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Article

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Mutual interdependence versus repeated interaction: An experiment studying voluntary social exchange

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Abstract

Relations of mutual interdependence have been regarded as necessary for human cooperation to evolve. However, many studies in the social sciences indicate that repeated interaction suffices to establish cooperation. We examine this issue by means of a voluntary social exchange experiment where mutually interdependent players coexist with merely dependent ones. We systematically vary the degree of mutual interdependence and the length of the time horizon. According to our data, repetition of interactions is crucial for fostering cooperation, although people remain attentive to mutual interdependencies.

Keywords

profit sharing, reciprocity, voluntary social exchange experiment

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1. Introduction

In any account of economic organizations we need an understanding of the nature and significance of human cooperation. Recently, some progress in this regard has been made by combining the methods of experimental economics with those of economic anthropology. The cross-cultural study of behaviour in ultimatum, public goods, and dictator experiments undertaken by Henrich et al. (2001) involved fifteen small societies. The highest cooperation rates were observed among the Lamelara whale-hunters, who go to sea in large canoes manned by a dozen or more men and must thus develop ways of sharing the joint outcome. Following Molm (1994), we shall refer to relations in which the control over the outcome is shared jointly by two or more individuals as being *interdependent*. In contrast, we will qualify as mutually *dependent* the relations in which each actor values resources that are under the control of the interaction partners so that each provides the others with benefits by means of exchange. The fundamental issue that we intend to address in this paper is whether only relations of mutual interdependence can encourage cooperation (as suggested by Henrich et al.'s study) or if mechanisms other than mutual interdependence can promote cooperation.

According to what we call the *'high mutual interdependence' hypothesis*, when structural relations of interdependence are absent, people fail to cooperate with each other (Molm, 1994; Molm and Wiggins, 1979). We do not deny that structural interdependence plays a central role in the emergence of cooperation. But, claiming that mutually interdependent relations are a necessary condition for cooperation seems questionable. Quite to the contrary, the presence of 'retributive emotions' in our psyche (Mackie, 1985) appears to indicate that a disposition to reciprocate (e.g. in 'truck and barter') may have become almost a kind of 'second nature' (Ofek, 2001). According to what we call the *'shadow of the future' hypothesis*, even in the absence of structural interdependence, repeated interaction can be successful in furthering cooperation.

When the shadow of the future appears large, the parties involved in repeated interactions may choose to cooperate because the temporary benefits from cheating today are outweighed by retaliatory punishments delivered in the future (see for example Axelrod, 1984; Axelrod and Hamilton, 1981; Nowak et al., 1995; Trivers, 1971 for formal studies). Kreps et al. (1982) proved that if each player assigns a small probability to the event that the other has a taste for reciprocity, then in a finitely repeated prisoner's dilemma game with a sufficient number of repetitions, cooperation is an equilibrium outcome for the initial stages of the game. More recently, Guttman (2003) applied the indirect evolutionary approach to the prisoner's dilemma and showed that if interactions are sufficiently long lived, then in the unique evolutionary equilibrium reciprocal types always cooperate and selfish types cooperate until one before the last period.

Moreover, it is well known from the psychological and sociological literature on social exchange that successful repeated interaction with the same others generates positive emotions, in the sense that group members feel good (Lawler and Yoon, 1996; Lawler et al., 2000; Willer et al., 1997).[1] If these positive feelings are attributed to the exchange relation, they may produce stronger affective attachments to the group. Hence, with repetition, the group becomes an expressive object, valuable in its own right (Lawler 1992). This salience of group membership has been conceptualized as 'relational cohesion' (Lawler and Yoon 1996), which is predicted to have behavioural consequences in that 'cohesive' group members should be more likely to cooperate. Lawler et al. (2000), among others, experimentally tested the theory of relational cohesion and showed that repeated success at exchange affects positive emotions and group cohesion.

In this paper, we use the experimental approach to compare the 'shadow of the future' and the 'high mutual interdependence' hypotheses. We do not seek to diminish the importance of mutual interdependencies nor do we claim that future dealings can explain by themselves the evolution of cooperation.[2] Rather, we want to investigate whether and to what extent repeated interaction can induce cooperation when relations of mutual interdependence are very low.

The basic experimental set-up is a repeatedly played voluntary social exchange game, where each of several exchange partners is the exclusive owner of a specific input commodity that she can share with all the other group members. The amount of all inputs that an individual collects determines the size of her output, which represents the individual's profit. To have something specific in mind, think of the individual input commodities as ingredients (flour, butter, eggs, ...) to produce the output commodity 'cake'. The exchange partners are therefore mutually dependent on each other. To experimentally induce elements of interdependence, we let each participant hold a share of a partner's profit so that there exist positive externalities between group members. In view of our illustrative example, this means that all group members can voluntarily share ingredients but only interdependent members automatically share the output commodity 'cake' as well. Since exchange partners can give unilaterally to each of the others without knowing what (if anything) they will receive in return, the exchange we consider is nonnegotiated, or reciprocal. Moreover, since interdependent partners pool their profits and then share the joint profit according to some exogenously imposed parameters, the social exchange we are dealing with has the properties of productive exchange as well.[3]

Our experimental setting embodies dependence of each actor on the group because (i) the exchange is efficiency enhancing, in the sense that each party enjoys a proper mixture of all inputs more than a single input, and (ii) the members of each group cannot collect inputs from groups outside their own.[4] However, in this type of mutual dependence the temptation not to reciprocate is very high because the other has the opportunity to receive something without giving anything in return. In contrast, in relations of mutual interdependence – as those created here – should individuals fail to exchange with the interdependent partners, their own payoff would deteriorate. This built-in dependence on the *relationship itself* produces cooperation (Michaels and Wiggins, 1976; Molm, 1994) and thus fulfils the same function as institutions imposing and maintaining social order.

We consider groups of four with two pairs of mutually interdependent subjects. In one treatment, interdependence is very low since interdependent members share only 5% of their profit with each other. In another treatment, interdependence is very high since interdependent members share 45% of their profit. If players are monetary payoff maximizers, this extreme increase in the degree of mutual interdependence renders cooperation with the highly interdependent partner an equilibrium outcome and lowers each individual's dependence on the group, defined (following Lawler et al., 2000) as the maximum payoff from the group minus the independent selfish payoff. The perfect symmetry between the players implies then that the total dependence on the group (namely, the average of the four members' dependence) equals the individual dependence. Moreover, if we follow Emerson's (1962, 1972a, 1972b) power dependence theory and see power as inversely related to levels of dependence on the group, our experimental manipulation implies greater total power when profit sharing is high (on this issue see also Bacharach and Lawler, 1981). The theory of relational cohesion (see, e.g., Lawler and Yoon, 1996) suggests that lower total dependence (or greater total power) should produce less frequent exchange among all group members. In view of these considerations, the 'high mutual interdependence' hypothesis predicts that there is no cooperation beyond pairs of individuals who are highly interdependent. In other words, positive input-exchanges should be observed merely between partners who share a high percentage of each other's profit.

To investigate whether repeated interaction can promote cooperation, we use a partner design and always allow for repetition, but vary the length of the time horizon. In the short horizon treatment, participants interact for four periods. In the long horizon treatment, they interact for 16 periods.

Varying the length of the time horizon does not change the theoretical solution based on own payoff maximization: since in the known last period players are predicted either to not cooperate (when profit sharing is 5%) or to cooperate only with the interdependent partner (when profit sharing is 45%), backward-induction arguments imply that this equilibrium behaviour should be expected in all periods. However, a longer time span of the relationship provides the group members the opportunity to overcome the social dilemma inherent in mutual dependence for at least two reasons. First, if the shadow of the future is long the threat of future retaliation makes it more beneficial for the parties to cooperate than to exploit the others (Axelrod, 1984). Second, more repetitions with successful exchange strengthen affective attachments to the group by producing positive emotional states, which in turn foster cooperation (Lawler 2001; Lawler and Yoon 1996). Taking into account these arguments, the 'shadow of the future' 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 degree of profit sharing (i.e., on interdependence). Rather, the length of the time horizon appears to be crucial because cooperation rates are found to be higher when interaction endures for 16, rather than four, periods. This seems to support the 'shadow of the future' hypothesis. Yet, what is allocated to the interdependent partner is always greater than what is given to the two other group members. Our results are, therefore, consistent with previous studies showing the importance of repeated interaction in human cooperation (Brown et al., 2004; Gächter and Falk, 2002), although people remain particularly attentive to mutually interdependent relations. In other words, although relational cohesion helps explain the emergence of cooperation, structural cohesion, defined as 'the structural potential for instrumental cooperation in an exchange relation' (Lawler and Yoon, 1996, page 92), plays an important role too. 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 reciprocal and productive social exchange as described in the introduction. Let $N = \{1, \dots, 4\}$ be a group of four individuals who interact for T periods. In any period $t \in \{1, \dots, T\}$, each individual $i \in N$ is endowed with $E = 4k$ (> 0) units of a specific input-commodity of which she is the only owner. Thus, there are four different inputs, one per individual.

In every period, each member i in N must decide about the amount of E that she wants to allocate to each group member, including herself. Sending units of one's own input to another group member is costly, i.e., when i gives units of her input to j ($j \neq i$), she must pay c, which we interpret as transportation costs and assume not to depend on the transferred amount. If $a_j(i)$ denotes the amount of her own input that i allocates to j (with $j = 1, \ldots, 4$), the period-strategy of each individual $i \in N$ is choosing an allocation $a(i) = (a_1(i), \ldots, a_4(i))$, with $a_j(i) \geq 0$ and $\Sigma_{j \in N} a_j(i) = E$.[5] As in reciprocal exchange, the allocation decisions $a(i)$ are taken simultaneously and independently so that when i gives units of her inputs to j, she does not know whether j will reciprocate.

The amount of each input that individual i owns at the end of each period allows her to produce an output commodity, which represents i's own profit. Denoting by $\mathbf{a} = (a(1), \ldots, a(4))$ the vector of individual strategies $a(i)$, the profit of i depends on $\mathbf{a}$ via

$$g_i(\mathbf{a}) = \alpha \sum_{j=1}^{4} a_i(j)^p - c \sum_{j \neq i} \delta_j \qquad (1)$$

where $0 < p < 1$, $\alpha > 0$, $c > 0$, and δ_j is a dummy variable that equals one if i sends units of her input to j and zero otherwise.

To induce mutual interdependence, we let player i (for all $i \in N$) hold a share of partner r's profit ($r \in N$, $r \neq i$) and vice versa, so that i's profit and r's profit are pooled and the joint profit determines their respective payoff (as in productive exchange). Let us denote player i's share of j's payoff by s_i^j. We impose $s_i^r = s_r^i > 0$ for the two interdependent partners i and r, and $s_i^l = 0$ for both other group members $l \neq i, r$. Each player i in N keeps for herself the share of her own profit that is not assigned to r, i.e. $s_i^i = (1 - s_r^i)$, which – due to symmetry within pairs – can be written as $s_i^i = (1 - s_i^r)$. The payoff of player i is the sum of her profit shares, i.e. $u_i(\mathbf{a}) = s_i^i\, g_i(\mathbf{a}) + s_i^r\, g_r(\mathbf{a})$.

$$u_i(\mathbf{a}) = (1 - s_i^r)\, g_i(\mathbf{a}) + s_i^r\, g_r(\mathbf{a}). \qquad (2)$$

Equation (2) describes the incentives of player i (for all $i \in N$) which will guide her strategic considerations. Maximization of her own profit $g_i(\mathbf{a})$ would require player i to keep her own endowment (i.e., $a_i(i) = E$). However, this would decrease i's total payoff $u_i(\mathbf{a})$ by deteriorating $g_r(\mathbf{a})$. Thus, mutual interdependence is expected to affect outcomes unless sending costs are too high. In particular, maximizing (2) with respect to $a(i)$, one gets that i's optimal decision (for all $i \in N$) is to choose an allocation $a^*(i)$ such that $a^*_\ell(i) = 0$ for all $\ell \neq i, r$ and $a^*_r(i) = E - a^*_i(i) \geq 0$. An interior maximum 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:

$$a_i^*(i) = \begin{cases} E \dfrac{s_i^{r\gamma}}{s_i^{r\gamma} + (1 - s_i^r)^\gamma} & \text{if } c < \bar{c} \\ E & \text{if } c \geq \bar{c} \end{cases} \quad \text{for all } i = 1, \ldots, 4 \tag{3}$$

where $\gamma = \dfrac{1}{p-1}$, and $\bar{c} = \alpha E^p \left[\dfrac{(1 - s_i^r)^{\gamma p} \dfrac{s_i^r}{1 - s_i^r} + s_i^{r\gamma p}}{[(1 - s_i^r)^\gamma + s_i^{r\gamma}]^p} - 1 \right]$. Hence, i should give a positive amount of her own input to the interdependent partner if c is sufficiently small, while i should keep all units of her input if c is large enough to prohibit voluntary exchange. The payoffs in case of general opportunism are

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

where $\mathbf{a}^*$ denotes the strategy vector when all players choose their opportunistic strategy (which is also dominant due to the additivity in (1)).

The result does not change essentially if the normal form game is repeated finitely often. All that needs to be assumed is a commonly known upper bound for the number of repetitions, which excludes folk-theorem results. In this case, there is the last period to which our solution applies. But then the allocation $a^*(i)$ 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.

An alternative benchmark is *efficiency*. Depending on the cost levels, different numbers of group members, who mutually exchange the same amounts of inputs, may be efficient. More specifically, mutual and equal exchange 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 number of members exchanging the same amount of inputs outweighs large 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 $u_i(\mathbf{a})$ over all $i \in N$. Since i's profit, $g_i(\mathbf{a})$, is strictly increasing and strictly concave in all $a_i(j)$, the candidate is $a_j^+(i) = k = E/4$ for $i, j = 1, \ldots, 4$. The payoff implications of this efficiency benchmark are $u_i(\mathbf{a}^+) = \alpha 4k^p - 3c$ for all $i \in N$, where $\mathbf{a}^+$ denotes the allocation that results if all players i choose $a_j^+(i)$.

Let us denote the individual payoff effect when substituting $\mathbf{a}^+$ for $\mathbf{a}^*$ by $D_i(\cdot)$. The function $D_i(\cdot) := u_i(\mathbf{a}^+) - u_i(\mathbf{a}^*)$ defines the dependence of each player i on the group[6] and varies with the parameters α, c, and p as follows:

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

Exchange among all group members is mutually profitable, thereby posing a social dilemma, if c is sufficiently small to render $D_i(\alpha, c, p)$ positive. In particular, the dilemma arises whenever $\alpha 4k^p - 3c > 4(4k)^p$ or, equivalently

$$c < \left[\alpha k^p (4 - 4^p)\right]/3 =: \underline{c}. \tag{4}$$

If the latter constraint holds, although maximization of own payoff would require player i either to keep all her endowment or to give a part of it to her interdependent partner (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 in a group of four 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' profit in each period depends on the amount of each input that she owns and is given by profit function (1) with $\alpha = 8$ and (to be easily understood) $p = ½$. Given these parameter values, inequality (4) implies $\underline{c} = 10.67$. Thus, mutual exchange with all four group members is profitable for any value of $\underline{c} < 10.67$. To provide sufficient incentives for mutual input exchanges, we set $c = 1$. Mutual profit sharing determines then the participants' payoff via Equation (2).

We manipulate mutual interdependence between group members by varying a player's share in the other's profit. In the *high interdependence treatment* (henceforth HI), 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 interdependence treatment* (henceforth LI), 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 four-person group, one player is in a mutually interdependent relation with another member and in a mutually dependent relation with the remaining group members. Since a participant benefits more from giving to the interdependent partner than to the two other group members, there is *structural cohesion* between interdependent partners (for a definition of structural cohesion see, e.g., Lawler and Yoon, 1996).

The shadow of the future is manipulated by varying the length of the time horizon. In the short time horizon, subjects interact for four periods. In the long time horizon, they interact for 16 periods. Both the degree of mutual interdependence and the length of the horizon are between-subjects factors.[7] The characteristics of our four different treatments are summarized in Table 1.

For each of the four treatments, we ran one session with 28 participants each. In each session, groups interacted in a partner design, yielding a total of 7 independent observations per treatment. All sessions were run computerized with the help of *z*-tree (Fischbacher, 2007) at the laboratory of the Max Planck Institute in Jena (Germany). Participants were undergraduate

Table 1. Summary of experimental design

Treatment	Mutual profit sharing	Periods of interaction
4-LI	Low (5%)	4
4-HI	High (45%)	4
16-LI	Low (5%)	16
16-HI	High (45%)	16

students from different disciplines at the University of Jena. Participants were identified by membership numbers (1 to 4), and mutually interdependent members were 1 and 2 on the one hand, and 3 and 4 on the other hand. At the end of each period, each subject got feedback on the amount of the different inputs that she received from each of the others as well as on her period profit and payoff.

Upon arrival, participants were randomly seated at visually isolated computer terminals. Written instructions (in German) were then distributed and read aloud to establish public knowledge (see the appendix for an English translation). Understanding of the payoff rules was assured by a control questionnaire that all subjects had to answer correctly in order for the experiment to start. To help participants compute profits and payoffs, we provided them with a profit table, and profit and payoff calculators as part of the experimental software. Furthermore, to 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. Each person was checked during the practice periods to insure that everyone understood the profit table and how to use the calculators. The 4-period sessions were finished in about 1½ hours and the 16-period sessions in about 2 hours. Payoffs were quoted in ECU (experimental currency units), where 100 ECU = €3. The average earnings (excluding a show-up fee of €2.50) per subject were €5.82 in the 4-period treatment, and €25.01 in the 16-period treatment.

The LI and HI treatments allow us to study whether structural relations of interdependence play a major role in shaping behaviour. Indeed, given our parameters choices, the value of c prohibiting voluntary exchange even toward the interdependent partner (i.e., $\overline{c}$ in Equation (3)) equals 9.346 in LI and 0.044 in HI. Since in both treatments $c = 1$, rational and strictly self-interested players should give part of their endowment to the interdependent partner in the HI treatment only. In particular, substituting 16 for E, −2 for γ, and 0.45 for s_i^r in the upper part of Equation (3), one obtains $a_i^*(i) = 9.58$, which implies $a_{r.}^*(i) = 6.42$. As choices were restricted to integers, player i in treatment HI maximizes her own payoff by choosing $a_i^*(i) = 10$ and $a_{r.}^*(i) = 6$. Thus, a selfish individual should keep all her endowment in the LI treatment, and give six units to the partner whose profit she shares in the HI treatment. As pointed out in Section 2, backward induction reasoning induces this solution in each period. Thus, in line with the 'high mutual interdependence' hypothesis, mutual interdependence should be crucial in shaping behaviour because cooperation is predicted to evolve only between highly mutually interdependent individuals.

Table 2. Experimental-period payoffs in case of universal opportunistic and efficient behaviour

	LI treatment	HI treatment
$u_i(\mathbf{a}*)$	32.00	43.89
$u_i(\mathbf{a}+)$	61.00	61.00
$D_i(8, 1, ½)$	29.00	17.11

Table 2 lists the payoffs $u_i(\mathbf{a}^*)$ and $u_i(\mathbf{a}^+)$ as well as the individual dependence on the group ($D_i(\alpha, c, p)$) for the LI and the HI treatment as implied by the experimental parameter specifications. The table spells out that in our setting all subjects are equally dependent on the group and this dependence is lower in HI than in LI. In the former treatment, the opportunity costs of choosing the selfish alternative are therefore lower, which should entail fewer exchanges with the whole group (Lawler and Yoon, 1996). This strengthens the game theoretical prediction discussed above. Accordingly, we test:

Hypothesis 1

(a) Cooperation with the interdependent member is higher when profit sharing is high, rather than low.

(b) There is no cooperation with the group members with whom one does not share profits.

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.[8] The last row of Table 2 makes clear that, in both treatments, individuals can gain substantially by relying on mutual reciprocity and engaging in exchanges involving all group members. Although a 'strong' reciprocator is predicted to react (un) kindly to friendly (hostile) actions even in non-repeated interactions (Fehr and Fischbacher, 2003), there is evidence indicating that material incentives stemming from repeated interactions strengthen implicit reciprocity-based incentives. Gächter and Falk (2002) and Brown et al. (2004), for instance, show that repeated interaction causes a huge increase in cooperation relative to one-shot situations in gift exchange experiments.

Furthermore, research on social exchange has revealed that, if players successfully exchange with each other and the group is perceived as stable, then equal dependence/power – as is the case in our experiment – is likely to produce positive emotions, which generate relational cohesion, which in turn fosters cooperation (Lawler, 2001; Lawler and Yoon, 1993, 1996, 1998; Lawler et al., 2000). Repetitive interaction appears however crucial for establishing stable exchange relations (Kelley and Thibaut, 1978; Molm, 1994).

The potential influence of different time horizons on cooperation rates is here captured by distinguishing the 4-period and the 16-period treatment. The 'shadow of the future' hypothesis would predict that cooperation increases with the time horizon because a longer horizon of future interaction makes easier (i) to establish and maintain mutually beneficial exchanges, and (ii) to enhance individuals' affective attachment to the group. Thus, we test:

Hypothesis 2
(a) Cooperation is higher in the long time horizon than in the short one.
(b) All members of the group benefit equally from increase in cooperation.

Part (b) of Hypothesis 2 corresponds to a strong version of the shadow of the future-hypothesis. A weaker version of the hypothesis would require only positive sharing with all. Hypothesis 1 and Hypothesis 2 tackle two research questions. Namely, what drives agents' cooperative decisions (profit sharing or time horizon), and who benefits from the latter (the interdependent partner or all group members). The two hypotheses, with their respective subparts, are not necessarily exclusive, but only reflect our main research motivations.

4. Results

To determine which (if any) of the two hypotheses explains our data, we consider both the amounts that individuals keep for themselves (which are taken, here, as an indicator of the level of cooperation),[9] and the amounts that they give to the interdependent partner and to the two other group members. In our analysis we pool the data concerning the structurally unconnected members (henceforth the 'others') so that they can be compared as a unique entity to the interdependent member.

The experimental results are summarized in Table 3 and Figure 1. Table 3 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 interdependent member (I-column) and to the two others on average ($\bar{O}$-column). Figure 1 graphically illustrates the independent group average shares given to the interdependent partner and to the other group members in case of low and high profit sharing for both time horizons. In the figure, the triangle ABC represents the area of feasible allocations. 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 no exchange should be observed in the LI treatment while six units should be given to the interdependent partner in the HI treatments).

Starting with the analysis of average amounts kept, Table 3 reveals the following effects: (i) whatever time span we consider, average amounts kept in LI do not appear to differ from those kept in HI; (ii) whatever the strength

Table 3. Average units kept *(K)*, given to the interdependent partner *(I)* and to the two others on average $(\bar{O})$ in all four treatments

Treatment	*K*	*I*	$\bar{O}$
4-LI	9.88	3.74	1.19
4-LI	8.87	4.11	1.51
16-HI	7.18	4.19	2.31
16-HI	7.89	5.04	1.53

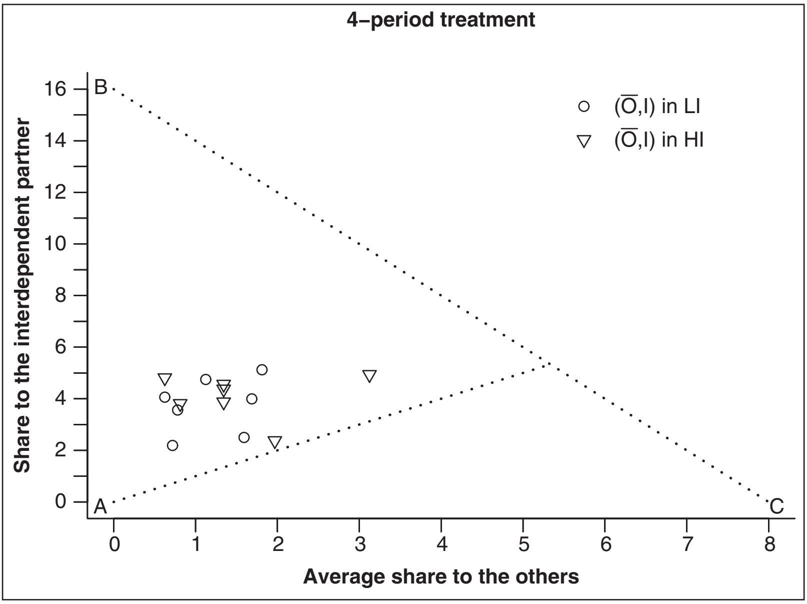

Figure 1a.

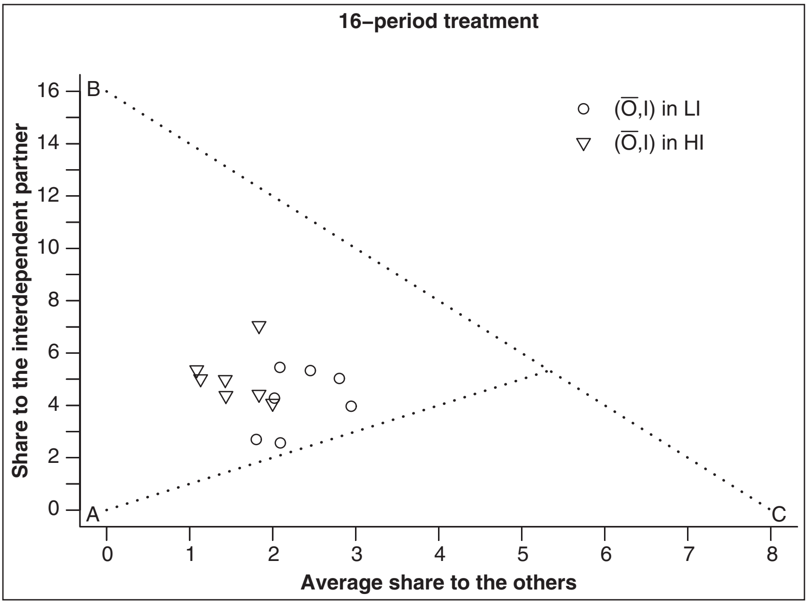

Figure 1b. Distribution of the seven independent group observations

of profit sharing, average amounts kept are lower in the 16-period horizon than in the 4-period horizon. Such observations suggest that allocators' behaviour does not change with the degree of mutual interdependence, but rather with the duration of interaction. This is confirmed by a series of Wilcoxon rank-sum tests (two-sided) showing that group average amounts kept are significantly different when comparing short and long time horizon for each mutual interdependence, but they are not so when comparing low and high mutual interdependence for each time horizon ($p < 0.05$ for 4-HI vs. 16-HI and for 4-LI vs. 16-LI; $p > 0.30$ for 4-HI vs. 4-LI and for 16-HI vs. 16-LI).[10] Thus, we can note:

Result 1

The HI and LI 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 degree of mutual interdependence.

Result 1 contradicts part (a) of Hypothesis 1 in that individuals are willing to cooperate even when profit sharing is low. Result 2 supports part (a) of Hypothesis 2 for the long horizon fosters cooperative actions.

We now examine how the non-kept average amounts are distributed between the interdependent partner and the two others, and who benefits from the higher cooperation level detected in the long horizon as compared to the short one. The first thing we notice is that, in all four treatments, the average amounts given to the others are positive, though lower than those granted to the interdependent partner. In the 4-period treatment, out of the 112 possible allocations to the others, 59.8% are greater than zero in HI and 51.9% in LI. The respective percentages for the 448 possible allocations in the 16-period treatment are 71% and 85.7%. The null hypothesis that, in any of the four treatments, the probability of giving to the others is equal to 0 can be rejected in favour of the alternative that such a probability is positive ($p < 0.001$ in all cases; one-sided binomial test) Hence, we can state:

Result 3
Independently of the treatment, there is positive exchange with group members with whom one does not share profits.

Result 3 provides evidence against part (b) of Hypothesis 1. However, according to Figure 1, no group in any of the four treatments granted, on average, lower amounts to the interdependent partner than to the two others (no data point lies below the 'equity line'). Statistical corroboration of the preferential treatment toward one's interdependent partner is provided by a series of Wilcoxon signed-rank tests (one-sided) comparing independent group average amounts given to the interdependent partner and to the two others in each treatment. The tests show that players always give significantly higher amounts to their interdependent group member ($p < 0.01$ in all four comparisons). Hence, even when mutual profit sharing is low, allocations are positively biased toward the interdependent group member. This yields our next result, which is in conflict with part (b) of Hypothesis 2.

Result 4
Regardless of the time horizon and the degree of mutual interdependence, average amounts given to the interdependent partner are significantly higher than those given to the two other group members.

Let us now investigate in more detail whether the time horizon and/or the degree of mutual interdependence affect allocations to the various parties.

As regards the interdependent member, Figure 1 indicates that group average amounts given to the interdependent partner are essentially unaffected by the degree of profit sharing: the data of the HI and LI treatments are quite stockpiled in the short horizon (top graph),[11] and lie parallel to each other in the long horizon (bottom graph). A comparison between the top graph and the bottom one suggests that allocations to the interdependent partner are the highest when interaction lasts longer and profit sharing is high. Wilcoxon tests (two-sided) support the lack of significant difference between HI and LI for both time horizons ($p = 0.62$ for 4-HI vs. 4-LI; $p = 0.38$ for 16-HI vs. 16-LI), and between the short and the long time horizon for low mutual interdependence ($p = 0.38$ for 4-LI vs. 16-LI). But, as suggested by the descriptive analysis, allocations to the interdependent partner in case of high profit sharing are weakly significantly higher when interaction lasts 16 rather than 4 periods ($p = 0.08$ for 4-HI vs. 16-HI).

Result 5

As compared to the short horizon, the long horizon triggers slightly significantly higher average allocations to the interdependent partner in the HI treatment.

Turning to the amounts given to the two partners with whom one does not share profits, Figure 1 clearly shows that the independent group observations are closer to the 'equity line' when subjects interact for 16 periods, especially so in the LI treatment. Wilcoxon rank-sum tests (two-sided) confirm that (i) as compared to the 4-period treatment, the 16-period treatment triggers significantly higher allocations to the others under low, but not under high, profit sharing ($p = 0.001$ for 4-LI vs. 16-LI; $p = 0.52$ for 4-HI vs. 16-HI), and (ii) as compared to the HI treatment, the LI treatment prompts significantly higher allocations to the others only when interaction lasts 16 periods ($p = 0.007$ for 16-LI vs. 16-HI; $p = 0.56$ for 4-LI vs. 4-HI).

Result 6

As compared to the short horizon, the long horizon significantly affects average allocations to the members with whom there is no profit sharing in the LI treatment.

From Results 5 and 6, we conclude that the higher cooperation levels detected in the 16-period horizon as compared to the 4-period horizon (cf. Result 2) benefit the interdependent partner in case of high profit sharing and the two other group members in case of low profit sharing.

To further analyse the effects of the different treatments on allocations to the interdependent partner and to the two others, Table 4 reports the results of generalized mixed models regressing individual *i*'s allocations to her interdependent partner and to the two other group members on the dummies *Interdependence*, *Horizon,* and *Recipient*.[12] *Interdependence* takes value 0 for the LI treatment and 1 for the HI treatment. *Horizon* is 0 for the 4-period horizon and 1 for the 16-period horizon. The variable *Recipient* captures whether *i*'s decision involves the interdependent or the two other partners; it equals 1 for the interdependent partner and 0 for the others. The model has random effects at two levels: the effects for the 28 independent groups – to allow for dependency of observations – and the effects for all 112 individual subjects, each one repeated for the periods of interaction. The estimation method accounts for first-order autocorrelation in the within-group residuals. In comparison to Model 1, the specification of Model 2 contains four additional terms representing the interaction between the various regressors.[13]

Table 4. Generalized linear mixed-effects regression on individual allocation decisions

	Model 1	Model 2
Independent variable		
Constant	0.352***	0.150**
	(0.062)	(0.108)
Interdependence	0.076	0.245
	(0.062)	(0.146)
Horizon	0.201***	0.631***
	(0.063)	(0.125)
Recipient	0.914***	1.144***
	(0.291)	(0.108)
Interdependence × *Horizon*		−0.620***
		(0.173)
Recipient × *Horizon*		−0.535***
		(0.116)
Recipient × *Interdependence*		−0.142
		(0.145)
Interdependence × *Horizon* × *Recipient*		0.721***
		(0.158)
Information criteria		
Akaike	4699.13	4666.39
Bayesian	4739.13	4729.25

Note: Std. errors are reported in parentheses. Significance levels: *** ≤ 0.01, ** ≤ 0.05, * ≤ 0.1.

In both models, the coefficient of *Interdependence* is not significant, meaning (in line with Result 1) that the difference in mutual interdependence has no effect *per se*. The coefficient of *Horizon* is always positive and significant, i.e. (as already summarized by Result 2) allocators tend to give higher amounts if they interact for 16 rather than 4 periods. However, this behaviour is less pronounced in case of high profit sharing. This is indicated in Model 2 by the significantly negative coefficient of the interaction effect between *Interdependence* and *Horizon*. The coefficient of *Recipient* is positive and significant in both models, i.e. (as suggested by Result 4) allocators tend to send higher amounts to the interdependent partner than to the others, but significantly less so when interaction lasts longer (the coefficient of the interaction effect between *Recipient* and *Horizon* is significantly negative). In line with Result 5, different degrees of mutual interdependence do not seem to affect amounts granted to the others (the coefficient of *Recipient* × *Interdependence* is not significant), although the HI treatment triggers significantly higher allocations to the interdependent member when interaction lasts longer. To conclude, the regression analysis corroborates all our previous results: allocators do not react differently to variation in the degree of

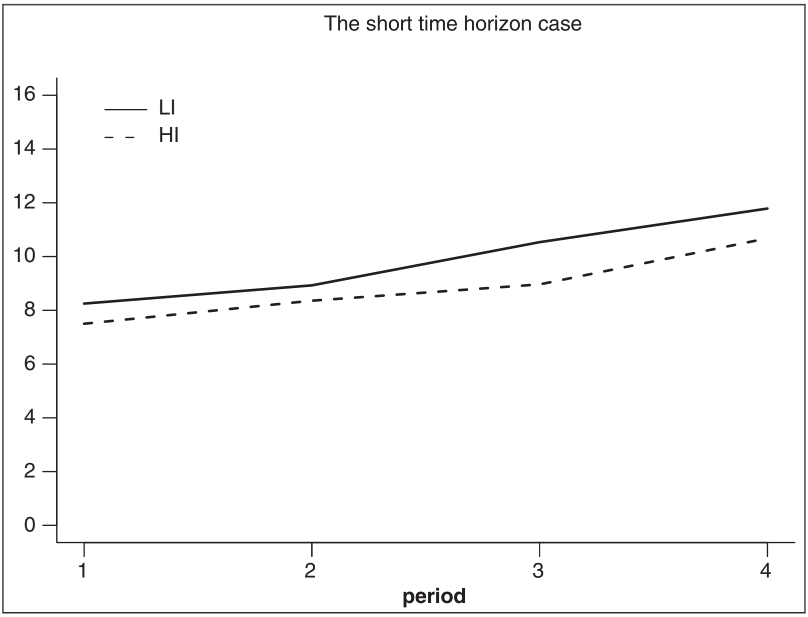

Figure 2a.

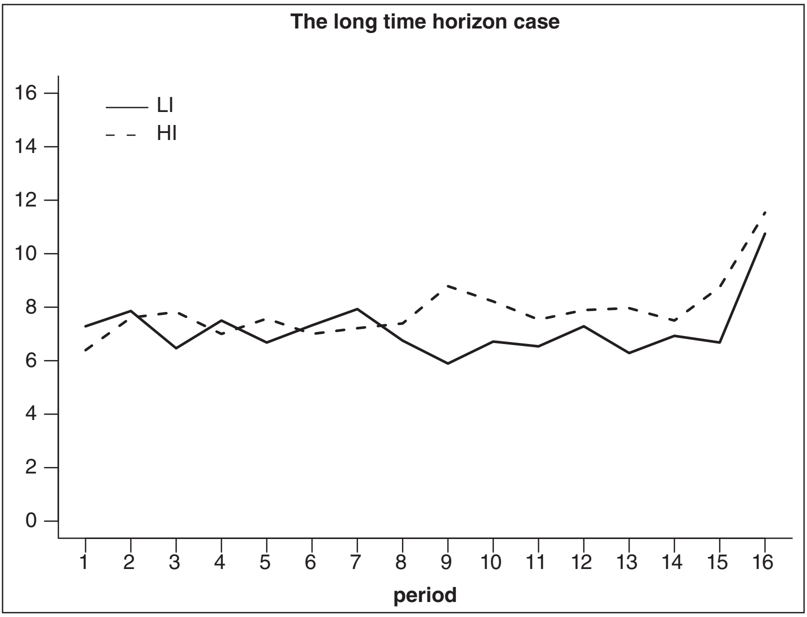

Figure 2b. Evolution of cooperation in LI and HI for the short and the long horizon

mutual interdependence, though they remain particularly attentive to the partner with whom they share profits.

Finally, we consider the evolution of cooperation rates over periods. Figure 2 displays the time paths of average amounts kept in the LI and the HI treatment for both horizons. Besides nicely illustrating the same aggregate effects discussed above, Figure 2 reveals a sharp end effect in each of the two time horizons, with average amounts kept rising in the final period of each treatment. In the 4-period treatment, for both degrees of mutual interdependence, most subjects start off by keeping about 8 units. The average kept amounts then slightly increase over time, and reach their maximum (10.68 in HI and 11.78 in LI) in the last period. The evolution of average kept amounts in the 16-period treatment exhibits by and large similar features:[14] starting at 7.28 in LI and 6.39 in HI, average kept amounts fluctuate between 5.89 and 7.92 in LI and between 7.00 and 8.78 in HI, before they sharply rise to 10.75 in LI and 11.53 in HI in the final period. Wilcoxon signed-rank tests (one-sided) 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 is in line with existing experimental research on public goods (see Ledyard, 1995 for an overview), and also with the results of Berninghaus et al. (2008) based on a similar voluntary social exchange game (excluding mutual interdependence).

5. Conclusions

Humans, like members of other species, tend to cooperate and help each other. But what are the conditions required for the emergence and maintenance of cooperation in a world of scarce resources and competition for the use of those resources? In this paper, we focused on two alternative explanations. One suggests that cooperation is more likely to emerge when there are relations of mutual interdependence and people have joint control over outcomes (Molm, 1994; Molm and Wiggins, 1979). We termed this explanation the 'high mutual interdependence' hypothesis. Another explanation involves repeated interaction, which provides a shadow of the future that can sustain reciprocity (Axelrod, 1984; Axelrod and Hamilton, 1981), possibly supported by mechanisms – such as positive attachment to the group – enhancing relational cohesion (Lawler and Yoon, 1996). Since under this view cooperation increases with the length of the time horizon, we called this explanation the 'shadow of the future' hypothesis.

We tested these two hypotheses in a laboratory experiment based on a voluntary social exchange game, where we induced mutual interdependence via profit sharing. We placed two pairs of mutually interdependent participants in a group of four and systematically varied both the degree of mutual interdependence and the duration of interaction. In other words, we created a hybrid social exchange context with features of both reciprocal exchange and productive exchange. This setting resembles real-world situations: people often interact as structurally connected members of subunits nested within larger units, e.g., a province within a nation, a division within a firm, a department within a university.

Our main results indicate that extending the scope of reciprocal exchange by longer duration inspires significantly more cooperation toward both the interdependent partner and the two other group members. In contrast, varying mutual interdependence alone does not account for much variation in cooperation. Although mutual profit sharing is no *conditio sine qua non* for establishing cooperation, allocators tend, on average, to give more to the interdependent partner than to the other group members.

How can we interpret these results? The non-confirmation of the game theoretic prediction (according to which only highly interdependent partners should exchange resources with each other) may be attributed to participants' misunderstanding of the payoff rule. We doubt that this can explain the high level of cooperation observed in all treatments, however, since the pre-experimental control questionnaire and the three practice periods ensured that subjects fully understood profit and payoff functions.

The further observation that the weakly interdependent partner receives more than the other group members in both the short and the long time horizons may reflect the group formation effects of productive exchange. In social identity theory (Brewer, 1993; Kramer, 1991; Tajfel and Turner, 1986), mutual interdependencies generate a sense of 'groupness' among individuals who, as a consequence, tend to develop some ingroup-favouring attitudes: those who mutually share profits may perceive themselves as belonging to the same ingroup with strong solidarity links, leading them to exchange more with each other. Similar ideas can be found in Collins's (1981) theory of interaction ritual chains. According to Collins, people act toward each other in ways that mostly constitute routines because the world is too complex to have to rethink it all the time. A situation of mutual interdependence is more likely to promote a common focus and a sense of shared responsibility so that actors become biased toward the interdependent partner and this 'ritual' is iterated over time.

In conclusion, while our data contradict both the 'high mutual interdependence' hypothesis and the 'shadow of the future' hypothesis in their strong versions, 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. There also seems to be an interesting implication for the theory of the firm. Joint tasks and shared responsibilities among managers of a firm's division foster cooperation within the division beyond what contracts can do, while leaving a strong role to repeated interaction in furthering cooperation across different divisions.

Appendix: Experimental instructions

This appendix reports the instructions (originally in German) we used for the 16-period 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, you will be divided into 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 group member will receive 16 units of a specific commodity. There are 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 choose 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 on 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, and A_4, respectively). Likewise, if you are member 2, you have to decide on 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, and 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, 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. Suppose that you are member 1 and, hence, own 16 units of commodity A. If you choose $A_1 = 3$, $A_2 = 2$, $A_3 = 5$, and $A_4 = 6$, this means that you keep 3 units of A for yourself, 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., $3 + 2 + 5 + 6 = 16$. 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.

Your period earnings

The quantities of each commodity type that you own at the end of each period determine your return, R, 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 that you are member 1. You keep A_1 units of commodity A for yourself. Member 2 sends you B_1 units of commodity B. Member 3 sends you C_1 units of commodity C. Member 4 sends you D_1 units of commodity D. Your return is given by

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

The same calculation applies to members 2, 3, and 4.

'*Sending costs*' are 0 (if you give nothing to the others), 1 (if you give something to one other group member), 2 (if you give something to two other group members), or 3 (if you give something to all three other group members).

Example. Suppose that you keep six 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: $\left[\left(\sqrt{6} + \sqrt{4} + \sqrt{4} + \sqrt{4}\right) \times 8\right] - 2 = \left[\left(2.45 + 2 + 2 + 2\right) \times 8\right] - 2 = \left[8.45 \times 8\right] - 2 = 67.6 - 2 = 65.6$

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, E, are given by

$$E = [0.95 \times (\textit{your } R)] + [0.05 \times (\textit{one other member's } R)].$$

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 period earnings are: (0.95 × 100) + (0.05 × 200) = 95 + 10 = 105. Similarly, member 2's period earnings are: (0.95 × 200) + (0.05 × 100) = 190 + 5 = 195. Member 3's period earnings are: (0.95 × 160) + (0.05 × 240) = 152 + 12 = 164. Finally, member 4's period earnings are: (0.95 × 240) + (0.05 × 160) = 228 + 8 = 236.

Attached to these instructions, you can find a *return table* displaying your return given what you keep and what you receive from the others. The table will help you in making your decisions.

In addition to this table, we provide you with a *return* and *earnings calculator* that allows you to compute your expected return, R, as well as your expected earnings, E. 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 (0, 1, 2, or 3). Given these figures, if you press the apposite button, you will know the corresponding per period expected return, R. Then, if you enter how much you expect to be the return of the person whose R you share, and press the apposite button, you will know the corresponding per period expected earnings, E.

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, R, and earnings, E, 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.

Notes

1. Emotions are defined as transitory feelings that constitute an internal response to an event or object (Kemper, 1978; Weiner, 1985).
2. 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; Fehr et al., 2002; McCabe et al., 1998). The nonexperimental evidence is equally telling: common actions in everyday life cannot be explained by the expectation of future reciprocation.
3. Besides productive and reciprocal exchange, other forms of social exchange identified in the literature include negotiated and generalized exchange (see, e.g., Ekeh, 1974; Lawler, 2001; Molm, 2003). Negotiated exchange involves explicit and binding agreements so that the flow of benefits is bilateral and actors know in advance what they are getting for what they are giving. Generalized exchange entails unilateral exchange among three or more actors who are not matched as senders and receivers.
4. Emerson (1962, 1972b) defines dependence of actor A upon actor B as a function of (i) the value to A of the resources received from B, and (ii) the availability of those resources outside of the A-B relation.
5. As each individual $i \in N$ owns only one input, to simplify notation we use the same index for the individual and for the input that she only owns.
6. Note that, due to symmetry, all group members are equally dependent on the group so that total dependence coincides with individual dependence.
7. We could, of course, have avoided any repetition in the short time horizon and excluded mutual profit sharing in the low interdependence treatment. 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 profit of one's partner.

8. 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. The possibility of reciprocal behaviour due to the pursuit of efficiency gains is explicitly discussed in Brandts and Schram (2001).
9. Although the level of cooperation is usually measured by the overall amount of units that player i gives to her fellow members, we take $ai(i)$ as a measure of cooperation because i's fellow members are unequal in our experiment.
10. All nonparametric tests are performed using strictly independent data.
11. A single group observation in the HI treatment is located more towards the efficient allocation. One participant in this group behaved always according to efficiency, which seems to have induced her partners to follow her behaviour.
12. Due to censored observations, we assume a quasi-Poisson distribution so as to model over-dispersion.
13. We estimated several models to test the interaction between the various explanatory variables. We report Model 2 which fits the data better on the basis of both the Bayesian Information Criterion and the Akaike Information Criterion.
14. While in the 4-period horizon the average amounts kept in HI are always below those kept in LI, in the 16-period horizon these averages intersect in the first 8 periods, after which they become (and remain) lower in LI as compared to HI. Since the difference is not statistically significant, we refrain from speculating about why this occurs.

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