend family bonds. However, many studies in economics and biology indicate that reciprocity based on repeated interaction suffices to establish cooperation with non-kin. We shed light on the issue by a voluntary social exchange experiment where related (via mutual shareholding) players coexist with unrelated ones. Systematically varying the degree of shared interests and the length of the time horizon, we provide evidence that repeated interactions play a crucial role in human cooperation, although humans remain attentive to relatedness.

Keywords: Reciprocity; Relatedness; Social institutions; Voluntary social exchange

JEL Classification: C72, C92, D30

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1 Introduction

Humans, and many other species, tend to cooperate and help each other. But what are the conditions required for the emergence and maintenance of cooperation? Obtaining a satisfactory answer to such a question is an enduring problem in biological and social sciences.

One explanation, which works for humans, but not for other species, is that we (the human species) first experienced cooperation within families, and then established formal institutions replacing the shared genetic interests by institutions which guarantee promise keeping and cooperation.[1] Central to this explanation is that humans are distinct from other animals in their cognitive, linguistic and physical capacities allowing to formulate general norms of social conduct, and to establish social institutions regulating this conduct (Bowles and Gintis, 2003). If this argument is correct, in the absence of social institutions, "kin selection" (cf., Hamilton, 1964) should be the driving force of cooperation.[2] Since it considers kinship as the primary condition for cooperation, we refer to such explanation as the "relatives"-hypothesis.

Evidence for this hypothesis appears to stem from a large cross-cultural study of behavior in ultimatum, public goods, and dictator games undertaken by Henrich et al. (2001) in fifteen small-scale societies. This study found a wide behavioral variability across societies that is mainly explained in terms of group specific conditions, such as social institutions or cultural fairness norms. In particular, the Machiguenga, a hunter-gatherer group living in the tropical forests of the Amazon, where cooperation above the family level is almost unknown, were the least cooperative.[3] By contrast, the Lamelara whale-hunters,

[1] This thesis has been proposed by, e.g., U. Witt in his presentation at the Workshop on "The Evolution of Designed Institutions", held at the Max Planck Institute for Research into Economic Systems in February 2004.

[2] In a recent model for the evolution of cooperation, Riolo et al. (2001) show through computer simulations that all that is needed to establish cooperation is some recognition of what is 'similar'. Sigmund and Nowak (2001) interpret Riolo et al.'s model as a form of kin selection.

[3] In the ultimatum game (cf., Güth et al., 1982; Camerer and Thaler, 1995; Roth, 1995)

who go to sea in large canoes manned by a dozen or more, exhibit the highest cooperation rates.[4] It seems, therefore, that the presence of institutions regulating social conduct (like the management of large canoes by a group of people) can encourage cooperation towards non-kin while individuals are unable to extend cooperation beyond family bonds without such institutions (see Bergstrom, 2002, for a similar interpretation of Henrich et al.'s study).

Reciprocity in repeated interaction provides another well-studied solution to how mankind could extend cooperation beyond family bonds. Many studies in both economics and biology reveal that strategies bestowing benefits on individuals who have bestowed benefits and withholding future benefits from individuals who fail to reciprocate can easily evolve in situations of repeated interaction (see, for instance, Trivers, 1971; Axelrod and Hamilton, 1981; Axelrod, 1984; Kliemt, 1986; Nowak et al., 1995). This sort of cooperation is naturally implied in the field by living in stable neighborhoods, and experimentally induced by using a "partner design" (the same participants interact over several periods). We refer to this alternative justification of the evolution of cooperation as the "neighbors"-hypothesis.

To justify this hypothesis one would refer to the fact that primates live in stable groups, whose large size questions their mutual relatedness (in chimpanzees, for instance, the family is mainly a mother and her offspring, see Goodall, 1971), and nevertheless manage to establish high degrees of cooperation. Free-riding in such groups is disadvantageous because it would be punished by expulsion from the group (de Waal, 1991). South American vampire bats provide a further example of cooperation based on reciprocity (see, e.g., Wilkinson, 1984; Stewart, 2000). Each night the bats leave the hollow trees where they spend the day to search for large animals. If a bat finds an animal, it will attempt

over 75% of Machiguenga offers were below 30% of the pie, yet they were accepted about 95% of the times.

[4] The Lamelara had mean offers greater than 50%, and responders preferentially rejected low offers.

to feed on the animal's blood. But there is no guarantee that an individual bat will successfully find and feed off an animal every night. If it has a few bad nights in a row, it can be in danger of starving. A closer study of the bats showed that this danger is avoided because the bats that hole up together share blood, though a particular individual would not give blood to all the others but only to some. It turned out that those who got the blood were not necessarily close relations but bats who had given the individual blood in the past. Those who were refused blood were those who had previously refused the individual blood. The bats know each other as individuals, know who is likely to return favors and who is not, and choose to give blood only to those who are likely to reciprocate. The relatives-hypothesis has the problem to explain why repeated interactions among non-humans lead to reciprocal (and cooperative) behavior whereas among humans it does not.

In this paper, we use the experimental approach (with *homo sapiens* participants) to compare the "neighbors"- to the "relatives"-hypothesis, and shed light on the debate about the relevance of reciprocity as opposed to formal institutions in explaining the evolution of cooperation. It is important to stress that we do not seek to diminish the importance of relatedness or to suggest that repeated interaction can explain by itself the evolution of cooperation.[5] Rather we want to investigate whether and to what extent reciprocity based on repeated interaction can induce cooperation towards non-kin in a society where kin selection is possible, and social institutions regulating group conduct are absent.

The basic experimental set-up is a repeatedly played voluntary social exchange experiment, where each of several exchange partners is the monopoly

[5] Many experiments suggest that individuals cooperate in anonymous one-shot situations or in the final round of a repeated interaction (see, e.g., Fehr and Gächter, 1998; McCabe et al., 1998; Fehr et al., 2002). The non-experimental evidence is equally telling: Common actions in everyday life cannot be explained by the expectation of future reciprocation. This behavioral propensity has been termed "strong reciprocity" (Fehr et al., 2002; Bowles and Gintis, 2003; Fehr and Fischbacher, 2003; Fehr and Henrich, 2003).

owner of a specific input commodity that she can share with others.[6] To have something specific in mind, think of the individual input commodities as ingredients (flour, butter, eggs,...) to produce the same output commodity "cake". To experimentally induce shared interests, as referred to in the evolutionary justification of "kin-altruism" (Hamilton, 1964), we rely on mutual shareholding.[7] A participant decides for a given role whose main share of payoff she collects, but also gets the minority share of other roles to whom she is related. In view of our illustrative example, this means that all group members can voluntarily share ingredients but only "relatives" share the output commodity "cake" as well. In this set-up, uniovular-twins would equally share all the cake that they produce. The "coefficient of relatedness" could correspondingly be ruled out by letting majority (minority) shares approach 1 (0).

Since we rely on groups of four participants, we induce "societies" with pairs of "relatives". In one treatment, relatedness is very high (relatives share 45% of the output of just one partner). In another treatment, relatedness is very loose (relatives share only 5% of one other partner's output).[8] As social institutions regulating group conduct are absent, the "relatives"-hypothesis predicts that the selfish genes driving kin-altruism would not allow for cooperation beyond family bonds. In other words, positive input-exchanges should be observed only in case of high shareholding, and merely among relatives.

To investigate whether reciprocity based on repeated interaction can promote beyond-family cooperation, we always allow for repetition but vary the length of the time horizon. In the short horizon treatment, participants interact for 4 periods. In the long horizon treatment, they interact for 16 periods. Since

[6]Berninghaus et al. (2004) use this set-up in their experimental study about evolution of spontaneous social exchange.

[7]See Bolle and Güth (1992) for a theoretical analysis and field evidence of mutual shareholding.

[8]One may argue that the way in which we capture kinship disregards, in principle, the role that emotions or similar feelings plays among relatives. However, in light of our results (showing that people are more cooperative towards kin than towards non-kin, irrespective of the degree of mutual shareholding), this argument seems lacking importance.

the shadow of the future lessens if interaction lasts longer (rendering groups more stable; see, e.g., Kelley and Thibaut, 1978), and since all can gain by mutual input-exchanges, the "neighbors"-hypothesis predicts that cooperation increases with the time horizon, and is directed at all group members.

Our findings reveal that cooperation levels do not depend significantly on the intensity of relativeness. Rather, the length of the time horizon appears to be decisive as cooperation rates are found to be higher when interaction endures for 16, rather than 4, periods. This provides evidence for the neighbors-hypothesis. Yet, what is allocated to the (either closely or loosely) related partner is greater than what is given to the other two group members (i.e., the neighbors). Our results are, therefore, consistent with previous studies showing the importance of repeated interactions in human cooperation (Gächter and Falk, 2002; Brown et al., forthcoming), although humans (like many other animals) remain particularly attentive to kinship (Silk, 1980; Daly and Wilson, 1988).

Section 2 introduces the model on which the experiment is based. Section 3 describes its experimental implementation in more detail and specifies our working hypotheses. Section 4 presents our major findings. Section 5 concludes.

2 The model

The basic game combines voluntary social exchange with mutual shareholding as described in the introduction. Let $N = \{1, \ldots, 4\}$ be a group of 4 individuals who interact for T periods. In any period $t \in \{1, \ldots, T\}$, each individual $i \in N$ is endowed with $E = 4k$ (> 0) of a specific input-commodity and must decide about the amount of E, $a_j(i)$, that she wants to allocate to each group member $j = 1, \ldots, 4$. Thus, in each period, the strategy of individual i is choosing an allocation

$$a(i) = (a_1(i), \ldots, a_4(i))$$

with $a_j(i) \geq 0$ and $\sum_j a_j(i) = E$ for all $i, j \in N$.

The allocation decisions $a(i)$ are taken simultaneously so as to produce a common output commodity ("cake" in our leading example). The amount of output produced by individual i represents i's own profit. Denoting by $a = (a(1), \ldots, a(4))$ the vector of individual strategies $a(i)$, the profit of i depends on a via

$$g_i(a) = \alpha \sum_j a_i(j)^p - c \sum_{j \neq i} \delta(a_j(i)) \quad \text{with} \quad 0 < p < 1 \quad \text{and} \quad \alpha > 0, \tag{1}$$

where

$$\delta(a_j(i)) = \begin{cases} 1 & \text{if} \quad a_j(i) > 0 \\ 0 & \text{if} \quad a_j(i) = 0. \end{cases}$$

Here c (> 0) are the costs of sending more or less of i's input to another player $j \neq i$.[9]

To induce shared interests, we introduce mutual shareholding and allow player i (for all $i \in N$) to hold a minority share, s_i^j, of j's profit. Of course, shares must be non-negative (i.e., $s_i^j \geq 0$) and add up to 1 (i.e., $\sum_{i=1}^4 s_i^j = 1$). The payoff of player i is simply the sum of all her profit shares, i.e.,

$$u_i(a) = \sum_{j=1}^{4} s_i^j g_j(a). \tag{2}$$

Actually, in the experiment, there is only one other group member $r \neq i$ for which $s_r^i = s_i^r > 0$, while $s_i^l = 0$ for all $l \neq i, r$. This means that while all group members can voluntarily exchange inputs, only "relatives" share the output commodity "cake" as well.[10] Payoff function (2) takes, therefore, the following form:

$$u_i(a) = (1 - s_i^r) g_i(a) + s_i^r g_r(a). \tag{3}$$

[9] One may interpret c as transportation costs.

[10] Note that, due to shareholding, player i suffers more if one of her neighbors takes a unit away from her endowment than if her relative does so.

Equation (3) describes the incentives of player i (for all $i \in N$) which will guide her strategic considerations. Maximization of her own profit would require player i to keep her own endowment (i.e., $a_i(i) = E$). However, this would decrease i's total payoff $u_i(a)$ by deteriorating $g_r(a)$. Thus, mutual shareholding is expected to affect outcomes unless sending costs are too high. In particular, maximizing (3) with respect to $a(i)$, one gets that i's optimal decision (for all $i = 1, \dots, 4$) is to choose an allocation $a^*(i)$ such that $a^*_\ell(i) = 0$ for all $\ell \neq i, r$ and $a^*_r(i) = E - a^*_i(i) \geq 0$. In case of interior maximum (i.e., $a^*_r(i) > 0$), $a^*_i(i)$ must satisfy the first order condition

$$(1 - s_i^r) a_i(i)^{p-1} = s_i^r (E - a_i(i))^{p-1}.$$

Solving the latter with respect to $a_i(i)$, and comparing the resulting payoff with that from keeping all endowment yields:

$$a^*_i(i) = \begin{cases} E \frac{{s_i^r}^\gamma}{{s_i^r}^\gamma + (1-s_i^r)^\gamma} & \text{if } c < \bar{c} \\ E & \text{if } c \geq \bar{c} \end{cases} \qquad \text{for all } i = 1, \dots, 4 \tag{4}$$

where $\gamma = \frac{1}{p-1}$, and $\bar{c} = \alpha E^p \left[\frac{(1-s_i^r)^{\gamma p} \frac{s_i^r}{1-s_i^r} + {s_i^r}^{\gamma p}}{\left[(1-s_i^r)^\gamma + {s_i^r}^\gamma\right]^p} - 1 \right]$. Hence, i should allocate a positive amount of her own commodity to her relative, r, if c is sufficiently small while i should keep all units of her commodity (and give nothing to r) if c is large enough to prohibit voluntary exchange. The payoffs in case of general opportunism are

$$u_i(a^*) = \begin{cases} \alpha (4k)^p \frac{(1-s_i^r)^{\gamma p} + {s_i^r}^{\gamma p}}{\left[(1-s_i^r)^\gamma + {s_i^r}^\gamma\right]^p} - c & \text{if } c < \bar{c} \\ \alpha (4k)^p & \text{if } c \geq \bar{c} \end{cases}$$

for all players i, where a^* denotes the strategy vector when all players choose their opportunistic strategy (which is also dominant due to the additivity in (1)).

Because of the unique equilibrium solution (excluding "folk-theorem-like" results for finitely often repeated games) the result does not change essentially if the (normal form) game is repeated finitely often. In this case, there is the last possible period to which our solution applies. But then $a^*(i)$ is optimal in the last but one period too, and so on until the first period. Thus, by backward induction, there is a unique solution prescribing $a^*(i)$ constantly for all players $i = 1, \dots, 4$.

An alternative benchmark is *efficiency*. In general, different cost levels may render different group sizes of positive equal sharing efficient. More generally, equal sharing by $m = 2, 3, 4$ agents is beneficial only if $f(m) = \alpha(m^{1-p} - 1)(4k)^p - (m-1)c > 0$. Assuming, for mathematical convenience, m to be continuous, whether a bigger or smaller equal sharing group survives larger costs depends on $f'(m) = \alpha(1-p)m^{-p}(4k)^p - c$ being positive or negative. Here, we focus on cost levels c which are small enough to guarantee $f'(m) > 0$ for all $m \in [2, 4]$ together with $f(4) > 0$. Thus, the alternative benchmark is *symmetric efficiency*, maximizing the sum of $u_i(a)$ over all $i \in N$. Since i's profit, $g_i(a)$, is strictly increasing and strictly concave in all $a_i(j)$ for $j = 1, \dots, 4$, the candidate is $a_j^+(i) = k = E/4$ for $i, j = 1, \dots, 4$. The payoff implications of this efficiency benchmark are $u_i(a^+) = \alpha 4k^p - 3c$ for all $i = 1 \in N$, where a^+ denotes the allocation which results if all players i realize the symmetric exchange pattern $a_j^+(i) = k$ for all $j = 1, \dots, 4$.

Let us denote the individual payoff effect when substituting a^+ for a^* by $D(\cdot)$. The function $D(\cdot) := u_i(a^+) - u_i(a^*)$ depends on the parameters α, c and p as follows:

$$D(\alpha, c, p) = \begin{cases} \alpha k^p \left[4 - 4^p \frac{\left(1-s_i^j\right)^{\gamma p} + s_i^{j\,\gamma p}}{\left[\left(1-s_i^j\right)^{\gamma} + s_i^{j\,\gamma}\right]^p} \right] - 2c & \text{if } c < \bar{c} \\ \alpha k^p \left[4 - 4^p\right] - 3c & \text{if } c \geq \bar{c}, \end{cases}$$

where, in the latter case, c does not question that $f'(m) > 0$ for $m = 2, 3, 4$ and $f(4) > 0$.

A social dilemma is posed if c is sufficiently small to render $D(\alpha, c, p)$ positive. In particular, the dilemma arises whenever $\alpha 4k^p - 3c > 4(4k)^p$ or, equivalently, $c < [\alpha k^p(4 - 4^p)]/3 =: \underline{c}$. If the latter constraint holds, although maximization of one's own payoff would require player i either to keep all her endowment or to allocate a part of it to her relative (depending on whether c is greater or smaller than $\bar{c}$), all players could be better off by distributing their own endowment equally among the four group members.

3 Experimental procedures and hypotheses

The experiment is based on the game introduced in the previous section. In each period, each participant receives an endowment of $E = 16$ units of her own input-commodity (implying $k = 4$), and must decide how many units she wants to keep for herself and how many she wants to give to each of the three others. In order to keep things as simple as possible, allocation decisions are restricted to integer values. The participants' profits in each period depend on the owned quantity of each commodity and are given by profit function (1) with $\alpha = 8$ and (to be easily understood) $p = \frac{1}{2}$. Thus, any value of $c < \underline{c} = 10.67$ causes a social dilemma. To provide sufficient incentives for mutual input exchanges, we set $c = 1$. Mutual shareholding determines the participants' payoffs via Equation (3). Participants are identified by membership numbers (1 to 4), and the "related" members are 1 and 2 on the one hand, and 3 and 4 on the other hand. After all group members have allocated their endowment, each subject learns about the amount of the different input-commodities that she has received from each of the others as well as about her period-profit and payoff.

There are four basic treatments, which differ with respect to the strength of mutual shareholding (high versus low) and the length of the horizon (4 versus 16 periods) as explained in the introduction. In the *high-shareholding treatment* (henceforth HS), each group member shares 45% of the profit of only one other group member; i.e. $s_i^r = s_r^i = 45\%$, and $s_i^\ell = s_r^\ell = s_\ell^i = s_\ell^r = 0\%$ for all $\ell \neq i, r$. In the *low-shareholding treatment* (henceforth LS), each group member shares 5% of the profit of only one other group member; i.e. $s_i^r = s_r^i = 5\%$, and (as before) $s_i^\ell = s_r^\ell = s_\ell^i = s_\ell^r = 0\%$ for all $\ell \neq i, r$. Thus, in each 4-person group, one member is strongly or weakly "related" to another member (i.e., they can share not only their inputs but also the common output) whereas she is just a "neighbor" to the remaining two members (i.e., they just exchange inputs). Both the intensity of relatedness and the length of the horizon are between-subjects factors: Participants play either for 4 or for 16 periods being either strongly or weakly related to another group member.[11] The characteristics of our four different treatments are summarized in Table 1.

Insert Table 1 about here

For each of the four treatments, we ran one session with 28 participants each.[12] In each session, groups interacted in a partner design, yielding a total of 7 independent observations per treatment. All sessions were ran computerized with the help of z-Tree (Fischbacher, 1999) at the laboratory of the Max Planck Institute in Jena (Germany). Participants were undergraduate students from different disciplines at the University of Jena.

After being seated at a visually isolated computer terminal, participants received written instructions (see the appendix for an English translation). Understanding of the rules was assured by a control questionnaire that subjects had to answer in order for the experiment to start. To help participants compute profits and payoffs, we provided them with a profit-table, and a profit- and payoff-calculator as part of the experimental software. Furthermore, to

[11]We could, of course, have avoided any repetition in the short time horizon and excluded mutual shareholding in the low shared interests-case. This, however, would have implied different verbal instructions for the four cases of our 2×2-factorial design and could have caused (un)conscious demand effects by (not) using certain (loaded) words. In our view, it is a major strength of our experimental design that its four treatments only differ in one or two numerical parameters, namely the number of repetitions and/or the share in the output ("cake") of one's relative.

[12]No subject participated in more than one session.

familiarize participants with the game and its incentives, three practice periods without interaction were run: The computer randomly determined the decisions of the others, and participants received no payment for these training periods. The 4-period sessions were finished in about $1\frac{1}{2}$ hour, and the 16-period sessions in about 2 hours. Payoffs were quoted in ECU (Experimental Currency Units), where 100 ECU = €3. The average earnings per subject were €5.82 in the 4-period treatment, and €25.01 in the 16-period treatment.

The different shareholding treatments (LS versus HS) allow us to study whether, in the absence of formal institutions regulating agents' social conduct, shared interests (or "kinship") play a major role as predicted by the "relatives"-hypothesis. Indeed, given our parameters choices, the value of c prohibiting voluntary exchange even towards the relative (i.e., $\bar{c}$) equals 0.044 in HS and 9.346 in LS. Since $c = 1$, rational and strictly self-interested players should allocate part of their endowment to their relative in the case of high shareholding only (cf., Equation (4)). In particular, substituting 16 for E, -2 for γ, and 0.45 for s_i^r in the upper part of Equation (4), one obtains $a_i^*(i) = 9.58$, which implies $a_r^*(i) = 6.42$. As choices were restricted to integers, player i maximizes her own payoff by choosing $a_i^*(i) = 10$ and $a_r^*(i) = 6$. Thus, the "selfish gene" sustaining kin-altruism should lead an individual to keep all her endowment in the LS-treatment, and give 6 units to the partner whose profit she shares in the HS-treatment.

As pointed out in the previous section, backward induction reasoning induces this solution in each period. Thus, in line with the relatives-hypothesis, kinship should be dominant in shaping behavior since cooperation is predicted to evolve only among individuals who are closely related (i.e., who hold a high share of each other's profits). On the basis of this reasoning, we test:

Hypothesis 1 *Regardless of the length of the horizon (4 versus 16 periods), cooperation is higher (i.e., subjects keep for themselves less endowment) in HS than in LS, and the only beneficiary of cooperative acts is the strongly related* *group member.*

There is, however, abundant empirical evidence that people act against monetary incentives and cooperate much more than predicted, especially so when the potential gains from cooperation are high.[13] Table 2 lists the payoffs ($u_i(a^*)$, $u_i(a^+)$) as well as the individual payoff effect when replacing a^* with a^+ ($D(\alpha, c, p)$) for low and high shareholding as implied by the experimental parameter specifications. The last row of the table makes it clear that, in both the LS- and the HS-treatments, individuals can gain substantially by relying on mutual trust and reciprocity and engaging in exchanges involving also the "neighbors".

Insert Table 2 about here

Although a "strong" reciprocator is predicted to react (un)kindly to friendly (hostile) actions even in non-repeated interactions and when material gains are absent (see, e.g., Fehr and Fischbacher, 2003), there is evidence indicating that material incentives stemming from repeated interactions strengthen implicit reciprocity-based incentives (cf., Fehr and Falk, 2002).[14] Gächter and Falk (2002), and Brown et al. (forthcoming), for instance, provide evidence that repeated interaction causes a huge increase in cooperation rates relative to one-shot situations in gift exchange experiments.[15] This, however, may not be the case when the shadow of the future is weak. It has been indeed argued that for the actors to establish stable exchange relations, the length of the relationship is crucial (see, e.g., Kelley and Thibaut, 1978, or Molm, 1994).

[13]Isaac et al. (1984), for instance, provide evidence that in public goods experiments, increasing the marginal per capita return from the public good increases the rate of contribution. On this issue see also Henrich et al. (2001). The possibility of reciprocal behavior due to the pursuit of efficiency gains through cooperation is explicitly discussed in Brandts and Schram (2001).

[14]In the biological literature (cf., Trivers, 1971; Axelrod and Hamilton, 1981) as well as in Fehr and Fischbacher (2003), those who reward or punish only if this is in their long-term self-interest are defined "reciprocal altruists".

[15]Evolutionary theorists have shown that natural selection can favor reciprocally cooperative behavior in bilateral interactions when the chances to interact repeatedly with the same individual in the future are sufficiently high (Trivers, 1971; Axelrod and Hamilton, 1981).

The potential influence of different time horizons on cooperation rates is here captured by distinguishing the 4-period and the 16-period treatment. The "neighbors"-hypothesis would predict that cooperation increases with the time horizon since it appears easier to establish and maintain mutually beneficial exchanges with a longer horizon of future interaction. Thus, in line with the neighbors-hypothesis, in alternative to (1), we test:

Hypothesis 2 *Regardless of the strength of mutual shareholding (high versus low), cooperation is higher in the long time horizon than in the short one, and all group members benefit equally from cooperation.*

Hypothesis 2 corresponds to a strong version of the neighbors-hypothesis. A weaker version of the hypothesis would require only positive sharing with all.

Note that both Hypothesis 1 and Hypothesis 2 tackle two research questions. Namely, what drives agents' cooperative decisions, and who benefits from the latter. How these main research questions are addressed by each hypothesis is shown in Table 3.

Insert Table 3 about here

4 Experimental results

In reporting our results, we first document and compare group behavior in the different treatments by averaging data across periods and subjects. Then, we describe the group average dynamics. To determine which of the two hypotheses describes better our data we consider both the amounts that individuals keep for themselves (which are taken, here, as an indicator of the level of cooperation),[16] and the amounts that they give to the relative and to the other two group members. In our analysis we pool the data concerning the unrelated group members because they are actually indistinguishable as well as because, in such

[16] Although the level of cooperation is usually measured by the overall amount of units that player i gives to others (see, e.g., Berninghaus et al., 2004), i.e., $E - a_i(i)$, we take simply $a_i(i)$ as a measure of cooperation since the others are unequal in our experiment.

a way, they can be compared as a unique entity (i.e, the "neighbors") to the related member.

4.1 Treatment comparisons

Table 4 summarizes our results. It displays for each of the four experimental conditions the average (across subjects and periods) amounts of endowment that are kept (K-column), and that are allocated to the relative (R-column) and to the two neighbors on average ($\bar{N}$-column).

Insert Table 4 about here

Although averages are far from the efficient benchmark solution (requiring to distribute one's own endowment equally among the four group members), they are also not in line with the equilibrium predictions (according to which the unrelated partners should receive nothing in all treatments while the relative should receive 6 in the HS-treatment). Table 4 shows various things. First of all, the strength of mutual shareholding seems to influence the kept average amounts conditional on the duration of interaction. Second, cooperation levels increase with the time horizon irrespective of the strength of mutual shareholding. Third, the average allocations to the relative seem to depend more on the time horizon than on the degree of shared interest. Finally, the average amounts given to the two unrelated group members are positive, though lower than those granted to the relative, in all four treatments.

To check whether the LS- and the HS-treatments trigger equivalent cooperation levels in each time horizon, we performed Wilcoxon rank-sum tests (two-sided) comparing the independent group average amounts kept in the two treatments for both the long and the short time horizon. The results show that average units kept do not differ significantly in the LS- and HS-treatments whatever the time horizon ($p = 0.38$ in the 4-period treatment; $p = 0.53$ in the 16-period treatment). Analogous non-parametric tests comparing average amounts kept in the two time horizons for both shareholding treatments confirm that groups keep less (i.e., are more cooperative) when they interact for 16 periods rather than 4 periods ($p = 0.03$ in HS; $p = 0.02$ in LS). Thus, we can note:

Result 1 *The HS- and the LS-treatments do not differ significantly in terms of average amounts kept, whatever time horizon we consider.*

Result 2 *Average amounts kept are significantly lower in the 16-period horizon than in the 4-period horizon, regardless of the shareholding strength.*

Result 1 contradicts Hypothesis 1 in that individuals are willing to cooperate even when mutual shareholding is low (and kin-altruism should not be relevant). Result 2 supports Hypothesis 2 for the long horizon fosters cooperative actions. In order to convincingly reject Hypothesis 1 and confirm Hypothesis 2, we need to examine how the non-kept average amounts are distributed between the "relative" and the "neighbors".

Figure 1 graphically illustrates the independent group average shares given to the related and the unrelated group members in case of low and high shareholding for both time horizons. The share that the two unrelated group members receive on average (x-axis) ranges from 0 to 8. The triangle ABC represents the area of feasible allocations. The 7 independent observations in the LS-treatment are marked by a '$\diamondsuit$' sign and those in the HS-treatment by a '∇' sign.

<u>Insert Figure 1 about here</u>

In all treatments (4-HS, 4-LS, 16-HS 16-LS), no data point lies below the "equity line". This indicates that subjects did not grant, on average, higher amounts to their unrelated partners than to their (strongly or loosely) related group member. Applying Wilcoxon signed-rank tests, we can reject the null hypothesis that, in each of the 4 treatments (i.e., 4-HS, 4-LS, 16-HS, and

16-LS) average amounts given to the neighbors and to the relative are equal in favor of the alternative that the neighbors receive less ($p < 0.05$ in all four comparisons). Hence, allocators always favor their related group member regardless of the extent of mutual shareholding.

To show that the difference in average allocations to the relative does not depend on the shareholding strength, consider Figure 1. If cooperation towards the relative were triggered by the degree of mutual shareholding, the observations in the HS-treatment should be higher compared to those in the LS-treatment. However, the data of the two treatments are quite stockpiled in the short horizon (top graph),[17] and lie parallel to each other in the long horizon (bottom graph). Wilcoxon rank-sum tests (two-sided) confirm that, for both time horizons, independent group averages allocated to the relative in HS and LS are not statistically significantly different ($p = 0.62$ in the 4-period treatment; $p = 0.38$ in the 16-period treatment). Average allocations to the strongly related member are weakly significantly higher in 16-HS than in 4-HS ($p = 0.08$) whereas average allocations to the loosely related member do not differ significantly over the two time horizons ($p = 0.38$). Finally, the average amounts given to the relative under 4-HS and 16-LS are not significantly different ($p = 0.62$). This suggests that strong intensity of relatedness in short time span of relationship and weak intensity of relatedness in long time span of relationship inspire equal concerns for one's own relative. The evidence about allocation decisions can be summarized as follows.

Result 3 *Whatever time horizon and mutual shareholding, average amounts given to the unrelated group members are significantly lower than those given to the relative.*

Result 4 *Independently of the time horizon, average amounts given to the*

[17] Actually, a single group observation in the HS-treatment is located more towards the efficient allocation. One participant in this group behaved always according to efficiency, what seems to have induced her partners to follow her behavior.

strongly related group member do not differ significantly from those given to the loosely related group member. High mutual shareholding leads to slightly higher average allocations in the 16-period treatment than in the 4-period treatment.

Result 4 opposes the relatives-hypothesis (as stated in Hypothesis 1), according to which positive contributions should be observed in case of strong relatedness only. Result 3, on the other hand, contradicts a strong version of the neighbors-hypothesis (as formulated in Hypothesis 2), predicting equal treatment of all partners irrespective of relativeness, but not a weaker version of the hypothesis, requiring only positive sharing with all in case of long interaction. Thus, we turn to investigate whether the 16-period treatment triggers more equitable allocation decisions than the 4-period treatment.

The differences in average amounts given to the unrelated members between the 16-period treatment under low shareholding and the 4-period treatment under either low or high shareholding are significant ($p = 0.001$ for 16-LS vs. 4-LS; $p = 0.04$ for 16-LS vs. 4-HS; Wilcoxon rank-sum tests, two-sided). The bottom graph of Figure 1 makes it also clear that average amounts allocated to the unrelated members in the 16-period treatment are higher when shareholding is low. A Wilcoxon rank-sum test (two-sided) confirms the picture ($p < 0.001$). However (in line with previous Result 4), when allocators are strongly related to one other group member, the longer time span has not effect on the level of cooperation towards the neighbors: Amounts allocated to the unrelated partners in the HS-treatment do not differ significantly according to the time horizon ($p = 0.52$, 16-HS vs. 4-HS).

Result 5 *Average amounts given to the unrelated group members are significantly higher in the long-lasting LS-treatment than in any other treatment.*

From Results 4 and 5, we conclude that the higher cooperation levels detected in the 16-period horizon as compared to the 4-period horizon (cf., previous Result 2) benefit the relative in case of high shareholding and the neighbors in case of low shareholding.

Interestingly enough, our data reveal that individuals sometimes give more to their neighbors than to their relative. Besides the different treatment variables (short and long time horizon, low and high mutual shareholding), the average level of group cooperation, measured by the average amount of kept endowment, $\bar{K}$, and the variance in group cooperation, $\sigma^2_{\bar{K}}$, may explain this observation.[18] We, therefore, estimate the following Probit model:

$$\text{Prob}(\text{“}R - \bar{N} < 0\text{”}) = \Phi(\beta_1 + \beta_2\bar{K} + \beta_3\sigma^2_{\bar{K}} + \beta_4 Share + \beta_5 Horizon),$$

where the dependent variable takes value one if the individual gave more to her neighbors than to her relative at least once after the first period, and zero otherwise. The independent variable $Share$ is a dummy taking value of zero for the LS-treatment and one for the HS-treatment. The dummy $Horizon$ is zero for the short horizon ($t = 4$) and one for the long horizon ($t = 16$). Among the 4 considered explanatory variables only the coefficient on period is found to be significantly positive ($\beta_5 = 0.087$, t-value $= 3.56$),[19] confirming that the longer the time horizon, the higher the likelihood to allocate more to the neighbors than to the relative.

4.2 Average dynamics

Figure 2 displays the time paths of the average amounts kept and given to the relative and the two unrelated partners (on average) in the LS- and the HS-treatment. The top graph refers to the short interaction horizon and the bottom graph to the long interaction horizon.

Insert Figure 2 about here

In the 4-period treatment, for both degrees of mutual shareholding, most subjects start off by keeping about 8 units. The average kept amounts then

[18] It seems reasonable to assume that low levels of cooperation in the group as well as high fluctuations in group cooperation affect the probability that the neighbors get more.

[19] These values are obtained by sequentially deleting non significant variables.

slightly increase over time, and reach their maximum (about 11) in the last period. The evolution of average kept amounts in the 16-period treatment exhibits by and large similar features: Starting at 7.28 in LS and 6.39 in HS, average kept amounts fluctuate between 5.89 and 7.92 in LS and between 7.00 and 8.78 in HS, before they sharply rise to 10.75 in LS and 11.53 in HS in the final period. Wilcoxon signed-rank tests (one-tailed) comparing average amounts kept in the first (either 3 or 15) periods and in the last (either 4th or 16th) period for each treatment confirm that participants keep significantly lower amounts in the first periods ($p < 0.05$ in each of the four treatments). This end-effect (cf., Andreoni, 1988) is in line with existing experimental research on public goods (see Ledyard, 1995 for a comprehensive survey), and also with the results of Berninghaus et al. (2004) based on a similar voluntary social exchange game (excluding mutual shareholding).

Whatever the time horizon, the average amounts kept in HS and in LS are very much synchronized, as stated in Result 1. While in the 4-period horizon the average amounts kept in HS are always below those kept in LS, in the 16-period horizon these averages intersect in the first 8 periods, after which they become (and remain) lower in LS as compared to HS. Thus, high shareholding triggers slightly more cooperation than low shareholding if the time horizon comprises only 4 periods whereas the opposite holds in the case of long time horizon.[20]

According to Figure 2, the average amounts given to the relative in LS and HS go hand in hand under the short time horizon while they are only fairly greater in HS than in LS under the long time horizon. This corroborates Result 4, according to which the degree of mutual shareholding does not play an effective role in determining allocations to the relative. Nevertheless, in both shareholding treatments participants give substantially more to their relative than to the two unrelated partners, as observed in Result 3.

[20]Since the difference is not statistically significant, we refrain from speculating about why this occurs.

Figure 3 shows the time path of the proportion of non-kept amount that is allocated to the relative. More specifically, if R denotes the amount given to the relative and $\bar{N}$ the amount given to the two unrelated partners on average, Figure 3 displays the dynamics of $R/(R+\bar{N})$ in each of the 4 treatments. Notice that, in the HS-treatment, the examined variable would be 1 if people behaved in accordance with the relatives-hypothesis, whereas it would be 0.5 if people followed the strong version of the neighbors-hypothesis. A weak version of the neighbors-hypothesis would justify any value between 0.5 and 1.[21]

Insert Figure 3 about here

In line with our previous results, Figure 3 suggests a negative trend of allocations to the loosely related group member (in favor of the unrelated group members) in the 16-period treatment only. Proportional allocations to the relative stay rather constant throughout the 16 periods in the HS-treatment, and they slightly increase over time in the 4-period treatment independently of the shareholding degree. A linear regression analysis with a time trend variable confirms that the coefficient on time is significantly negative (-0.0082, $p = 0.004$) for the LS-treatment whereas it is non-significantly positive (0.0031, $p = 0.11$) for the HS-treatment.

5 Conclusions

The faculty to act pro-socially is crucial to the survival of many species in the animal kingdom. Mankind has been able to extend such cooperation to completely anonymous partnerships, e.g., when trading via internet platforms like e-bay. Cooperation between genetically unrelated individuals in large groups can have several driving forces. In this paper, we focused on two alternative explanations.

[21] In the LS-treatment, if people's behavior was driven by their selfish gene, $R + \bar{N}$ would be 0 and, therefore, $R/(R + \bar{N})$ would be undetermined.

One suggests that humans, being very distinct from other animals, have laid down social institutions regulating group conduct, via, e.g., sanctioning systems (cf., e.g., Bowles and Gintis, 2003; Witt, 2004). According to such an explanation, kin-altruism (cf., Hamilton, 1984) is the spontaneous condition for cooperation, which would not transcend family bonds in the absence of these institutions. Thus, we termed it the relatives-hypothesis.

Another cooperation-enhancing force that has been proposed is reciprocity based on repeated interaction (cf., e.g., Trivers, 1971; Axelrod and Hamilton, 1981). Since this explanation predicts that cooperation involves also non-kin, we called it the neighbors-hypothesis.

To discriminate between these two alternative hypotheses, we performed an experiment systematically varying both how much group members are related, by inducing varying degrees of shared interests, and how stable their groups are, i.e., how much they can rely on reciprocity due to repeated interaction.

We find that extending the scope of reciprocal exchange by longer duration inspires significantly more cooperation towards both related and unrelated partners. In contrast, varying relatedness alone does not account for much variation in cooperation. Although kinship is no *conditio sine qua non* for establishing cooperation, allocators tend, on average, to give more to their related partner than to their unrelated group members. Since none of the benchmarks yields unequal earnings, inequity aversion (cf., Fehr and Schmidt, 1999; Bolton and Ockenfels, 2000) cannot account for the most crucial data features like positive allocations to the neighbors and more generosity towards the relative. Any utility function including both own material payoffs and efficiency can explain why allocators favor their relative but give positive amounts to their neighbors too.

Our analysis neglected the dynamics of mutual gift-giving in the different groups. Such an analysis would try to explain the positive assignment to the neighbors by path dependence, e.g., by the differences in given and received amounts in the previous periods. However, this kind of analysis would go beyond the scope of this paper, which is testing the neighbors- and the relative-hypothesis.

To conclude, our data contradict both the relatives-hypothesis and the neighbors-hypothesis in its strong version, while they convincingly confirm a weak version of the latter. In line with previous experimental research, this implies that cooperation was strongly promoted by cognitively perceiving the shadow of future, i.e., by the expectation of reciprocation in future interactions.

Appendix: Experimental Instructions

This appendix contains the instructions (originally in German) we used for the 16-*LS* treatment. The instructions for the other treatments were adapted accordingly and are available upon request.

Welcome and thanks for participating in this experiment. You receive €2.50 for having shown up on time. Please read the following instructions carefully. From now on any communication with other participants is forbidden. If you have any questions or concerns, please raise your hand. We will answer your questions individually.

During the experiment you will be able to earn money. How much you will earn depends on your decisions and the decisions of other participants. Your experimental income will be calculated in ECU (Experimental Currency Unit), where 1 ECU = €0.03. At the end of the experiment the ECU you have earned will be converted to Euros and the obtained amount will be paid to you in cash.

Detailed information on the experiment

The experiment consists of 16 periods. Before the first period, participants are divided in groups of four members each, so that you will interact with three other persons. The identity of your group members will not be revealed to you at any time. The composition of your group will remain THE SAME throughout the experiment. That is, the members of your group will NOT change from one period to the next.

Within your group you are identified by a number between 1 and 4. Your identification number will be assigned to you at the beginning of the experiment, and will remain unchanged over the entire experiment.

What you have to do

In each period, each member of a group receives 16 units of a specific commodity. Commodities differ across group members. There are, therefore, four different commodities: A, B, C, and D. Member 1 is the only owner of commodity A; member 2 is the only owner of commodity B; member 3 is the only owner of commodity C; and member 4 is the only owner of commodity D.

Your task (as well as the task of the other three members of your group) is to decide

how much of your own commodity you want to give to each member of your group.

If, for instance, you are *member 1*, you have to decide the amount of commodity A you want to keep for yourself (denoted by A_1) and the amounts you want to give to members 2, 3, and 4 (denoted by A_2, A_3, A_4, respectively). Likewise, if you are *member 2*, you have to decide the amount of commodity B you want to keep for yourself (denoted by B_2) and the amounts you want to give to members 1, 3, and 4 (denoted by B_1, B_3, B_4, respectively). You have to take similar decisions if you are *member 3* (in this case, you keep C_3 and give C_1, C_2, and C_4 to members 1, 2 and 4) or *member 4* (in this case, you keep D_4 and give D_1, D_2, and D_3 to members 1, 2 and 3).

Your decision must fulfil two conditions:

1. You must distribute all the 16 units at your disposal. If, for example, you are member 1, this means that $A_1 + A_2 + A_3 + A_4$ must be equal to 16. The same holds if you are member 2 or 3 or 4.
2. You cannot subdivide the single units of your commodity, i.e., you must choose only integers between 0 and 16.

EXAMPLE 1

Suppose that you are *member 1* and, therefore, own 16 units of commodity A. You must decide how you want to distribute these 16 units among the four group members. If you choose: $A_1 = 3$, $A_2 = 2$, $A_3 = 5$, and $A_4 = 6$, this means that you keep 3 units of commodity A for yourself, and give 2 units to member 2, 5 units to member 3, and 6 units to member 4. This exhausts the 16 units at your disposal, i.e., 3 + 2 + 5 + 6 = 16.

EXAMPLE 2

Suppose now that you are *member 3* and, therefore, own 16 units of commodity C. If you choose $C_1 = 4$, $C_2 = 4$, $C_3 = 8$, and $C_4 = 0$, this means that you keep 8 units of commodity C for yourself, give 4 units to members 1 and 2, and nothing to member 4. Again, 4 + 4 + 8 + 0 = 16.

You have to make your decision without knowing what you receive from the other group members, and the same holds for them.

Sending positive amounts of your commodity to another group member causes you some costs. Specifically, you pay 1 ECU for *each person* to whom you send something. That is, if you give some units of your commodity to only one other member of your group, costs amount to 1 ECU; if you give some of your commodity to two other members, costs amount to 2 ECU; if you give some of your commodity to all three other members, costs are equal to 3 ECU.

Your period earnings

The quantities of each commodity type that you own at the end of each period determine your return, E, for that period. This return is calculated by:

- taking the square root of the units of each commodity that you own;
- summing up the square root(s);
- multiplying the obtained sum by 8; and
- subtracting the "sending costs" from the resulting number.

Suppose, for instance, that you are member 1. Then you will have kept A_1 units of commodity A for yourself. Member 2 will have sent you B_1 units of commodity B, member 3 will have sent you C_1 units of commodity C, and member 4 will have sent you D_1 units of commodity D. Then, your return is given by:

$$E = \left[\left(\sqrt{A_1} + \sqrt{B_1} + \sqrt{C_1} + \sqrt{D_1}\right) \times 8\right] - \left[\textit{Sending costs}\right].$$

The same calculation applies to members 2, 3, and 4.
"*Sending costs*" are either *0* (if you gave nothing to the others) or *1* (if you gave something to one other member of your group) or *2* (if you gave something to two other members of your group) or *3* (if you gave something to all three other members of your group).

<u>Example</u>

Suppose that you keep 6 units of your commodity for yourself, distribute the remaining 10 units of your commodity to only *two* other members of your group and receive 4 units of each of the other commodities, Then, your return is: $[(\sqrt{6}+\sqrt{4}+\sqrt{4}+\sqrt{4}) \times 8] - 2$ $= [(2.45 + 2 + 2 + 2) \times 8] - 2 = [8.45 \times 8] - 2 = 67.6 - 2 = 65.6$

Your period earnings depend on your own return as well as on the return of one other person in your group. In particular, you keep 95% of your return and share 5% of the return of one other group member. Hence, your period earnings, U, are given by:

$$U = [0.95 \times (your\ E)] + [0.05 \times (one\ other\ member's\ E)].$$

The person whose return you share is:

- member 2 if you are member 1;
- member 1 if you are member 2;
- member 4 if you are member 3;
- member 3 if you are member 4.

Suppose, for example, that member 1's return is 100, member 2's return is 200, member 3's return is 160 and member 4's return is 240. Then, member 1's periods earnings are: $(0.95 \times 100) + (0.05 \times 200) = 95 + 10 = 105$. Similarly, member 2's periods earnings are: $(0.95 \times 200) + (0.05 \times 100) = 190 + 5 = 195$. Member 3's period earnings are: $(0.95 \times 160) + (0.05 \times 240) = 152 + 12 = 164$. Finally, member 4's periods earnings are: $(0.95 \times 240) + (0.05 \times 160) = 228 + 8 = 236$.

Attached to these instructions, you can find a *table* displaying your return for some examples of what you keep and what you receive from the other members of your group. The table will help you in making your decisions.

In addition to this table, we provide you with a *calculator* that allows you to compute your *expected* return, E, as well as your *expected* earnings, U. You can start the calculator by pressing the corresponding button on your screen. If you do so, a window will appear on your screen. Into this window you must enter how many units of your commodity you want to keep (i.e., any integer number from 0 to 16), how many units of each of the other commodities you expect to receive (i.e., three integer numbers from 0 to 16), and the number of other group members to whom you want to give something (either 0 or 1 or 2 or 3). Given these figures, if you press the apposite button, you will know the corresponding per period expected return, E. Then, if you enter how much you expect to be the return of the person whose E you share, and press the apposite button, you will know the corresponding per period expected earnings, U.

The information you receive at the end of each period

At the end of each period, you will be informed about the amount of commodity that you receive from each of the other three members of your group as well as about your own return, E, and earnings, U, in that period.

Your final earnings

Your final earnings will be calculated by adding up your period-earnings in each of the 16 periods of the experiment. The resulting sum will be converted to euros and paid out to you in cash, together with the show-up fee of €2.50.

Before the experiment starts, you will have to answer some control questions to verify your understanding of the experiment. Once everybody has answered all questions correctly, three practice periods will be played. During these three periods, you will not be matched with other persons in this room, but with a computer that will determine randomly the others' decision. You will get NO payment for these practice periods.

Please remain quiet until the experiment starts and switch off your mobile phone. If you have any questions, please raise your hand now.

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Treatment	*Mutual shareholding*	*Periods of interaction*
4-LS	Low (5%)	4
4-HS	High (45%)	4
16-LS	Low (5%)	16
16-HS	High (45%)	16

Table 1: Summary of experimental design

	Share of relative's profit	
Incentives	LS (5%)	HS (45%)
$u_i(a^*)$	32.00	43.89
$u_i(a^+)$	61.00	61.00
$D(8, 1, 1/2)$	29.00	17.11

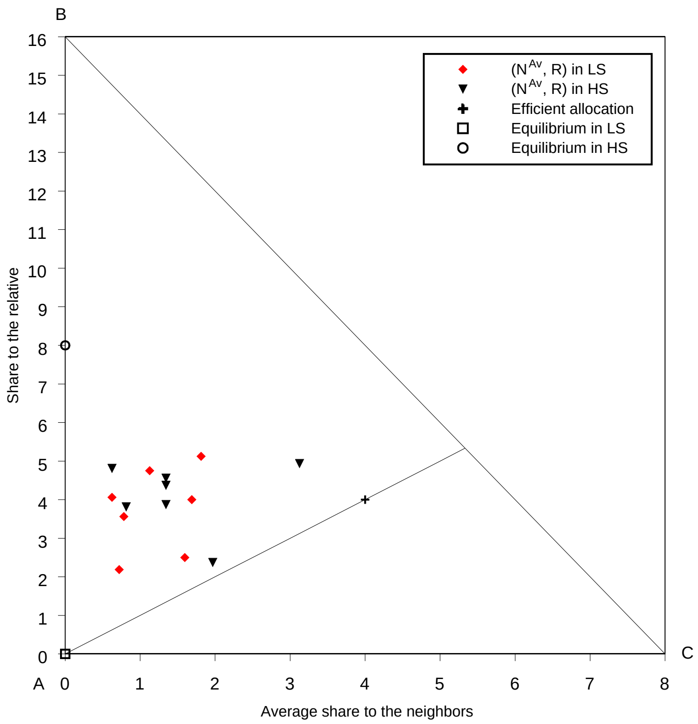
Table 2: Experimental period-payoffs in case of universal opportunistic and efficient behavior

		What fosters cooperation	
		Relatedness	*Time horizon*
Who benefits from cooperation	*Strong relative*	Hypothesis 1	
	All group members		Hypothesis 2

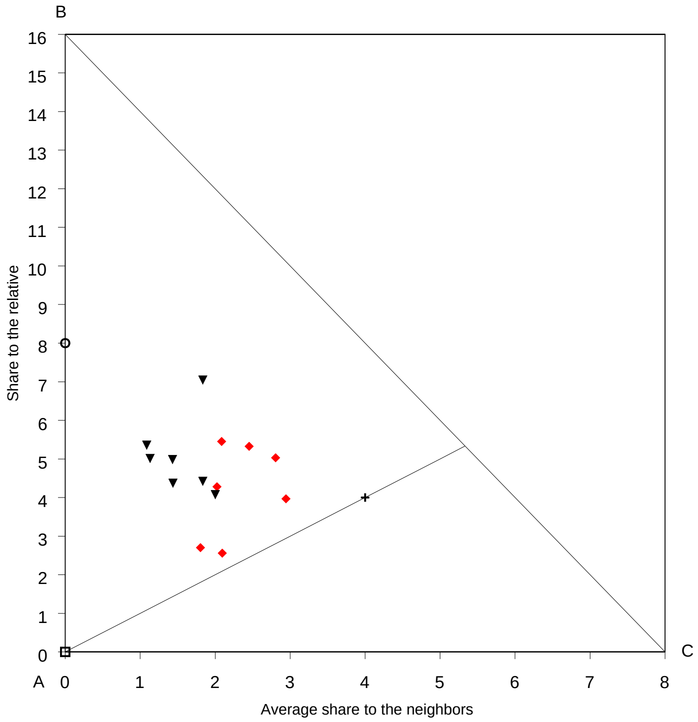
Table 3: Relation between research questions and hypotheses

Treatment	K	R	$\bar{N}$
4-LS	9.88	3.74	1.19
4-HS	8.87	4.11	1.51
16-LS	7.18	4.19	2.31
16-HS	7.89	5.04	1.53

Table 4: Average units kept (K), given to the relative (R) and to the neighbors on average ($\bar{N}$) in all four treatments



4-period treatment



16-period treatment

Figure 1: Distribution of the 7 independent group observations in LS and HS for both the short and the long time horizons.

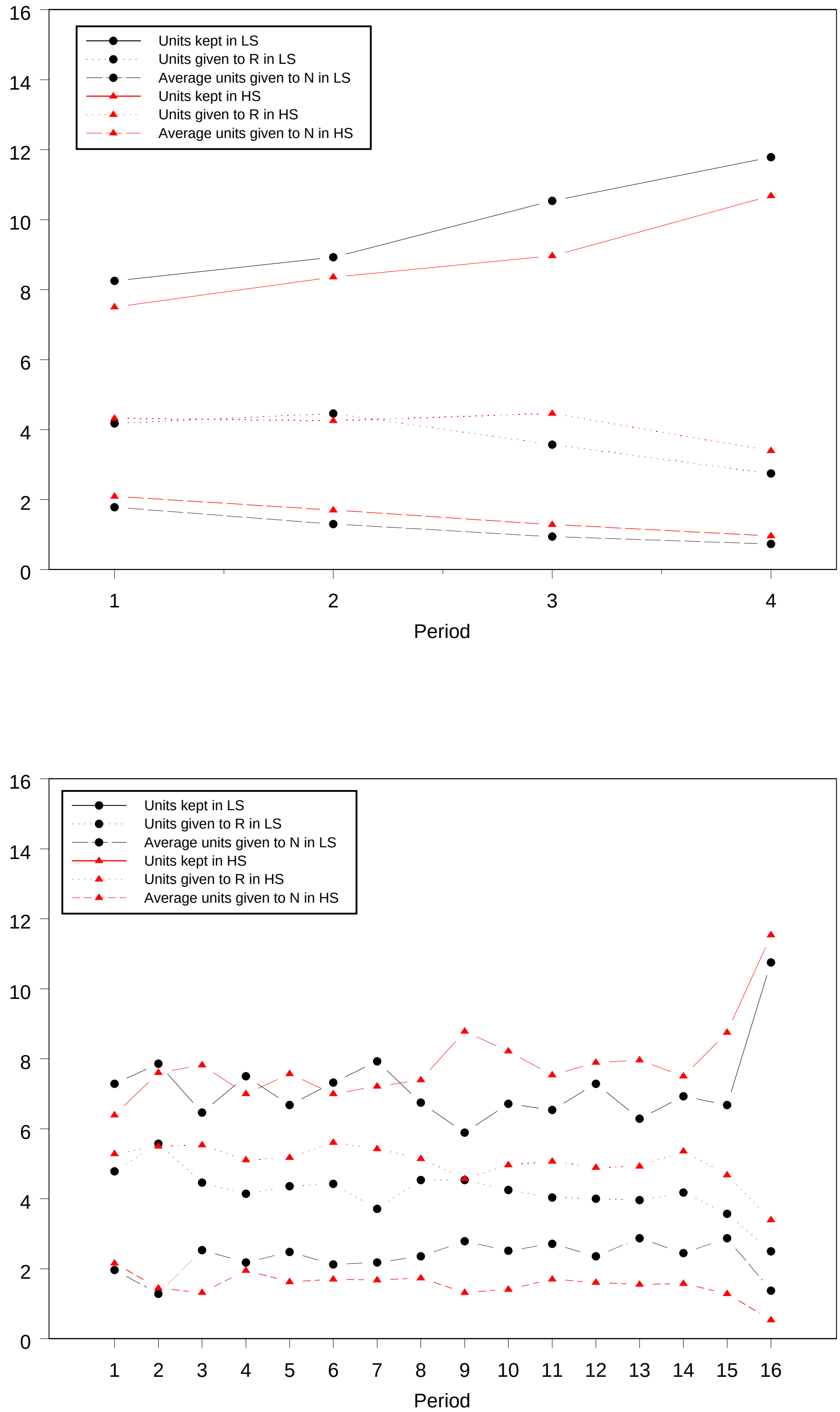


Figure 2: Evolution of cooperation in the *LS*- and *HS*-treatments in case of both short and long time horizons.

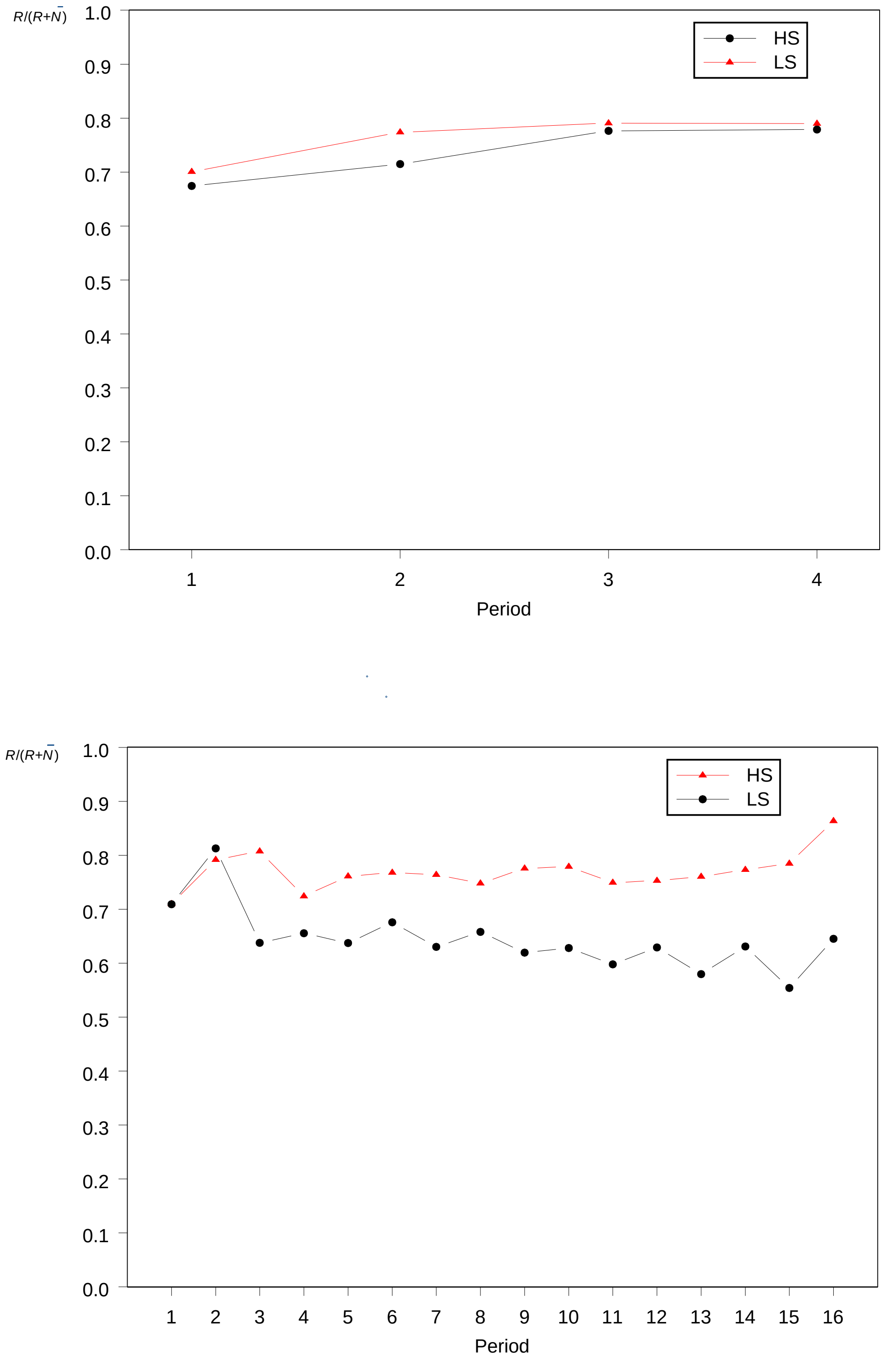


Figure 3: Evolution of $R/(R+\bar{N})$ in the LS- and HS-treatments in case of both short and long time horizons.