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On the (in)effectiveness of rewards in sustaining cooperation

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Abstract We study the effectiveness of costly rewards in mitigating excess extraction in a standard Common Pool Resource (CPR) game experiment. We implement two treatments. In the first, rewards are a pure transfer from one player to the other. In the second, the benefits of receiving a reward are higher than the cost of providing it. Referring to the latter as "net positive" rewards, we observe that these are used more frequently than transfer rewards, and that, unlike transfer rewards, they are effective in sustaining cooperation in the CPR game.

Keywords Peer enforcement · Rewards · Common pool resource · Economic experiment

JEL Classification C72, C92, D74

1 Introduction

Previous research on self-regulatory mechanisms in social dilemma games shows that peer sanctioning is effective in mitigating the freerider problem inherent to these games. Experimental subjects are willing to incur costs to impose (monetary and non-monetary) sanctions on those who fail to contribute to the common good, and the punished subjects respond by acting more cooperatively. This behavior is observed in a wide variety of social dilemma games, including Public Goods games (e.g., Fehr and Gächter, 2000; Carpenter, 2006; Masclet et al., 2003) and Common Pool Resource games (Ostrom et al.,1992; van Soest and Vyrastekova, 2006).

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Although rewards have not been researched as thoroughly as sanctions, earlier results suggest that they are not as effective—if effective at all. In the context of social dilemma situations, there are two studies that analyze the impact of rewards on contributions in linear Public Goods games; one by Sefton et al. (2006) and one by Walker and Halloran (2004). Both focus on so-called transfer rewards, where the subject giving the reward incurs a cost of a certain number of experimental currency units while the recipient's payoff goes up by the same amount (that is, the impact ratio is 1:1). The two studies differ with respect to whether interaction is one-shot or finitely repeated, but both find that transfer rewards are unable to sustain cooperation.

Given that these studies focus on transfer rewards (that is, a 1:1 impact ratio), the question arises how sensitive this conclusion is to the impact ratio used. One paper that suggests that the parameterization matters is by Andreoni et al. (2003). They study a simple proposer-responder game in which the responder can affect the proposer's payoff using either 1:5 sanctions, or 1:5 rewards, or both. Both sanctions and rewards tokens are used frequently, and their presence positively affects the amounts offered by the proposer. As a result, offers exceed the Nash equilibrium level in all three treatments, and more so in the rewards treatment than in the sanctions treatment (albeit that they are highest in the treatment where both instruments are at the responder's disposal).

The above research suggests that whereas transfer rewards fail to induce cooperation in social dilemma situations, rewards may be effective if the benefits of receiving a reward exceed the costs of providing them, as is the case in the 1:5 parameterization of Andreoni et al. This is important because in many instances, a recipient's valuation of a reward is not likely to be exactly equal to the costs incurred by the donor. When rewards take the form of monetary transactions, the costs of giving up a dollar by the donor is not necessarily equal to the benefits derived by the recipient, for example if the subjects involved differ with respect to income or wealth. And rewards may also take the form of the exchange of goods or services, for which marginal utilities may differ substantially between individuals. Food sharing in times of scarcity in hunter-gatherer societies is an example in point. Also, assisting fellow community members with activities such as crop harvesting or child minding implies that the recipient's time constraint becomes less binding, and the recipient's marginal value of time may well be above that of the donor. So, whereas rewards are effectively transfers in some instances, it is not difficult to imagine situations in which the recipient's valuation of a reward exceeds the costs incurred by the donor.

In this paper, we re-examine the effectiveness of rewards in sustaining cooperation in social dilemma games. We compare the (in)effectiveness of transfer rewards (i.e., with a 1:1 impact ratio) to that of what we label 'net positive' rewards, where the benefits of receiving a reward are larger than the costs incurred by the provider. More specifically, we use a 1:3 impact ratio, where a reward costs one point (our experimental currency unit) but increases the recipient's payoff by three points. Changing impact ratio's has been found to substantially affect the effectiveness of sanctions (Carpenter, 2006; Egas and Riedl, 2005), and we conjecture that the same holds for rewards.

Net positive rewards increase the recipient's payoff more than do transfer rewards, and we conjecture that this is important because of two reasons. First, the higher the payoff foregone by a freerider when not receiving rewards, the more likely he/she is to act (more) cooperatively in the social dilemma game in order to attract rewards.

Second, the higher a reward's benefit/cost ratio, the more likely it is to compensate the provider (in terms of utility derived from increasing another subject's payoff) for his/her costs incurred; cf. Andreoni and Miller (2002). Hence, the higher this ratio, the more frequently rewards are expected to be given. Combining these two aspects, we hypothesize net positive rewards to have a stronger impact on behavior in social dilemmas than transfer rewards.

Whereas the bulk of the experimental literature on self-regulation employs linear Public Goods games, we study rewards in a non-linear public bad game (the Common Pool Resource game; cf. Ostrom et al., 1992). Thus, we (i) provide a robustness check with respect to whether transfer rewards are indeed also inefficient in games with negative as opposed to positive externalities, and (ii) expose the net positive rewards to a very harsh environment which is even less conducive to cooperation than Public Goods games.

We find that rewards are given more frequently when their impact is higher. Whereas transfer rewards do not significantly affect behavior in the CPR game, net positive rewards do. This result is not very surprising in itself, but the underlying mechanisms are interesting. Changing the impact ratio not only affects the number of rewards exchanged, but also who rewards whom.

The set-up of this paper is as follows. In Section 2 we present the game and the experiment design, and we formulate our behavioral hypotheses. The data are analyzed in Section 3, and Section 4 concludes.

2 The game and experimental design

2.1 The game

We use a standard finitely repeated Common Pool Resource (CPR) game in line with earlier work by Ostrom et al. (1992). There are N players, $N > 1$. In every period $t = 1, \ldots, T$, each player $i = 1, \ldots, N$ can divide a fixed endowment of discrete tokens (referred to also as extraction tokens), $e > 0$, between CPR extraction (option I) and an alternative economic activity (option II). The number of tokens put into option I by player i in period t is denoted by $x_{i,t}$, and hence the number of tokens player i puts into option II is equal to $(e - x_{i,t})$. For each token player i puts into option II, he/she receives a fixed number of points (our experimental currency unit); this number is equal to w. When putting tokens in option I, however, players incur costs that are linear in the number of tokens with marginal cost equal to v. The group's total number of points earned in option I in period t, R_t, depend on the aggregate number of tokens put in in that period, $X_t = \sum_{i=1}^{N} x_{i,t}$, according to the function $R(X_t) = AX_t - BX_t^2$. Player i's share in these total revenues is proportional to his/her share in the aggregate number of tokens put into option I $(x_{i,t}/X_t)$. Hence, player i's payoff in period t equals

$$\pi_{i,t}^{CPR} = w[e - x_{i,t}] + \frac{x_{i,t}}{X_t}\left[AX_t - BX_t^2\right] - vx_{i,t}.$$

The group's aggregate payoff is maximized if the number of tokens in option I is equal to $X^* = (A - v - w)/2B$. So, in the absence of transfers, the social optimum is obtained if each player uses $x^* = (A - v - w)/2BN$ 'extraction tokens'.[1] The unique symmetric Nash equilibrium number of extraction tokens equals $x^{NE} = (A - v - w)/B(N + 1)$ for each individual, and $X^{NE} = Nx^{NE}$ for the group as a whole. Observe that the CPR game poses a social dilemma because $x^{NE} > x^*$ if $N > 1$.

The game described above will be referred to as the unregulated CPR game. In the experiment, all subjects play it before being confronted with the CPR game in which rewards can be given. Let us now turn to describing the CPR game with the option to reward. The first stage of this game is identical to the unregulated CPR game described above, but we add a second stage in which subjects can send 'reward tokens' to other group members.[2] Each subject receives an endowment of z reward tokens and can send any integer number of these tokens to any other member of his/her group. Each reward token kept by a subject is worth one point to that subject. Each reward token sent to another subject increases the recipient's payoff by r points, where $r = 1$ in Treatment R11 (the transfer reward treatment) and $r = 3$ in Treatment R13 (the net positive rewards treatment). Therefore, the payoff of subject i in the second stage of the CPR game with rewards, $\pi_{i,t}^{REW}$, is given by:

$$\pi_{i,t}^{REW} = z - \sum_{j \neq i} p_{ij,t} + r \sum_{j \neq i} p_{ji,t},$$

where $p_{ij,t}$ is the number of reward tokens sent by subject i to subject j in period t, and $r \in \{1, 3\}$ is the impact one reward token has on the earnings of the receiver. The total payoff of subject i in period t, denoted $\pi_{i,t}$, in the game with rewards is given by $\pi_{i,t} = \pi_{i,t}^{CPR} + \pi_{i,t}^{REW}$.

The standard game-theoretic predictions for the finitely-repeated 'regulated' CPR game (i.e., the one with the option to reward) are straightforward. Applying backward induction, no rewards will be given in any round. Hence the aggregate number of extraction tokens used is always equal to the Nash equilibrium level, and the same level of efficiency of resource use is achieved as in the unregulated CPR game. The parameter values and the implied Nash equilibrium and social optimum values can be found in Tables 1 and 2.[3]

But results may change dramatically if subjects are present who are endowed with other-regarding preferences (including altruism, reciprocal preferences, and inequality aversion). Such subjects may be willing to incur costs to reward their peers for acting cooperatively in CPR stage of the game, and more so in case of net positive rewards

[1] The experiment itself was framed neutrally, and we consistently used the phrase 'the number of tokens (to be) put into option I' to denote the subjects' decision variable.

[2] In the experiment, we did not use the term rewards; the 'stage 2 tokens' were simply referred to as as 'tokens.' This did not cause subjects to confuse these tokens with the 'tokens that can be put into options I and II' of the first stage because all subjects had played the unregulated game before being exposed to either of the two rewards treatments. To avoid confusion in this article, however, we will refer to the 'stage 2 tokens' as 'reward tokens.'

[3] We chose $e = 13$ because it yields a nice spread between the maximum number ($x = 13$), the symmetric socially optimal number ($x^* = 6$) and the Nash equilibrium level ($x^{NE} = 10$). We set $z = 12$ so that each individual subject (i) can give an equal number of reward tokens to all other four subjects in his/her group, if he/she wishes to do so, and (ii) is able to (almost) fully compensate at least one of his/her peers for the payoff reduction associated with putting in the socially optimal number of extraction tokens even if $r = 1$.

Table 1 Experiment parameterization

Variable	Description	Value
N	Number of individuals per group	5
T	Number of rounds of the stage game	15
w	Wage per extraction token allocated to the outside option	0.5
A	Parameter of the resource revenue function	11.5
B	Parameter of the resource revenue function	0.15
v	Per unit cost of extraction token in resource extraction	2
e	Individual endowment of 'extraction' tokens	13
z	Individual endowment of 'reward' tokens	12
r_T	Impact of receiving reward tokens in Transfer rewards treatment R11	1
r_E	Impact of receiving reward tokens in Net positive reward treatment R13	3

Table 2 Socially optimal and Nash equilibrium levels of all variables of the stage game

Variable	Description	Value
x^*	Number of extraction tokens of the symmetric socially optimal outcome	6
X^*	Number of extraction tokens per group of the socially optimal outcome	30
x^{NE}	Number of extraction tokens in Nash equilibrium per subject	10
X^{NE}	Number of extraction tokens in Nash equilibrium per group	50
p_{ij}^{NE}	Nash equilibrium number of reward tokens given	0
π^*	Symmetric socially optimal payoff to CPR use	33.5
π^{NE}	Symmetric Nash equilibrium payoff to CPR use	21.5

than if rewards are just transfers.[4] This last prediction is based on the ideas that (i) higher benefits of receiving rewards are more likely to compensate subjects for acting cooperatively in the social dilemma game (that is, to forego the higher profits associated with playing best response), and (ii) the higher the benefit/cost ratio of rewards, the more likely it is that the (non-material) benefits of giving a reward exceed the financial costs of giving it.

Additionally, the pattern of the use of reward tokens is likely to differ for transfer and net positive rewards. In case of net positive rewards, subjects have incentives to exchange reward tokens as this is efficiency increasing. However, they only can base their reward decision on the behavior of others as observed in the CPR stage. That means that the number of extraction tokens used may effectively function as a criterion for selecting partners for mutually beneficial exchange of reward tokens. The reasoning is as follows. Consider subject $j(k)$ who uses more (not more) extraction tokens in the CPR stage as compared to subject i. Subject i does have an incentive to send reward tokens to subject k as subject k behaved at least as cooperatively as subject i. Also, subject i would not have incentive to send reward tokens to subject j who did freeride on subject i. By symmetry, subject i would not expect to receive reward tokens from subject j. That means that apart form the motivation to reward cooperative behavior in the CPR stage, subjects may send reward tokens to other subjects using the

[4] In the CPR game, cooperating (freeriding) means to put fewer (more) tokens into option than one or more other subjects, thus imposing smaller (larger) negative externalities on all members of the group than the others do. Therefore, cooperating (freeriding) is defined in relative terms.

same number of extraction tokens in order to establish mutually profitable exchange of reward tokens.

2.2 Experiment design

In the Spring semester of 2005, we ran four experimental sessions at Tilburg University, the Netherlands. In total, 80 subjects participated (40 in each treatment, resulting in 8 independent groups), and they were students in economics, law, or business. The language of the experiments was English. Upon arrival, participants were randomly assigned to a computer terminal. They were informed that the experiment consists of three tasks in total, and all instructions were read out aloud just before the next task was implemented. The experiments were fully computerized; the software was programmed using *z*-Tree (Fischbacher, 1999).[5]

The following three tasks were implemented (in this order): (1) a social orientation task, (2) the finitely repeated unregulated CPR game, and (3) the finitely repeated CPR game with a reward stage (either the 1:1 or 1:3 impact ratio, that is Treatment R11 or R13, respectively). The social orientation task, task 1, is implemented to measure the distributional preferences of each of our subjects. We used the decomposed games approach as developed by Messick and McClintock (1968), and the data suggest that if there are any differences in behavior across the two rewards treatments, they are not due to differences in our subject pools.[6]

In tasks 2 and 3, subjects were matched into groups of five. They remained in the same group in all 15 rounds each of these tasks lasted, but their identity numbers were randomly changed at the beginning of every round. Therefore, the decision to give a reward to another subject in stage 2 of a specific round can only be based on that subject's actions in stage 1 of that same round. If such a scrambling of subjects' identities was not introduced, subjects might have incentives to engage in reciprocal exchange of reward tokens across rounds in treatment R13 but not in treatment R11. Our design rules out this direct reciprocity regarding the use of reward tokens and only reciprocity with respect to the behavior in the CPR stage is relevant—if at all—in both treatments. As a result, the pattern of the use of reward tokens is likely to differ for transfer and net positive rewards. In case of net positive rewards (treatment R13) subjects have incentives to exchange reward tokens as this is payoff increasing. However, they can only base their reward decision on the behavior of others as observed in the CPR stage in the same round. That means that the number of extraction tokens used may effectively function as a criterion for selecting partners for mutually beneficial exchange of reward tokens. The reasoning is as follows. Consider subject j who uses fewer extraction tokens in the CPR stage than subject i. Subject i does have an incentive to send reward tokens to subject j as this subject acted more cooperatively than subject i. Also, subject i would not expect to receive reward tokens from subject j in return—especially if the difference in the number of extraction tokens used is large—as subject i freerode on subject j's cooperative behavior. That means that apart from the motivation to reward cooperative behavior in the CPR stage, subjects may

[5] Instructions are available from the journal's webpage. Computer screenshots and software are available upon request from the authors.

[6] For more information about this social orientation task, see for example Offerman et al. (1996).

send reward tokens to other subjects using more or less the same number of extraction tokens in order to establish a mutually profitable exchange of reward tokens. In treatment R11, the latter motivation is absent as exchange of reward tokens is payoff neutral.

To facilitate decision making in the experiment, we provided subjects with a payoff table of the CPR game, but we indicated neither the socially optimal nor the Nash equilibrium number of tokens. To test our subjects' understanding of how payoffs are earned, we asked them to answer three test questions before the start of the experiment. In each round, subjects were informed about the number of extraction tokens used by each member of their group as well as about his/her payoffs associated with CPR use in that round. In task 3, subjects were given information about the number of reward tokens received by each subject, the number of reward tokens *not* used by this subject, as well as each subject's total payoff in the current round. The experiment lasted about 2 hours, and participants earned on average 15.90 Euro (including 5 Euro participation fee).

3 Data analysis

Let us first analyze extraction behavior in the CPR game, as reflected by the number of tokens put into option I. Figure 1 presents the aggregate number of extraction tokens used (averaged over all groups) over all 30 rounds (with rounds 1–15 and 16–30 representing play in the unregulated and regulated CPR games, respectively). The development of play in the first 15 rounds is very similar for the groups which were subsequently exposed to either the transfer reward treatment or the net positive reward treatment (Treatment R11 and R13, respectively), and the null hypothesis of equal average numbers of extraction tokens used cannot be rejected on the basis of a

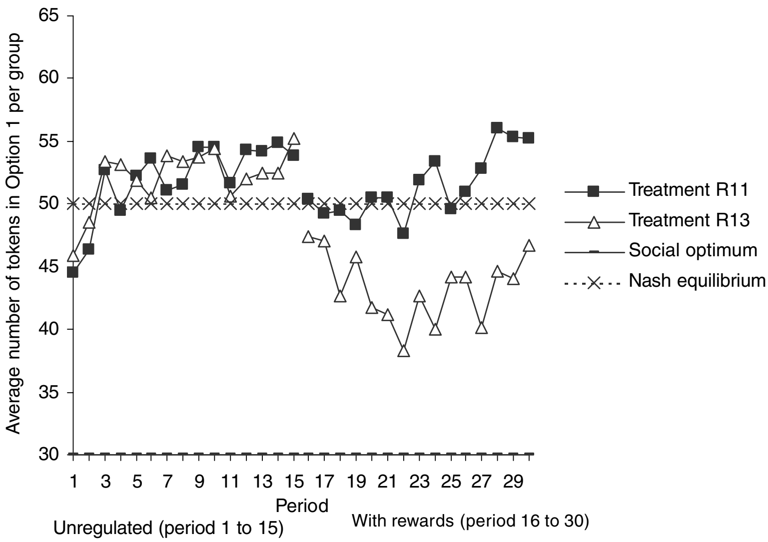


Fig. 1 Average number of extraction tokens used per group in the CPR game

two-sided Mann-Whitney U-test ($N = 16$, comprising 8 groups in R11 and 8 groups in R13, $p = 0.959$).

Given the similarity of behavior in the first 15 rounds, the difference in play between the two treatments in rounds 16–30 is striking. The aggregate number of extraction tokens used is closer to the socially optimal level in Treatment R13 than in Treatment R11. Indeed, a pairwise test between the aggregate numbers of tokens in a group in rounds 1–15 and in rounds 16–30 does not allow us to reject the null hypothesis of equal numbers in Treatment R11 (two-sided Wilcoxon test, $N = 8$, $p = 0.674$), but it does so for Treatment R13 (two-sided Wilcoxon test, $N = 8$, $p = 0.012$). In both treatments, subjects earn 50% of total earnings in the CPR stage. However, subjects earn on average 86% of the CPR stage Nash Equilibrium payoff in Treatment R11, while this percentage equals 121% in Treatment R13. Therefore, there are clear efficiency gains in the CPR stage when rewards are of the net positive type. Consistent with these findings, the average number of tokens in rounds 16 to 30 in Treatment R13 is significantly below that in Treatment R11 (two-sided Mann-Whitney U-test, $N = 16$, comprising 8 groups in R11 and 8 groups in R13, $p = 0.003$). This difference cannot be attributed to differences in prior expectations as the total number of tokens in option I in period 16 of Treatment R11 does not differ significantly from that in R13 (two-sided Mann-Whitney U-test, $N = 16$, comprising 8 groups in R11 and 8 groups in R13, $p = 0.447$). The difference between transfer and net positive rewards is thus found to develop over time.

In terms of aggregate efficiency, we find that both treatments perform equally well; subjects obtain respectively 67% and 65% of the maximum payoffs in Treatments R11 and R13 (p-value of 0.178 according to the relevant Mann-Whitney U test). This is interesting because by definition, there is no welfare loss associated with *not* using reward tokens in Treatment R11, but there is in case of Treatment R13. Given that total efficiency is equal, the gains in CPR efficiency just match the welfare losses of not using all reward tokens in every round.

Given that the possibility to use reward tokens has a very dissimilar impact on subjects' behavior in the CPR game in the transfer (R11) and net positive (R13) rewards treatments, we now turn to analyzing the use of rewards in each treatment to uncover the underlying mechanisms. Figure 2 plots the number of reward tokens used over time for each of the two treatments. Clearly, the number of reward tokens used is higher in Treatment R13 than in Treatment R11 (Wilcoxon test for paired observations with a pair being the group average use of reward tokens per period in R11 and in R13, $N = 15$, $p = 0.001$), but not so in the first round (Mann-Whitney U-test on number of reward tokens used per group in period 16, $N = 16$, $p = 0.432$). In both treatments, though, the number of reward tokens used declines over time, and more prominently so in Treatment R11 than in Treatment R13.[7]

Having established that reward tokens are being used, the question arises who receives them. As subject identifiers are reshuffled at the beginning of every round, subjects can only base their decision to use reward tokens in the second stage of a particular period on the observed number of tokens subjects put into option I in the first stage of that round. In both treatments we observe that the fewer tokens one puts

[7] The Spearman rank-order correlation coefficients between period and average number of tokens used equals -0.915 and -0.877 in Treatments R11 and R13, respectively, which are both significant at $p = 0.000$.

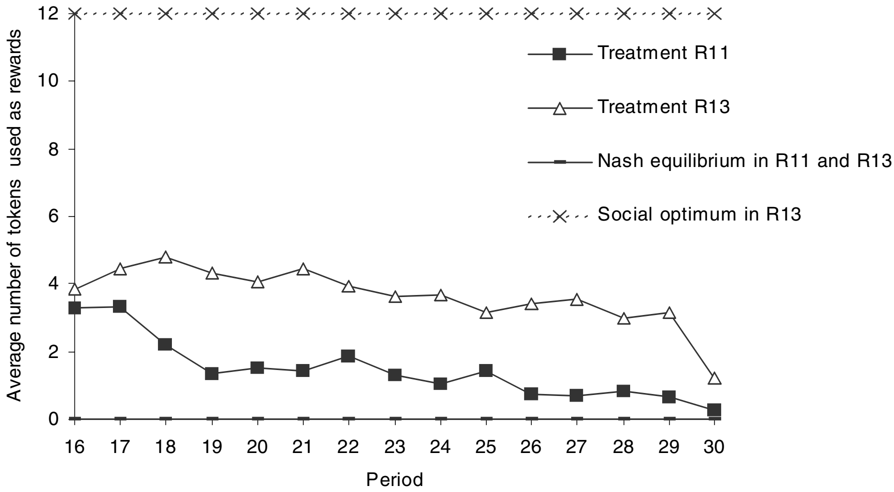


Fig. 2 Average number of tokens used as rewards by a subject

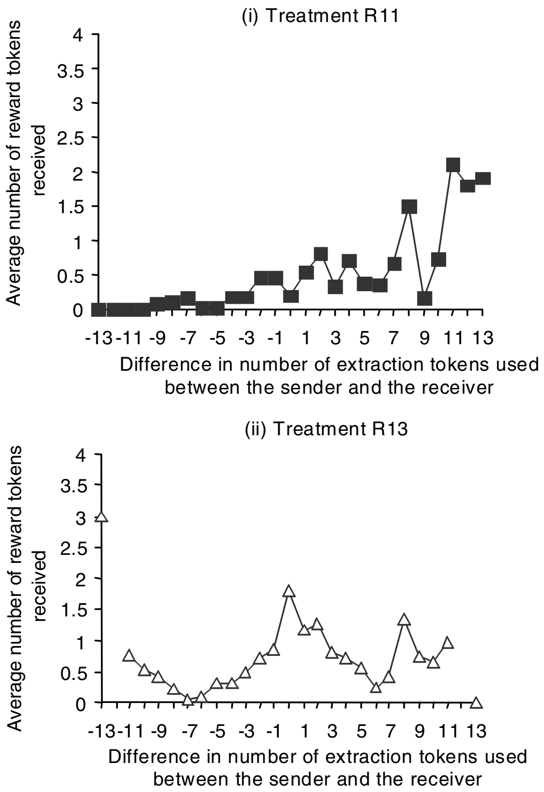
into option I as compared to the average of the other four members of one's group (i.e., $x_{i,t} - \frac{1}{N-1}\sum_{j\neq i} x_{j,t}$), the more reward tokens one receives. The Spearman correlation coefficients for Treatments R11 and R13 equal −0.920 and −0.846, respectively, which are both significant at the 1% level.[8]

So, at first glance, the difference between the two types of rewards seems to be a matter of the sheer number of tokens used. But we also find marked differences with respect to who sends rewards to whom, see Fig. 3. This figure plots the difference between a donor's extraction decision and that of the subject who receives the reward (on the horizontal axis), and the number of reward tokens received (on the vertical axis). Whereas the resulting line is upward sloping in the transfer treatment, it is hump-shaped in the treatment with net positive rewards.[9] Rewards are most frequently given to subjects who put in about the same number of tokens into option I in Treatment R13, but not so in Treatment R11. In the latter case it is the subjects free riding in the CPR game who reward the subjects acting cooperatively, thus ex-post reducing payoff inequality within groups. Both these observations are supported by the Spearman correlation coefficients of the absolute value of the difference in the number of extraction tokens used by the sender and by the receiver (in the CPR stage of the game) and the number of reward tokens sent. The Spearman correlation coefficient is negative and significant in Treatment R13 (−0.227, $p = 0.001$), while it is positive and significant in Treatment R11 (0.057, $p = 0.001$). These conclusions are also supported by regression analysis, as discussed below.

[8] Note one is always better off the fewer the number of extraction tokens used by other subjects in the group. Therefore, the willingness to reward others is expected to be a decreasing function of the number of tokens used by the (potential) recipient. This conjecture is supported by the data.

[9] This difference in patterns is significant. The relevant Spearman correlation coefficients are 0.876 ($p = 0.000$) in Treatment R11 and 0.102 ($p = 0.629$) in Treatment R13.

Fig. 3 Average number of reward tokens sent plotted as a function of the difference between the number of extraction tokens used by the sender and by the receiver in treatment R11 and R13



The difference in the way in which reward tokens are used in the two treatments explains the difference in their effectiveness in sustaining cooperation in the CPR stage of the game. The second stage enables subjects to (i) reciprocate—positively or negatively—to observed behavior in the CPR stage, and/or (ii) to mitigate payoff inequalities caused by differences in the use of extraction tokens across subjects. Independent of the parameterization, these motivations to use reward tokens imply that subjects using relatively few extraction tokens (the 'cooperative' subjects in the CPR stage) are the reward recipients, and some—but not necessarily all-subjects using relatively many extraction tokens (subjects freeriding in the CPR stage) are (among) those sending reward tokens.

But the two treatments differ with respect to the incentives to use reward tokens for subjects acting cooperatively in the CPR stage. The reward stage does not change net material payoffs if transfer reward tokens are exchanged between subjects using an equal number of extraction tokens in the CPR stage. That means that the possibility to reward does not enable cooperative subjects to reinforce cooperation in the CPR stage. But net positive rewards do allow for such reinforcement. Given the 1:3 ratio, cooperative subjects exchanging rewards may end up with higher payoffs than subjects who freeride in the CPR stage and do not receive any rewards. This might stimulate freeriders to adjust their behavior in the CPR stage in order to attract rewards as well.

Table 3 Spearman correlation coefficients between the change in individual extraction effort and the change in the number of reward tokens received (p-values in parenthesis)

Correlation between $dx_{i,t}$ and:	Treatment R11	Treatment R13
$dP_{i,t-1} > 0$	0.132 ($p = 0.178$)	0.088 ($p = 0.230$)
$dP_{i,t-1} < 0$	−0.016 ($p = 0.849$)	0.150 ($p = 0.029$)

Let us now have a quick look at how subjects actually respond to changes in reward tokens received. We conjecture that the opportunity costs of not receiving rewards across the two treatments affect subjects' response to a change in the number of reward tokens received over time. To show this, we calculate the correlation coefficients between each subject's change in the number of extraction tokens used between periods $t-1$ and t, and the change in the number of rewards received between period $t-2$ and $t-1$. Let us define $dx_{i,t} \equiv x_{i,t} - x_{i,t-1}$, and $dP_{i,t-1} \equiv \sum_{j \neq i} p_{ji,t-1} - \sum_{j \neq i} p_{ji,t-2}$. If subjects interpret a decrease in the number of rewards received ($dP_{i,t-1} < 0$) as an expression of disapproval about their behavior in the CPR game, we should observe $dx_{i,t}$ to be negative, and hence the associated correlation coefficient is expected to be positive. The prediction for cases where subjects experience an increase in the number of reward tokens received ($dP_{i,t-1} > 0$) is ambiguous, though. The increase may motivate subjects to further decrease the number of extraction tokens used ($dx_{i,t} < 0$), but it can also be interpreted as an approval of the current situation; then, we expect subjects not to change their use of extraction tokens ($dx_{i,t} = 0$). The correlation coefficients are presented in Table 3.

The results are revealing. Whereas subjects do not change their use of extraction tokens when confronted with an increase in the number of rewards tokens received in both treatments, their response to a decrease in the number of tokens received is markedly different between the two treatments. It induces subjects to subsequently decrease their use of extraction tokens in case of the net positive rewards treatment ($p = 0.029$), whereas such an effect is absent in the transfer rewards treatment ($p = 0.849$).

All analyses presented above are based on straightforward (non-parametric) tests, but we also ran formal regressions to corroborate our results. Using specifications that include both time and group fixed effects, we analyzed the determinants of (i) the number of tokens put into option I, (ii) the number of rewards sent by a subject, and (iii) the total number of rewards received by a subject. The results support our conclusions presented above, and therefore we just summarize them briefly here.[10]

Regarding the determinants of the number of extraction tokens used ($x_{i,t}$), we find in both treatments that the number of extraction tokens used is smaller (i) the larger the number of extraction tokens used by the other four group members in the previous period ($X_{-i,t-1}$, i.e. subjects play myopic best response), and (ii) the more reward tokens the subject received in the previous period ($\sum_{j \neq i} p_{ji,t-1}$).

More interesting is the analysis of the decision how many reward tokens subject i sends to another subject j in his/her group ($p_{ij,t}$). Figure 3 suggests that an important explanatory variable is likely to be the absolute difference between the number of

[10] The regression results are available on this journal's web page.

tokens put into option I in the CPR stage by the sender and by the receiver $|x_{i,t} - x_{j,t}|$. When controlling for own behavior in the CPR stage ($x_{i,t}$) as well as for the total number of reward tokens received in the previous period ($\sum_{j \neq i} p_{ji,t-1}$), we find indeed that the sign of the coefficient on this absolute difference is positive and significant in Treatment R11, but negative and significant in Treatment R13. Thus, if there is a mutual gain in exchanging rewards (as is the case in R13), subjects' behavior in the CPR game coordinates their rewarding: the smaller the difference in the number of extraction tokens they used, the more reward tokens are sent among two subjects. This is not the case if rewards are just pure transfers (as in R11).

Finally, regarding the factors that affect the total number of reward tokens received ($\sum_{j \neq i} p_{ji,t}$), again we find marked differences between the two treatments. In both treatments, the number of tokens received depends negatively on the number of tokens a subject puts into option I ($x_{i,t}$), but the comparison with how much the other group members put into option I ($X_{-i,t}$) does not play a role in Treatment R11, whereas it does in Treatment R13. This is consistent with the observation that in Treatment R11 it is the free riders in the CPR stage who reward cooperating subjects (which means that it is just the absolute number of extraction tokens used by a subject that determines how many reward tokens he/she receives), whereas in Treatment R13 subjects behaving cooperatively are willing to reward too (and hence a subject's use of extraction tokens relative to the group also matters).

4 Conclusions

We revisit the common wisdom in the experimental literature that costly rewards are unable to sustain cooperation in social dilemma games. Previous studies (Sefton et al., 2006; Walker and Halloran, 2004) found that transfer rewards are indeed ineffective in Public Goods games, and we find that this type of rewards is also unable to raise efficiency in Common Pool Resource games. But this does not mean that rewards are generally ineffective. This paper finds that if the benefits of receiving a reward exceed the cost of providing it, the use of extraction tokens in the CPR game is significantly closer to the social optimum than in case of transfer rewards.

This difference in effectiveness arises because of (i) the difference in profitability of receiving rewards (and hence also in the opportunity costs of not receiving them), and (ii) differences in who rewards whom. The first point is self-explanatory, the second is more surprising. When there are positive net gains from exchanging reward tokens, establishing such bilateral exchange is in the interest of the players involved. As subjects who act cooperatively in the CPR stage of the game do not have incentives to send reward tokens to other subjects free-riding in that CPR stage, bilateral exchange is established among subjects using the same number of extraction tokens. This gives material payoff incentives to the freeriders in the CPR stage to decrease the number of extraction tokens used to attract rewards. Such considerations are absent when there are zero net gains from exchanging rewards, as in the case of the transfer rewards treatment.

This explains why efficiency in the CPR game with positive net rewards is unambiguously higher than in both the unregulated CPR game and the CPR game with transfer rewards. Whereas transfer rewards are indeed ineffective in sustaining cooperation in CPR extraction, net positive rewards do induce subjects to decrease the number of extraction tokens used towards the socially optimal level.

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