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Shut Up and Fish: The Role of Communication when Output-Sharing is used to Manage a Common-Pool Resource

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Abstract

Schott et al. (2007) have shown that the "tragedy of the commons" can be overcome when individuals share their output equally in groups of optimal size and there is no communication. The assignment of individuals to groups as either strangers or partners does not significantly affect this outcome. In this paper we investigate whether communication changes these results. Communication reduces shirking, increases aggregate effort and reduces aggregate rents, but only when communication groups and output-sharing groups are linked. The effect is stronger for fixed groups (the partners treatment) than for randomly reassigned groups (the strangers treatment). Performance is not distinguishable from the no-communication treatments when communication is permitted but subjects share output within groups different from the groups within which they communicate. Communication also tends to enhance the negative effect of the partnered group assignment on the equality of individual payoffs. We use detailed content analysis to evaluate the impact of various categories of communication messages on behaviour across treatments.

Key words: Common pool resources, communication, coordination, cooperation, free-riding, behaviour in teams, partners and strangers, experiments

JEL classification codes: Q20, C92, C72

1. INTRODUCTION

Economic decisions are frequently made by groups of individuals who are competing with other groups of individuals. These may be firms competing with other firms to sell a product in a market or to extract a resource from a common pool or they may be teams of workers competing with other teams of workers within a firm. Typically, the success of a firm or a team is dependent upon the effort expended by the members of the firm or team. These environments are particularly interesting because of the interplay of conflicting incentives that may exist within and between groups. The conflict between groups may lead to an inefficient allocation of resources. In a tournament all competitors exert effort, but only one may win the tournament and receive the reward. The effort expended by losing competitors goes unrewarded. When extracting resources from a common pool, such as a fishery, competitors impose congestion costs on one another. The effort expended will typically exceed the efficient level of effort necessary to generate the resulting extraction level. When the competitors are groups or teams of individuals, conflict among group or team members may result in shirking, which is typically a problem associated with the voluntary provision of public goods. Several studies have explored the cooperative and non-cooperative outcomes in games between groups of individuals, but only a very limited number of studies have explored what causes cooperation and coordination within and between groups.

Previous experimental studies have shown that communication in the form of non-binding cheap talk improves cooperation in common-pool resource and public good games (Ostrom et al., 1994; Ledyard, 1995) and can overcome the "tragedy of the commons" or free-riding behavior in the provision of public goods. This implies that the decentralized governance of CPRs and public goods is possible as long as members of a single group are able to communicate with each other on a regular basis, and are not in conflict with other groups appropriating from the same CPR.

A few studies have examined the effect of communication in inter-group public good games. Rapoport and Bornstein (1989), Schram and Sonnemans (1996) and Zhang (2009) study a step-level public good game played by two groups with the threshold determined by the contribution level of the opponent group. They report a significant increase in group contributions when within-group communication is allowed. Sutter and Strassmaier (2009) evaluate intergroup and between-group conflict with and without communication in a tournament that involves two teams that compete for a fixed prize which the winning team members share equally. They find that free-riding dominates when teams either cannot communicate or can only communicate with members from other teams. Communication within teams, on the other hand, enables teams to coordinate actions and overcome the free-rider problem. The latter is in the interest of principals or employers but not in the collective interest of team members because they supply excessive levels of effort in order to win the prize. In a weakest-link tournament game, where the effective group effort is determined by the lowest effort expended by an individual in the group, Cason et al.,(2009) report that within-group communication not only leads to greater coordination and more aggressive competition, but also reduces efficiency significantly. However, in these tournament designs there is no connection between the output teams produce and the effort they supply. A CPR environment, on the other hand, establishes a direct link between individual and group effort and total output when teams receive a share of output depending on their supply of effort relative to all other teams and the total effort supplied by all individuals. This connection to output enables one to derive the socially optimal allocation of effort and to evaluate deviations from the optimal aggregate effort level.

Intergroup conflict in CPRs without communication has been examined by Schott et al. (2007) and Heintzelman et al. (2009) for equal-sized output-sharing partnerships in a CPR environment. Output sharing within partnerships introduces a free riding incentive which potentially has the power to offset the excessive effort provided by CPR appropriators. Schott et al. (2007) examine strategic interactions both within and between groups in a laboratory setting where output sharing in partnerships is allowed. Partnership sizes were varied between single resource users (no output sharing), a socially optimal partnership size and a larger than optimal partnership size. They find that sharing output in partnerships significantly reduces effort devoted to appropriation from the common pool because the resource user's tendency to provide excessive effort into extraction from the common pool (between-group conflict) is substantially offset by his or her tendency to free-ride on the efforts of other group members (within-group conflict). They also find that when the theoretically optimal group size is established, the groups allocate the optimal amount of effort in appropriating from the common pool. The latter is shown to be a socially optimal group Nash equilibrium and is independent of random (stranger) or fixed (partner) assignment to groups. Heintzelman et al. (2009) study the endogenous formation and stability of output-sharing groups and determine the conditions under which output sharing in optimal partnerships becomes a subgame perfect Nash equilibrium in a two-stage game.

Communication among members of a group is an important factor influencing the success of an output-sharing plan. Laboratory results for public goods environments with communication indicate that under-contribution, which characterizes environments with no communication, disappears when communication is possible (Isaac and Walker, 1988; Ledyard, 1995; Chan et al., 1999; Kinukawa et al., 2002). For the CPR environment, these results suggest that communication among group members may lead to coordination that offsets the free riding incentives provided by output sharing, thereby causing an inefficient increase in harvesting effort. The impact of communication on effort and output when communication is confined to subgroups of players, therefore, needs to be examined in more detail. Furthermore it is important to investigate how the effectiveness of output sharing in optimal-sized partnerships is affected when there are different ways groups can communicate and how institutional features such as the anonymity and rotation of partnerships might impact the type of messages used by groups and its consequences for individual effort supply.

The purpose of this paper is to investigate the effect of communication on effort supply in different output-sharing partnership environments and to investigate the relationship between the provision of effort and the type and volume of messages. A set of treatments were created to both investigate the effects of communication on output-sharing as a possible CPR management instrument and to investigate how various forms of communication interact with inter- and intra-group incentives. We design a CPR game with equal output-sharing in partnerships, which allows us to analyze within and between group conflicts and to evaluate deviations from the socially efficient outcome. We derive hypotheses based on theoretical insights and empirical evidence from past experimental studies for a variety of different communication group and CPR output-sharing group arrangements. We then evaluate individual and group behaviour in a controlled laboratory experiment with online communication in chat rooms. We contrast our results to no-communication treatments with partners and strangers and other related empirical results in the literature. Finally we analyze the frequency and content of messages in the different communication treatments and offer insight into how message content and frequency are related to differences in behaviour.

The first environment we examine reflects the case of a number of communities, businesses or social groups that communicate among themselves, share output equally with members from their community or group, but compete for the yield from the CPR with other communities or groups. This setting takes the "partners" treatment presented in Schott et al. (2007) and allows output-sharing partners to communicate within their group every period. The treatment is comparable to Sutter's and Strassmair's (2009) within-group communication treatment in a tournament setting, but is evaluated here with respect to individual, group and social efficiency criteria. A second scenario randomly assigns subjects to groups every period (a strangers treatment). Group members then share output equally and communicate with each other, but are randomly allocated to new groups within which members can then communicate at the start of each round. This scenario is relevant for centralized allocation to randomized output-sharing groups and would be applicable if the central manager announced the anonymous identities of randomized group membership before each period of extraction began. It also allows us to evaluate intra-group communication in a one-shot stranger setting in which communication groups are linked to output-sharing groups, i.e. to further delineate the effects of group member assignment and communication within groups on effort levels. This experimental design explores if the strong cooperation within groups and the high effort levels observed by Sutter and Strassmair (2009) sustain when groups are reassembled each period. Our third, and final, scenario is one in which groups always communicate with the same group members (as in many communities or teams) but share output randomly with others not necessarily from their community or team. This scenario, in which communication groups and output-sharing groups are not linked, is a potentially important middle ground if linked output-sharing groups are able to avoid free-riding on each other, and thereby circumvent the efficiency enhancing attributes of output-sharing in partnerships without communication. Allowing for fixed group communication alongside anonymous randomized output-sharing group formation might also be a useful mechanism for managers who realize that their teams are over-supplying effort and wish to avoid direct coordination but want to reduce effort across members of competing teams.

2. EXPERIMENTAL DESIGN

The common-pool resource environment implemented in this experiment requires participants to allocate a fixed amount of effort, e, between an activity which will provide a certain return per unit of effort, r, and an activity which will provide a return that depends upon the effort expended by all of the participants who are trying to obtain output from the common-pool resource. The total output and return (price is normalized to one) from the common-pool resource is given by:

$$Y = 32.5 X - 0.09375 X^2 \tag{1}$$

where Y is total output and X is the sum of the effort expended by all attempting to appropriate from the common-pool resource.

We implement a design which includes four factors: production group assignment, communication, communication group assignment and linkage. The last two are relevant only when communication is present. We test three communication treatments: a fixed-fixed-linked (FFL) specification in which appropriators are assigned to output-sharing groups for the entire session and the group members are permitted to communicate prior to each decision round, a random-random-linked specification (RRL) in which appropriators are randomly assigned to new output-sharing groups prior to each decision round in a session and the newly arranged group members are permitted to communicate prior to their effort decisions each period and a fixed-random-not-linked (FRNL) specification in which communication groups remain fixed but output sharing groups are scrambled every period and no longer linked to the communication group. We compare these with no-communication treatments in which output-sharing groups are either fixed (F) or randomly assigned each round (R)[1]. We analyze harvesting effort, relative rents and dispersion of payoffs by treatment. We also code and analyze the content of the chat messages, and evaluate how each type of message might influence individual effort.

There are 12 participants in each session who are assigned to three output-sharing groups of 4 participants each. This is the optimal group size for a common-pool resource environment which uses output sharing as a management instrument given the parameterization in Schott et al. (2007). For this group size the free-riding incentives created by output-sharing offset the inefficient over-harvesting incentives in the CPR so as to induce the socially optimal level of effort and output. Table 1 summarizes the five treatments in this experiment.

Communication is introduced by way of a chat window that appears on the computer screens of the participants.[2] Prior to the first decision round, individuals are given four minutes to send messages to other members in their communication group. No private messages are allowed. After the four-minute communication period, individuals make private and anonymous decisions about the number of units of effort they will allocate to appropriation from the common pool. The remaining units of effort are automatically allocated to the activity that yields a certain payout per unit of effort (i.e. acts as an opportunity cost of effort). Subjects then share their output from the common pool amongst all output-sharing group members and are given a summary providing their earnings for the period, the average earnings of others in their group and the average earnings of others outside of their group. Prior to the second and third decision rounds, individuals are given three minutes to communicate. Prior to the fourth round this is set at two minutes and from the fifth through the fifteenth rounds, communication is limited to one minute.

[1] Five possible combinations of our treatments are not tested in this paper. Linking fixed and random production groups and communication groups is not possible (FRL and RFL) and the remaining three (RFNL, FFNL and RRNL) were judged to be implausible in the context of CPR management.
[2] Bochet et al. (2006) compare different forms of communication in public goods laboratory experiments and find little difference between the effects of face-to-face communication and verbal communication through a chat room.

Communication is non-binding. Individuals are not required to adhere to any agreement they may have reached during the communication period by way of the chat window.[3]

2.1. Treatments R and F

In the conventional common-pool resource environment, each participant receives a share of the total output appropriated from the common-pool that is in proportion to the participant's share of effort expended, x_i /X , where x_i is the output of individual i. In this treatment, the participant's profit function depends upon individual effort, x_i, the effort by all four members of the individual's group, X_g, and the effort by all individuals using the common-pool resource, X. Output is distributed to output sharing groups in proportion to their group effort and this output is distributed equally to all group members. The individual profit function under output-sharing is, therefore, determined by

$$\pi_i = r(e - x_i) + (1/4)(X_g/X)Y \qquad (2)$$

If r = 3.25 and e = 28, substituting equation (1) into (2) , differentiating π_i with respect to x_i and setting this equal to zero yields

$$[(32.5 - 13)/0.09375] = X + X_g \qquad (3)$$

There is an equation like (3) for each member of each group. When the groups have more than one member, the equations for all of the members in any particular group are identical. Using m as a group identifier, for this case we have three unique equations of the form $[(32.5 - 13)/0.09375] = X + {}^{m}X_g$.

In the case of three four-person groups, there are three equations with three unknowns, ${}^{1}X_g$, ${}^{2}X_g$, and ${}^{3}X_g$. Solving these three equations for the three values of ${}^{m}X_g$ we

[3] Groups used up to 234 seconds, 178 seconds, 177 seconds and 118 seconds respectively in the first four periods and less than 60 seconds in the following periods. Thus there was no evidence that decisions were forced because of time pressure in our experiment.

find the group Nash equilibrium values ${}^{m}X_g = [(32.5 - 13)/0.09375]/[4] = 52$ (a system effort of 156).[4]

Treatments R and F are differentiated in the manner by which participants are assigned to output-sharing groups. Although theory offers no prediction on the effect of group assignment, Schott et al. (2007) report that the dispersion of cumulative earnings for the individual participants is significantly reduced in random group assignment compared to fixed group assignment. One possible explanation they provide is that individual players are more likely to manipulate others' future choices in a fixed group assignment because they can best respond to other players accounting for the efforts from previous periods. These results might change when within-group communication is introduced.

2.2. Treatments RRL, FFL and FRNL

The parameters underlying treatments RRL, FFL and FRNL are identical to those for treatments R and F with the addition of non-binding communication by way of an electronic chat room among subgroups of the 12 participants in each session prior to the start of each decision round. Communication typically helps individuals in groups to overcome the tendency to shirk when payoffs can be characterized as the return to a public good, but it also helps them to reduce effort exerted in the extraction of the common pool in the absence of output sharing (Ostrom, et al., 1994, Chapters 7, 8; Muller and Vickers, 1996). When output sharing is used as a management instrument in a common-pool resource environment without communication, it succeeds because individuals shirk on others' effort to appropriate on behalf of the group. Introducing communication may break down this shirking behavior as members of the group have the means to attempt to collude and compete against other groups to obtain a larger share of the system output.

Profit for the group can be found by aggregating equation (2) across the four members of the group. After substituting for Y from equation (1) this can be expressed as

[4] It is important to note that there is not a unique equilibrium quantity for the individual. The equilibrium condition requires that the sum of the contributions of the individuals in a group equal a unique value. There is a unique group Nash equilibrium allocation of 52 units of effort to appropriation from the common pool from each group. This is the optimal effort to allocate to appropriation from the common pool (see Schott et al. (2007)).

$$\pi_g = 3.25(28)4 - 3.25X_g + 32.5X_g - 0.09375X(X_g) \qquad (4)$$

Differentiating π_g with respect to X_g and setting this equal to zero yields the first order condition for group payoff maximization, $X_g + X = 29.25/0.09375$. Using the methodology described in section 2.1, and indexing the group contribution X_g as ${}^mX_g$ we obtain ${}^mX_g = 312/4 = 78$ (a system effort of 234). This is the unique Nash equilibrium for each group when there are three four-person output-sharing groups who compete against each other for system output. There is no unique individual Nash equilibrium level of effort allocated to appropriation from the common pool. Note that when the output-sharing groups compete against each other as groups, aggregate system appropriation is predicted to rise from the optimal level of 156 to 234.

3. EXPECTATIONS REGARDING EFFORT

3.1. Treatments R and F

Given the parameterization of the common-pool resource environment introduced in section 3, the expectation is that with three four-person output-sharing groups each group will supply 52 units of effort for appropriation from the common pool. The system effort will be 156 units. This is the expectation for group and system effort for both treatments R and F.

3.2. Treatments RRL, FFL and FRNL

If communication groups and output-sharing groups are linked (treatment RRL and FFL), then it is possible that the effect of output sharing may diminish. This may occur if individual players act collusively and exchange information about the optimal level of effort in the one-shot version of the CPR game for which the group wants to maximize its share of system output. This suggests that within the context of treatment RRL and FFL, group effort will be greater than the optimal level of 52 units and may approach 78 units. However, it may take longer to reach 78 units for treatment RRL than if the output-sharing and linked communication groups had fixed membership throughout the session, because group members in the RRL treatment receive different feedback every round from new group members, and, therefore, will find it more difficult to form consistent expectations about the coordination of effort among group members.

On the other hand, it will be difficult for individuals to coordinate on a specific group strategy when communication groups and output-sharing groups are not linked (treatment FRNL). This difficulty arises because individuals will not know into which output-sharing group their communication group members are placed. However, comparing the FRNL treatment with the F or R treatments, participants may be better able to deduce and agree on achieving the symmetric Nash equilibrium outcome in which everyone allocates the optimal level of 13 units of effort to appropriation to maximize the system output, which would achieve the most efficient and equitable solution. This is not a unique Nash equilibrium allocation for the individuals, but the focus on the symmetric Nash equilibrium is reasonable given that communication groups are not linked to output-sharing groups. Treatment FRNL may be more likely to induce shirking compared to the other communication treatments because participants will have a weaker incentive to focus on group output maximization than on system output maximization.

The following expectations result from the discussion above:

Expectation 1: Effort allocated to appropriation from the common pool will not differ between treatments R and F.

Expectation 2: Effort allocated to appropriation from the common pool will be greater in treatment FFL than in treatment RRL during early periods of a session.

Expectation 3: Effort allocated to appropriation from the common pool under treatment RRL will tend to converge over time towards that from treatment FFL.

Expectation 4: Effort allocated to appropriation from the common pool will be less in treatment FRNL than in treatments RRL and FFL.

4. RESULTS

A total of 240 subjects participated in our experiment. There were four sessions in each of the five treatments. In each session, three groups of four subjects participated in 15 decision rounds after three practice rounds. Laboratory currency was converted at the exchange rate of 200 Lab dollars for 1 Canadian dollar 1. On average, subjects earned $25 each (the standard deviation was $2 and earnings ranged from $17.70 to $30.30 including a $5 show-up fee). Sessions were completed within 60 minutes in treatments without communication and within 90 minutes in treatments with communication.

Table 2 summarizes the mean system effort allocated to appropriation from the common pool. There is one observation in each session. Table 2 also provides numerical predictions based on the expectations discussion in section 3 above. A Kruskal-Wallis test indicates that there is a statistically significant difference among the 5 treatments (p-value = 0.0073 for mean system effort).[5]

4.1. Aggregate effort

For treatments F and R, the socially optimal Nash equilibrium with players maximizing individual payoffs predicts the mean system effort of 156 units and mean individual session payoff of L$4217. The actual mean system efforts and mean individual session payoffs in both treatments are not significantly different from the predictions (sign test, two-sided, $n = 4$, p-value = 0.625 for mean system effort in both treatments). There is also no significant difference between treatments F and R (Mann-Whitney U test, two-sided, p-value = 1.000, $n = m = 4$).

In short, when there is no communication, the mean system appropriation effort and relative rents realized from the common pool are consistent with the equilibrium prediction of individual optimization. Group assignment (fixed versus random) makes no difference. These are identical to the results documented in Schott et al. (2007).[6] This evidence supports *Expectation 1*.

[5] All non-parametric tests reported in this paper take each session as an independent observation. Test results from an OLS regression using robust standard errors are consistent with all non-parametric tests reported. The regression is of the form syseffort = a + bR + cFRNL + dRRL + eFFL, where the dependent variable is mean system effort per session, R, FRNL, RRL, FFL are treatment dummies, and “a” captures the value of the mean system effort in the F treatment.

[6] We have added an additional replication of F and R treatments for this paper which were not reported in Schott et al. (2007) in order to increase accuracy and provide symmetry to the three communication treatment sessions. Results from the new replications confirm the robustness of results reported by Schott et al. (2007).

When pre-play non-binding communication is allowed, system effort allocated to appropriation differs significantly from the median of the no-communication treatments (Mann-Whitney U test, p-value = 0.0026, n = 8, m = 12). There is a significant increase in aggregate effort in treatment RRL relative to treatment R (Mann-Whitney U test, p-value = 0.0433, $n = m = 4$) and an even larger significant increase in treatment FFL relative to treatment F (Mann-Whitney U test, p-value = 0.0209, $n = m = 4$). The null hypothesis that the mean system effort in FFL is equal to the predicted value of 234 units cannot be rejected (sign test, one-sided, p-value = 0.6250, n = 4). However, the null hypothesis that the mean system effort in RRL is equal to the predicted value of 234 can be rejected in favor of the alternative that it is less than 234 (sign test, one-sided, p-value = 0.0625). While the mean system effort in FFL is not different than 234 units, the mean system effort in RRL falls between the predicted value of 156 units with individual optimization (which is achieved in R) and the predicted value of 234 units with group optimization.

Thus our expectation that communication that is linked to output-sharing leads individuals to reduce shirking in order to increase group payoffs can be supported by the data. This suggests that communication among group members counteracts the free-riding incentives provided by output sharing and leads to an increase in appropriation effort. Moreover, the offset effect is much larger when appropriators are communicating and sharing output with the same group of participants each decision round than with a different group each decision round (comparing FFL with RRL, Mann-Whitney U test, p-value = 0.0209, $n = m = 4$). Intuitively, it is more difficult for appropriators to enter into tacit or explicit agreement regarding appropriation when they are randomly assigned to groups in each decision round. The results, however, also indicate that it is more difficult for appropriators to coordinate effort when they are communicating with the same group across all rounds of a session but sharing output with a different group each round (treatment FRNL). Groups in the FRNL treatment thus performed as well as the no communication treatments, with effort not significantly different from the predicted individual-optimization level of 156 units (sign test, one-sided, p-value = 0.6250).[7]

[7] Appropriation effort in treatment FRNL is not significantly different from treatment R (Mann Whitney U test, p-value = 0.3865, $n = m = 4$) or treatment F (Mann Whitney U test, p-value = 0.1489, $n = m = 4$).

Result 1. When subjects are communicating with and sharing output with the same people each round, there is a significant increase in mean system effort in random output-sharing groups (treatment RRL vs. R) and an even larger increase in fixed output-sharing groups (treatment FFL vs. F), where group effort is at the predicted group-optimization level. Compared to random linked group assignment (treatment RRL), fixed linked group assignment (treatment FFL) leads to better coordination and thus significantly more appropriation effort.

Result 2. Group assignment has a significant impact on appropriation effort only when output-sharing and communication are linked. No significant difference is observed when communication groups and output-sharing groups are not linked, and the mean system effort is at the predicted individual-optimization level (treatment FRNL vs. R).

Figure 1 reports the mean system effort across periods in each treatment. After the first decision round, effort in treatment FFL is higher than all the other treatments across rounds. This series shows a bit of a cycle that ends near to the predicted effort of 234 units. The RRL series falls between the FFL and FRNL treatments. The difference between treatment RRL and treatment FRNL is, however, not significant (Mann-Whitney U test, *p*-value = 0.1489, $n = m = 4$). Ignoring the first decision round where subjects were getting acquainted with the rules of the game and the last decision round with potential end-game effects, none of the series display a convergence pattern. Thus the role of communication in improving the understanding of the game does not appear to be crucial in any of the treatments other than FFL. This evidence supports *Expectation 2* but refutes *Expectation 3* from section 3 above. In addition there is partial support for *Expectation 4* since effort in the FRNL treatment was found to be significantly lower than FFL but not RRL.

Result 3. When output-sharing group membership changes after each decision round, whether communication group is linked (treatment RRL) or not linked to the output-sharing group (treatment FRNL) makes no significant difference to system effort.

Result 4. None of the treatments indicate a convergence pattern.

4.2. Payoffs to participants in the CPR

The impact of output sharing on the returns to the participants is also important to evaluate as adverse equity considerations or reduced incomes are likely to hinder the approval of a regulatory mechanism even if it is economically efficient.

With output sharing in groups of four, the average individual session payoff reaches a maximum at the socially efficient level (52 units of effort per group), which equals 4217 lab dollars in our experiment.

Table 3 reports the mean and coefficients of variation (CoV) of payoffs of individual session payoffs. An OLS regression with robust standard errors indicates significant differences between the mean CoV of payoffs across treatments. The smallest CoV of payoffs is observed in treatment FRNL while the biggest is in FFL (Table 4).[8] Pairwise comparisons of the mean CoV between treatments indicate significant differences between all paired treatments except treatments RRL and R. With linked communication groups the distribution of session payoffs for fixed output-sharing groups is less equitable than that of the random output-sharing groups, just as in the no-communication treatments. In addition, the payoffs for participants in the former treatments are less than those in the latter. However, when communication groups are fixed and output-sharing groups are randomly matched and no longer linked with communication groups (FRNL), payoffs are most equitably distributed among the five treatments and payoffs are significantly greater than those realized by participants in all other communication treatments. This supports the conjecture in Schott et al. (2007) that random output-sharing groups would likely be more desirable than fixed output-sharing groups in an environment involving communication. Communication in social groups and random output-sharing outside of social networks (FRNL) might be the most desirable output-sharing environment. Figure 2 displays the distributions of individual session payoffs across the five treatments.

[8] The mean CoV in treatment FRNL is significantly different from treatment F, R, FFL and RRL (t test, *p*-value = 0.0002, 0.0114, 0.0002 and 0.0001 respectively). There is significant difference between treatments F and R (t test, *p*-value = 0.0091) and also significant difference between treatments FFL and RRL (t test, *p*-value = 0.0000). Treatment FFL is significantly different from treatment F (t test, *p*-value = 0.0000) while the difference between RRL and R is not significant (t test, *p*-value = 0.1480). Treatment R is significantly different from treatment FFL (t test, *p*-value = 0.0000) and treatment F is significantly different from treatment RRL (t test, *p*-value = 0.0402).

Nonparametric tests on mean individual session payoffs, whose distributions are presented in Figure 2, indicate similar results. Taking one observation in each session, there is no significant difference in the mean individual session payoffs between treatments F and R (Mann-Whitney test, $n = m = 4$, p-value = 0.1489). When communication is allowed but communication groups are not linked with output-sharing groups (treatment FRNL), the mean individual session payoffs are neither significantly different from treatment F (Mann-Whitney test, $n = m = 4$, p-value = 0.1489), nor from treatment R (Mann-Whitney test, $n = m = 4$, p-value = 0.5637). When the linkage between communication and output sharing is established (treatments FFL and RRL), the mean individual session payoffs are significantly different from corresponding treatments F and R, as well as treatment FRNL (Mann-Whitney tests, for comparisons of treatments FFL and F, treatments RRL and R, treatments FFL and FRNL and treatments RRL and FRNL report identical results: $n = m = 4$, p-value = 0.0209). The mean cumulative payoffs in FFL are significantly less than in RRL (t-test, $p < 0.01$).

5. CONTENT ANALYSIS AND EFFORT

Our results indicate that communication leads to a reduction of within-group shirking with linked output-sharing groups. This results in greater effort to appropriate resources from the CPR than when communication is not permitted. The next step is to explore further how communication in linked groups differs from non-linked groups, and to identify the impact that different communication messages have on effort levels. We apply a detailed content analysis to address these questions.

5.1. Coding the messages

Following Zhang (2009), we identified 14 categories of communication messages. Some messages sent by a subject may fit into several categories so categories are not assigned in a mutually exclusive fashion. The categories are listed in Table 5. Two coders, who were not involved in the analysis of the data from this experiment, independently coded all messages according to the 14 categories. A coded-message consists of the information submitted by a participant to the other members of the participant's group during one communication sequence in a communication round preceding a decision round. A coded-message sequence can be a single word or several sentences. It starts when the participant begins typing a message to be sent to the group and ends when the participant hits the "enter" button on the keyboard to submit the message to the group. A message is coded as a 1 if it is deemed to fit into the relevant category of content and 0 otherwise. Each message can be coded under as many or few categories as the coders deem appropriate.

Treatment RRL contains the most coded-message units (3218 units) as subjects were coordinating efforts with a new group every period. Treatment FRNL contains the least coded-message units (1808 units) as communication with people outside your output-sharing group is unlikely to affect harvesting efforts and so not as worthwhile pursuing.

Table 5 summarizes the average frequency of coded-message units by two coders along with the Cohen's Kappa statistics. The Kappa statistic measures the degree of agreement between two coders above that expected by chance. It has a maximum value of 1 when agreement is perfect, 0 when agreement is no better than by chance and it takes negative values when agreement is less than by chance. The general conventions regarding the interpretation of other values are: $0 < K \leq 0.20$ is poor agreement, $0.20 < K \leq 0.40$ is fair agreement, $0.40 < K \leq 0.60$ is moderate agreement, $0.60 < K \leq 0.80$ is good agreement and $K > 0.80$ is very good agreement (Neuendorf, 2005).

All of the measured Kappa's are significantly greater than 0, and so even the low levels of agreement between coders are greater than chance occurrences. Only three of the 42 Kappa estimates indicate less than moderate agreement (Kappa < 0.40, with a conditional mean Kappa of 0.23). This is true for category codes 4, 9 and 10 in treatment FRNL, occurring in categories for which messages are coded with very low frequencies (2.1%, 1.83%, and 0.94% of messages sent, where the average across the remaining 11 categories in treatment FRNL is 10.48%). We have no conjecture for why these categories had such low agreement from the coders (the mean Kappa exceeds 0.55 for these same three categories in both treatments RRL and FFL).

The three most frequently coded categories are category 3 (propose an amount to invest in market 2), which represents 28% of all messages sent across treatments, category 5 (agreement with other group members) at 22% and category 7 (talk about investment decisions or payoffs made in previous rounds) at 18%. Thus group discussions were focused on proposing and expressing agreement to particular proposals concerning effort levels. Category 2 (ask for/inquire/clarify proposals of other group members), category 8 (talk about the conflict/competition/coordination), category 11 (talk about the game rules) and category 14 (other things that are irrelevant to decision making) are moderately common with relative frequencies of 9.44%, 9.34%, 7.14% and 7.83% respectively. Initiating discussion (category 1), mentioning the relationship between investment decisions and payments (category 6), speaking positively about the group (e.g., team work and group spirit, loyalty, honesty) and speaking negatively about the group (e.g., distrust, dishonesty, defection) each accounted for between 4% and 6% of the coded-message units. Surprisingly, discussions within groups result in only 3% of the coded-message units expressing disagreements or doubts (category 4).

Figure 3 illustrates the distribution of message types according to treatment. One can see from this that messages involving investment proposals dominate discussion within the RRL treatment, and that these kinds of messages are more frequent in RRL than the other two treatments. Again this supports the conjecture that linked communication and output-sharing groups that are randomly reassigned each period would have the greatest incentive to communicate each period in order to foster cooperation and reduce shirking to maximize the group's profit. This would require renegotiation and new effort proposals with new group members each period. On the other hand, the only messages that are relatively more frequent in the FFL treatment than the other two treatments are messages concerning conflict, competition and coordination. It is interesting to see that linked output-sharing groups that are fixed over the length of the experiment spend less time making proposals each period and instead focus their discussion on strategies surrounding the inter- and intra-group conflict inherent in the environment. Lastly, the only message category which was found to be relatively more frequent in the FRNL treatment related to messages discussing decisions or payoffs made in previous rounds. It is possible that subjects in this treatment found there was little incentive to communicate other than to discuss what happened in previous periods to each of the group members.

5.2. Correlations between chat messages and effort

The relationship between the chat variables and individual effort within the group is probably bi-directional. That is, the number and content of chat messages may influence the level of group effort and also the level of group effort may influence the number and content of messages. To avoid this issue of causality we first examine the simple correlations between individual effort per period and the total number of messages seen by the individual within a period as well as the total number of messages in each category seen by the individual each period. We adopt the Kendall Tau Rank Correlation coefficient, which is a non-parametric measure of association between observations on two variables. This coefficient is computed by classifying every possible pair of observations as concordant (ranked the same on both variables) or discordant (ranked differently on the two different variables) and expressing the difference as a fraction of the total number of pairs. A value of 1 implies that every pair of observations is concordant, -1 implies that ever pair is discordant, and 0 implies that half the observations are discordant and half concordant.

We examine the treatments separately. The Kendall Tau correlation coefficients and the p-values associated with tests that the correlation coefficients are not significantly different from zero are presented in Table 6. The simple fact of sending messages does not seem to have any significant impact on effort in any treatment; however effort in each treatment is correlated with specific types of messages.

For treatment FFL, individual effort is significantly negatively correlated with message categories 1, 2, 7, 10, 11 and 12 (messages focusing on clarification, previous rounds and negative talk about the group), and significantly positively correlated to categories 9 and 14 (messages focusing on positive talk about the group and noting the last round). There are no other significant correlations. While correlations with most of these categories may be subject to reverse causation in fixed groups (i.e. previous effort affecting messages), it is likely that messages asking group members to clarify their proposals (category 2) are associated with poor group coordination and likely the cause of significantly reduced effort levels.

Treatment RRL had the highest number of messages; however there are only three significant correlations. Individual effort is positively correlated with talk about previous rounds and positive talk about the group (categories 7 and 9) but is negatively correlated with talk of luck or random play (category 12). Unlike in FFL, the significant positive correlation between positive talk about the group and effort is not likely the consequence of reverse causation (due to the random anonymous group matching each period) suggesting that messages that help build team spirit and team identity help groups reduce shirking to increase the group's share of the CPR. In treatment FRNL only message category 13 (other miscellaneous messages) is significantly correlated to individual effort.

5.3. Regression analysis

While the Kendall Tau statistics did not show evidence of a correlation between the raw quantity of messages and individual effort, the relationship between messages and effort may change over the length of the experiment. To estimate this effect we test the linear regression model reported in Table 7 that interacts message volume with a trend variable. Significant interactions between the inverse period and message volume variables in the FFL and FRNL signify that message volume is negatively correlated with individual effort in the first period but positively correlated for all later periods. It is interesting to note that only for the RRL treatment, the correlation between message volume and effort is positively correlated and constant across all periods, likely due to the fact that for randomly reassigned output-sharing groups the first period is no different from any other. To investigate these treatment effects any further requires estimating a regression model that focuses on the effects that messages from different categories have on individual effort. Table 8 reports the estimation results of a random effects panel model regressing individual effort levels on communication message categories in each period for each of the three communication treatments. Estimation assumes random effects at the subject level to account for correlation among effort decisions made by each subject and uses robust standard errors to correct for possible heteroskedasticity across subjects. The assumption of random-effects at the individual level fits the experimental context well, for any subject-specific effects (individual heterogeneity) are independent of changes in the experimental treatments (exogenous regressors). In addition to the message category variables in the model we include a trend variable and lagged variables for the total contributions of others in your group and total contributions of the others not in your group in the previous period. These lagged variables control for the outcome from the previous round (reverse causation), i.e. for the strategic responses to the actions of other subjects within and outside of someone's group in the previous round. In this way the regression model allows the message category variables to possibly explain deviations from individual best responses.

First we find that the constant in the model is not significantly different from the symmetric individual-level effort prediction summarized in Table 2 (16.99 vs. 19.5, 11.74 vs. 13 and 11.41 vs. 13 for treatments FFL, RRL and FRNL, respectively). While the trend variable is not significant for any of the three treatments, the remaining independent variables explain the deviations of effort from the predicted levels. We find that the lagged variables controlling for the past contribution levels of others are only significant in the FFL treatment in which communication group composition was fixed and was linked to the output-sharing group. This is as expected since the other treatments both involved randomized output-sharing group assignment each period so rational subjects would not be expected to respond to decisions made in previous groups. In the FFL treatment individual effort is positively related to the past contributions by others in your group but negatively related to past contributions made by others outside your group. This suggests that independent of the communication content, subjects match effort levels of those of their group members (consistent with tit-for-tat) in a likely effort to reach the cooperative group profit maximum, but respond by lowering contributions if other groups are raising their contributions. The latter is a best response strategy when groups are already contributing more than the socially efficient effort level, which is the case for the FFL treatment.

In terms of significant communication message effects, results depend on the treatment. In the FRNL treatment in which communication groups were not linked to output-sharing groups, none of the message categories was found to be significant at a 5% level. This confirms the neutral effect of communication in social groups that do not directly share output with each other. In the RRL treatment, messages in categories 5 (agreement), 7 (previous effort/profit), 8 (conflict/competition/coordination) and 9 (positive talk about group) have a significantly positive effect on effort and messages in category 11 (talk about game rules) have a significantly negative effect on effort. This suggests that when group membership is randomized every period, discussions focusing on group spirit or the coordination of effort based on logical considerations of the outcomes of previous rounds are most likely to successfully reduce shirking and achieve higher effort levels. Lastly, in the FFL treatment, effects of communication categories 3 (propose amount to invest) and 5 (agreement) are significantly positive on effort and effects of communication category 2 (ask for clarification) is significantly negative on effort. Positive talk about the group and discussion of coordination efforts in previous periods is far less effective in raising individual effort levels than making proposals that are not challenged or debated when groups share with fixed partners for the length of the experiment. The significant relationships between effort and communicating proposals and clarifications in the FFL treatment are consistent with the fact that fixed group membership allows for the building of trust (or mis-trust) over time with group members. In other words, subjects are not likely to respond to proposals by increasing effort (decreasing shirking) when they do not know or trust the subjects who they are grouped with and will likely not be grouped with again. The results, therefore, support the conjecture that positive talk about the group and messages involving team spirit are more helpful in increasing effort than simply making proposals when subjects are strangers.

To summarize the content analysis of the effect of communication messages on individual effort we now report consistent results found across all three analyses reported in Tables 6 through 8. First, when communication groups are not linked to output-sharing groups (FRNL), communication has no effect on effort. Second, when groups are randomized each period (RRL) positive talk about the group and discussion involving decisions and outcomes from previous periods are crucial to increasing effort levels. Lastly, when groups are fixed over time (FFL) messages asking for clarifications are associated with decreasing effort levels, while proposing an amount and agreements are associated with increasing effort levels. Our regression results also confirm that lagged total effort by others in the groups and others outside the group significantly influence individual decision in the FFL treatment only.

Our results indicate some interesting similarities and differences to the experiment in a tournament setting conducted by Sutter and Strassmair (2009). There are three crucial differences in the design of both experiments that can shed some light on the differences in results. First, we have a CPR game with an interior solution that brings payoffs to each member of a team directly in proportion to the team's relative effort level. There are, therefore, no distinct winners and losers in our experiment, but each group's effort level is directly linked to its payoff. Second, Sutter and Strassmair give more information to each individual subject. Subjects were informed about the effort level that each member of their own team chose, while we only supplied average effort and payoff information for the group and all other groups. Third, we have both a partner and stranger treatment, while Sutter and Strassmair use only a partner treatment. We find that lagged effort decisions are only influential in current effort decisions for the partnered groups but not for stranger groups. We confirm Sutter and Strassmair's observation that communication with people outside of your team does not affect individual effort behaviour, but in our case teams are strangers not partners when they communicate with people outside of their group. One would expect that strangers had a bit more of an incentive to influence others not in their groups through communication as one might be matched up with them later on in the experiment. We also found that groups focused on very different communication topics. In Sutter's and Strassmair's experiment, groups were much more concerned about unequal efforts within their team and appeals to fairness. In none of our groups was equity a major discussion topic. This seems to suggest that communication contents and consequently behaviour are influenced by the information provided to subjects. Cheap talk seems ineffective in overcoming shirking within groups with non-linked output-sharing, which is desirable in our case from a social perspective and from a group and individual perspective as it maximizes payoffs. This result is in contrast to tournaments and applications to effort provision in the firm, where the employer's objective differs from the employee's objective and the best interest of the group.

6. DISCUSSION AND CONCLUSIONS

Communication among group members in a setting in which multiple groups compete with one another may not lead to optimal resource allocation. In particular, the success of introducing shirking incentives through output-sharing groups in a common pool resource environment may not be maintained when communication is permitted among group members. We have shown that groups manage to coordinate quite effectively through cheap talk and induce members to increase effort and therefore to avoid free-riding on the effort of others that is so apparent in output-sharing partnerships without communication. While shirking is reduced when output-sharing and communication groups are linked regardless of whether the output-sharing groups are fixed over time or randomly reassigned each production period, breaking the link between output sharing and communication has a remarkable impact on efficiency. If output-sharing groups are reassigned each period but communication groups remain fixed over time, shirking in output-sharing groups is not substantially reduced and effort remains at levels comparable to the no-communication treatments. In addition, the average income earned system-wide is higher and more equitably distributed than when communication groups are linked.

Our online chat room design allows us to further explore the communication contents in different treatments and therefore to analyze the impact of specific communication contents on individual effort decisions. Through a systematic content analysis we find that the content of communication differs by the group allocation method and by whether or not communication groups are linked to output-sharing groups. The finding that high message volumes in fixed communication groups who shared output was correlated with lower effort levels suggests that in a multiple group environment such as this one, once a group has coordinated its behavior, it does not require frequent repeated communication. This is unlike the communication pattern in the randomly formed output-sharing groups, which suggests that more communication is needed in these settings for cooperative behavior to take hold. Because people were always reassigned to new output-sharing groups, high chat volumes had to be maintained to reassure commitment to effort provision of partners.

This paper reports on the effects of communication in an environment in which appropriators of a common pool resource share output with members of an exogenously formed group. While the evidence suggests best practices for carrying out an output-sharing policy, it also allows for unique insight into the effects of communication in a multiple group setting in which communication does not necessarily increase welfare. This is in contrast to the literature on the provision of public goods and extraction from common pool resources without between-group conflict which focuses on the role of communication in increasing overall welfare. Further research needs to explore the effect of permitting group members to communicate with members of other groups as well as their own group. When communication groups and output-sharing groups are linked and membership is fixed, will the ability of all participants to communicate with everyone in the CPR lead to increased shirking and convergence to the efficient level of effort? If unlinked communication and output-sharing groups have this same opportunity, will the high efficiency be maintained or will it collapse?

In the environment we have presented, an outside agency establishes output-sharing groups as a means to manage the CPR. A further extension of this work could examine the role of communication and output sharing in an environment with endogenous group formation or in an environment with communication in which the appropriators are able to design and implement the control mechanism. Resource users could, for example, either vote on the optimal size of output-sharing groups or an outside mediator could simply suggest the optimal group size (as suggested by Heintzelman et al., 2009). Pre-play communication furthermore has been shown to induce subjects to pursue the payoff-dominant strategy (see for example Cooper at al., 1992) Will groups evolve that correct group size for the effects different communication environments create and will there be a role for randomly assigned output-sharing groups in this environment? These research questions are relevant not only in the area of the provision of public goods and harvesting resources from a common pool, but also for competition in oligopolistic markets and the efficient supply of effort by teams in large corporations.

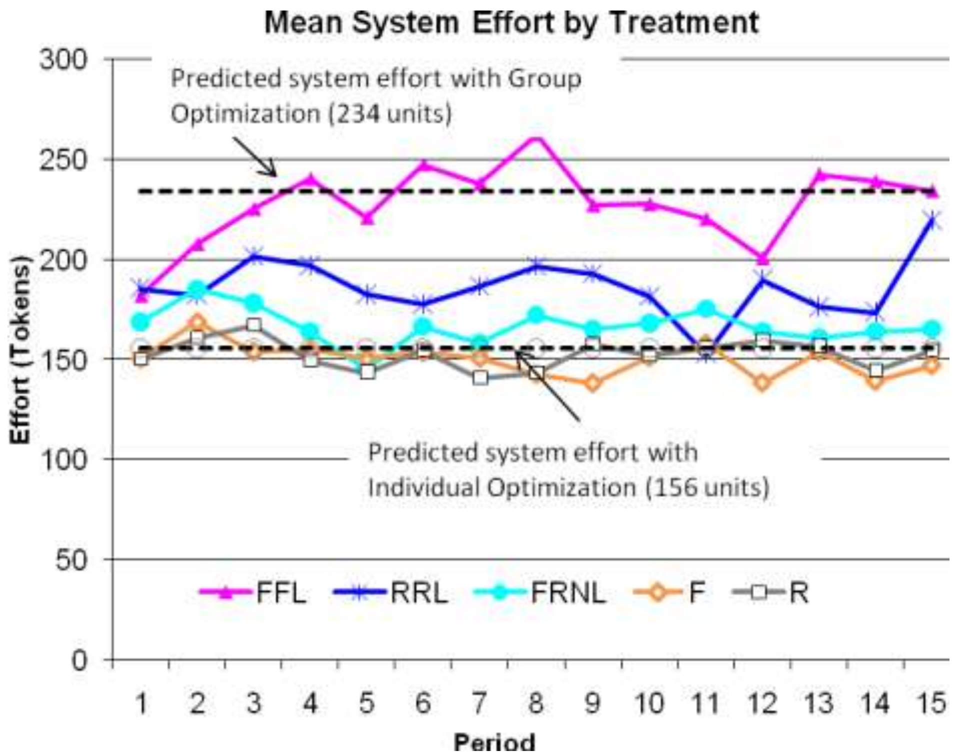

Figure 1. Mean system effort allocated to appropriation from the common pool

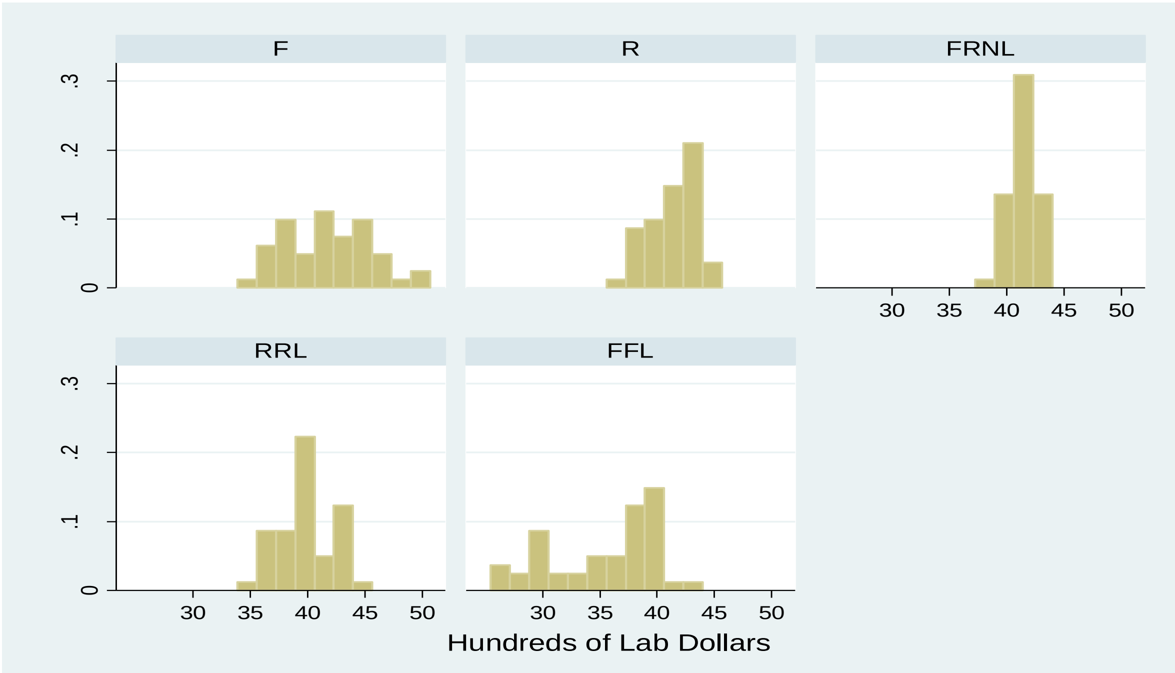

Figure 2. Distribution of individual session payoffs by treatment

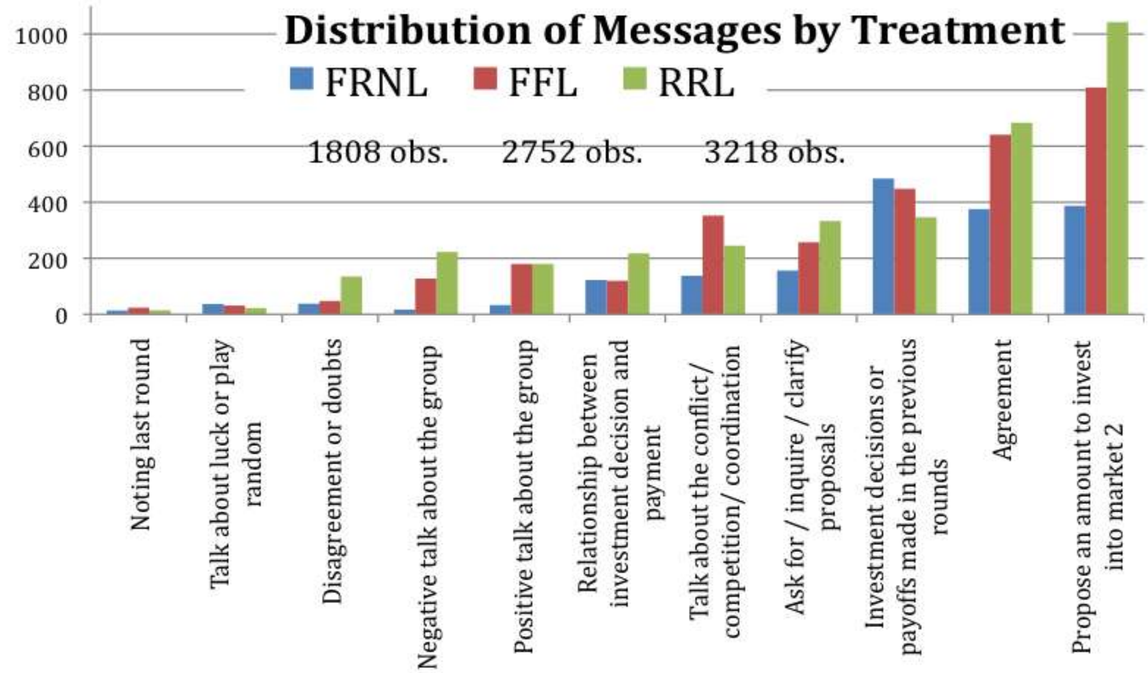

Figure 3. Distribution of communication messages by treatment

Table 1. Experimental Design

Treatment	# of Sessions	Communication	Group Assignment
R	4	No	Random
F	4	No	Fixed
RRL	4	Yes, linked to output-sharing group	Random Communication Group Linked to Random Output Sharing Group
FFL	4	Yes, linked to output-sharing group	Fixed Communication Group Linked to Fixed Output Sharing Group
FRNL	4	Yes, not linked to output-sharing group	Fixed Communication Group not Linked to Random Output Sharing Group

Table 2. Mean system effort per session by treatment

Treatment	F	R	FRNL	RRL	FFL
Predicted system effort	156	156	156	156-234	234
Mean system effort	150.40 (7.38)	152.77 (20.27)	166.87 (17.21)	186.57 (10.90)	227.92 (6.97)

Notes: Standard deviations of the session means are in parentheses. The means and standard deviations are based upon four observations for each treatment.

Table 3. Mean individual cumulative payoffs and coefficients of variation of payoffs per session by treatment

Treatment	F	R	FRNL	RRL	FFL
Mean individual session payoff in lab dollars	4174.26 (21.67)	4147.10 (33.99)	4137.98 (42.90)	3989.53 (61.51)	3528.27 (123.95)
Mean coefficients of variation	0.09 (0.03)	0.05 (0.01)	0.03 (0.01)	0.06 (0.01)	0.13 (0.02)

Notes: Standard deviations of the session means are in parentheses. The means and standard deviations are based upon four observations for each treatment.

Table 4. OLS regressions on coefficient of variation

Treatment	Coefficient (robust standard errors)
F	-0.04**
	(0.02)
R	-0.08***
	(0.01)
FRNL	-0.10***
	(0.01)
RRL	-0.07***
	(0.01)
Constant	0.13***
	(0.01)
Observations	20
R-squared	0.854

Notes: Robust standard errors in parentheses ; *** $p \leq 0.01$, ** $0.01 < p \leq 0.05$, * $0.05 < p \leq 0.1$

Table 5. Reliability indexes and frequency of message coding by treatments

Code	Category Description	FRNL (1808 units)		RRL (3218 units)		FFL (2752 units)	
		Kappa	Relative frequency	Kappa	Relative frequency	Kappa	Relative frequency
C1	Initiating discussion	0.97	6.14	0.93	6.67	0.81	1.05
C2	Ask for / inquire / clarify proposals of other group members	0.57	8.63	0.62	10.35	0.56	9.34
C3	Propose an amount to invest into market 2	0.79	21.40	0.72	32.40	0.76	29.41
C4	Disagreement or doubts	0.33	2.10	0.55	4.20	0.48	1.72
C5	Agreement	0.84	20.77	0.77	21.24	0.79	23.28
C6	Talk about the relationship between investment decision and payment	0.46	6.78	0.58	6.76	0.52	4.35
C7	Talk about the investment decisions or payoffs made in the previous rounds	0.80	26.80	0.63	10.77	0.62	16.28
C8	Talk about the conflict/competition/ coordination	0.51	7.61	0.52	7.61	0.60	12.81
C9	Positive talk about the group (e.g., team work and group spirit, loyalty, honesty, equity)	0.26	1.83	0.52	5.59	0.62	6.53
C10	Negative talk about the group (e.g., distrust, dishonesty, defection)	0.11	0.94	0.63	6.91	0.56	4.64
C11	Talk about the game rules (e.g., conversion rate, grouping; what can be revealed in the chat)	0.63	6.91	0.45	8.45	0.44	6.17
C12	Talk about luck or play random	0.75	2.05	0.57	0.70	0.87	1.14
C13	Others (e.g., humor, time, comments)	0.47	7.44	0.61	7.27	0.57	8.77
C14	Noting last round	0.59	0.75	0.83	0.45	0.55	0.86

Notes: Messages coded as Category 2 do not specifically refer to a contribution level. For each category, the *p*-value is less than 0.005 for the relevant Kappa. These p-values are the probabilities of incorrectly rejecting the null hypothesis that coder agreement is no better than chance.

Table 6. Kendall Tau Correlation Coefficients: Individual Effort versus Number of Messages (probability of making an error by rejecting null that coefficient is equal to zero)

	Treatment		
Message Type	FFL	RRL	FRNL
Total Messages	-0.035 (0.207)	0.002 (0.935)	0.041 (0.172)
C1:Initiating discussion	-0.071 * (0.023)	0.042 (0.168)	0.005 (0.868)
C2:Ask for / inquire / clarify proposals of other group members	-0.136 * (0.000)	-0.055 (0.058)	0.023 (0.452)
C3:Propose an amount to invest into market 2	0.020 (0.484)	0.011 (0.678)	0.055 (0.061)
C4:Disagreement or doubts	-0.057 (0.065)	-0.014 (0.644)	0.000 (0.988)
C5:Agreement	0.049 (0.081)	0.008 (0.775)	0.012 (0.694)
C6:Talk about the investment decision and payment relationship	-0.028 (0.350)	0.027 (0.369)	0.050 (0.102)
C7:Talk about the investments or payoffs made previously	-0.094 * (0.001)	0.060 * (0.040)	-0.003 (0.913)
C8:Talk about the conflict/competition/ coordination	0.052 (0.075)	0.014 (0.642)	-0.016 (0.597)
C9: Positive talk about the group	0.133 * (0.000)	0.103 * (0.001)	0.031 (0.318)
C10:Negative talk about the group	-0.122 * (0.000)	0.033 (0.273)	0.033 (0.297)
C11:Talk about the game rules	-0.073 * (0.016)	0.010 (0.736)	0.029 (0.345)
C12:Talk about luck or play random	-0.120 * (0.000)	-0.080 * (0.010)	0.052 (0.096)
C13:Others	-0.032 (0.287)	-0.017 (0.567)	0.062 * (0.043)
C14:Noting last round	0.087 * (0.005)	0.041 (0.188)	0.036 (0.255)

Notes: Kendall Tau statistics that are significantly different from zero at the 5% level are marked with an asterisk.

Table 7. Effects of volume of messages on individual effort

Dependent Variable: individual effort			
Independent Variables	FFL	RRL	FRNL
Inverse period	0.35	-0.73	3.87**
	(2.64)	(2.39)	(1.95)
volume of messages	0.15***	0.14***	0.16***
	(0.05)	(0.05)	(0.05)
volume*inverse period	-0.27***	-0.08	-0.25**
	(0.10)	(0.08)	(0.10)
Constant	17.86***	13.54***	12.28***
	(1.01)	(1.08)	(0.63)
Observations	720	720	720
Number of individual	48	48	48

Notes: Robust standard errors in parentheses. *** significant at 1%, ** significant at 5%, * significant at10%. All models include a random effects error structure, with the individual subject effects. The volume of the message is the total messages that an individual sent and received from his own group in a given period.

Table 8. Effects of various types of messages on individual efforts

Dependent Variable: Individual effort Independent Variables	FFL	RRL	FRNL
Inverse period	-2.82	-2.07	1.84
	(2.55)	(3.23)	(2.21)
Lagged period total contribution from others in your group	0.12***	-0.01	0.02
	(0.02)	(0.02)	(0.02)
Lagged period total contribution from others not in your group	-0.03**	0.01	0.01
	(0.01)	(0.01)	(0.01)
C1:Initiating discussion	1.74	0.42	0.13
	(2.58)	(0.31)	(0.28)
C2:Ask for / inquire / clarify proposals of other group members	-0.61***	-0.15	-0.07
	(0.17)	(0.23)	(0.19)
C3:Propose an amount to invest into market 2	0.22***	-0.08	0.19
	(0.05)	(0.11)	(0.13)
C4:Disagreement or doubts	-0.52	0.09	-0.34
	(0.53)	(0.35)	(0.42)
C5:Agreement	0.20**	0.32**	-0.03
	(0.10)	(0.13)	(0.10)
C6:Talk about the investment decision and payment relationship	0.17	0.07	0.49
	(0.27)	(0.32)	(0.36)
C7:Talk about the investments or payoffs made previously	0.18	0.38**	0.02
	(0.13)	(0.16)	(0.10)
C8:Talk about the conflict/competition/ coordination	-0.15	0.69***	-0.26
	(0.14)	(0.25)	(0.26)
C9: Positive talk about the group	-0.17	1.12***	0.28
	(0.22)	(0.28)	(0.58)
C10:Negative talk about the group	-0.19	0.29	0.48
	(0.30)	(0.19)	(0.90)
C11:Talk about the game rules	0.30*	-0.76***	0.23
	(0.17)	(0.27)	(0.18)
C12:Talk about luck or play random	-0.80	-0.53	0.64*
	(0.53)	(0.92)	(0.38)
C13:Others	-0.15	-0.39*	0.13
	(0.16)	(0.21)	(0.19)
C14:Noting last round	0.18	0.99	0.66
	(0.69)	(0.98)	(0.60)
Constant	16.99***	11.74***	11.41***
	(2.57)	(2.06)	(1.45)
Observations	672	672	672
Number of individuals	48	48	48

Notes: Robust standard errors in parentheses. *** significant at 1%, ** significant at 5%, * significant at10%. All models include a random effects error structure, with the individual subject effects. Variables C1-C14 are the volume of group messages by coding categories, i.e., the total messages exchanged within a group that fall into a given category.

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APPENDIX I

1. Equilibrium for CPR Environment when Individuals in Groups Attempt to Maximize Individual Profits when Output Sharing is Used as a Management Instrument

Total output as a function of "effort" of all individuals using the CPR (X):

$Y = 32.5\ X - 0.09375\ X^2$

Individual Profit as a function of individual effort (x), the effort by members of the individual's group (X_g) and the effort by all individuals using the CPR (X):

$\prod = 3.25(28 - x) + (1/n)(X_g/X)Y$

where n is the number of people in the individual's group. If n = 1 then $X_g = x$.

Differentiating $\prod$ with respect to x and setting this equal to zero yields

$-3.25 + (1/n)32.5 - (0.09375/n)(X_g + X) = 0$

This reduces to

$[(32.5 - 3.25n)/0.09375] = X + X_g$

There is an equation like this one for each member of each group. When the groups have more than one member, the equations for all of the members in any particular group are identical. This results in three unique equations of the form

$[(32.5 - 3.25n)/0.09375] = X + {}^{m}X_g$ where m is the group identifier.

In the case of three four-person groups, there would be three equations with three unknowns, ${}^{1}X_g$, ${}^{2}X_g$, and ${}^{3}X_g$. The solution will be

${}^{m}X_g = [(32.5 - 3.25n)/0.09375]/[(12/n)+1]$

The important result is that there is not a unique equilibrium quantity for the individual. The equilibrium condition requires that the sum of the contributions of the individuals in a group equal a unique value. There is a unique group Nash equilibrium allocation of effort to appropriation from the common pool.

2. Equilibrium for CPR Environment when Individuals in Groups Attempt to Maximize Group Profits when Output Sharing is Used as a Management Instrument

Individual Profit as a function of individual effort (x), the effort by members of the individual's group (X_g) and the effort by all individuals using the CPR (X):

$\prod = 3.25(28 - x) + (1/n)(X_g/X)Y$

Profit for the group is

Individual Profit as a function of individual effort (x), the effort by members of the individual's group (X_g) and the effort by all individuals using the CPR (X):

$\prod_g = 3.25(28)n - 3.25X_g + 32.5X_g - 0.09375X\,X_g$

Differentiating $\prod_g$ with respect to X_g and setting this equal to zero yields

$X_g + X = 29.25/0.09375$

As demonstrated in section 1, $X_g + X$ may be written as ${}^{m}X_g + (12/n)^{m}X_g$. Therefore,

${}^{m}X_g = 312n/(12 + n)$

The Nash equilibria in the situations described above result in the following values

Members in Group (Number of Groups)	Group Effort with Individual Optimization	System Effort with Individual Optimization	Group Effort with Group Optimization	System Effort with Group Optimization
1 (12)	24	288	24	288
2 (6)	39.6	237.7	44.6	267.4
4 (3)	**52**	**156**	78	234
6 (2)	46.2	92.4	104	208

Note: The allocation of effort that will maximize system profits occurs when the system effort is 156. This will be a Nash equilibrium if the group size is 4 and each group allocates 52 units of effort to appropriating from the common pool. The distribution of effort among group members is not unique.