Shirking for Dollars: Regulating the Exploitation of a Common Pool Resource

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Abstract

This paper provides an experimental testing ground for an equal output-sharing partnership approach as a common pool resource (CPR) management instrument. It examines the behaviour of resource users in output-sharing partnerships of different sizes, and evaluates the impact of partnership size and the way partners are assigned on effort (extraction) levels. Experimental results are very close to Nash predictions, and confirm that group size significantly affects resource user's effort supply. The first best solution is achieved when resource users are privately extracting from the CPR and equally sharing their output with the socially optimal number of partners. The way partners are allocated (randomly or with the same partners over 15 periods) does not significantly affect aggregate effort contributions. Income distribution, however, is more equitable with random allocation of partners than with fixed partners.

1. Introduction

Agents extracting resources from a common pool tend to ignore the impact they have on others when they make their extraction decisions. This tends to lead to more than optimal extraction. Frequently this can lead to destruction of the resource. Hardin (1968) described this destruction the "tragedy of the commons" and implied that it could not be avoided, given the nature of the resource and of individual behaviour. His solution has been interpreted as top-down management and regulation. Regulatory mechanisms have included taxes, subsidies, and quota schemes.

Empirical evidence shows that neither the state nor the market have been uniformly successful in enabling individuals to sustain long term, efficient and productive use of common pool resources (CPRs), while voluntary collective action may be successful (Copes, 1986, Ostrom, 1990, Ostrom *et al.*, 1994, Yamamoto, 1995, Berkes *et al.*, 2001). This tends to require communication among appropriators. Voluntary commitment to output sharing by groups of extractors, or appropriators, from the CPR can lead to a reduction of the over-appropriation common to these environments, even in the absence of communication (Schott, 2002). If the optimal number of

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groups can be determined, the optimal exploitation of the CPR can be achieved as a competitive equilibrium.

The logic behind output-sharing follows from the recognition that the unregulated competitive appropriation from a CPR leads to over-exploitation, as appropriators fail to consider the impact that they have individually on the costs of others. By creating groups of appropriators who share the output obtained from their collective effort to appropriate from the CPR, a countervailing incentive is introduced. Having payoffs determined through the sharing of gains introduces an incentive to shirk, which leads to appropriators reducing their effort in an attempt to *free-ride* on the effort of others. The more members in the group, the greater the incentive to shirk and the greater the offset to appropriation from the CPR. The optimal sized group, given the total number of appropriators, will lead to optimal appropriation through voluntary exercise of effort.

If output-sharing groups were established for appropriation from a CPR, an obvious concern would be the effect that communication among group members will have on shirking. Laboratory results for public goods environments with communication indicate that the under-contributions which characterize environments with no communication disappear with communication (see Chan *et al.* (1999) for a good example of the effects of communication in public goods environments with homogeneous agents and heterogeneous agents). This suggests that communication among group members may offset any advantages which might be associated with the introduction of output-sharing groups for the exploitation of a CPR. A way to control for this effect, would be to randomly and repeatedly assign appropriators to groups so that they do not have an opportunity to enter into tacit or explicit agreements regarding appropriation.

It is important to establish that a mechanism which appears to deliver a desirable result in a theoretical environment will induce the desired behaviour from decision-makers in a controlled laboratory environment. This paper presents the experiment in a programme to evaluate output-sharing among individuals who appropriate from a CPR. Ultimately, an environment in which communication among appropriators will be considered, but in this paper communication among appropriators is not permitted. The treatments include groups of different sizes and allocations of group members in which either group members remain together over a number of rounds of appropriation from the CPR or group members are reassigned for each decision round. The former gauges the robustness of the mechanism and the latter establishes a baseline for future experiments with communication. The results indicate that group size has a significant effect on appropriation from the CPR (system effort), but that the method by which groups membership is assigned is not significant. These results suggest that output-sharing can be an effective mechanism for managing appropriation from a common pool resource if communication among appropriators is not an issue. In addition, if communication is likely and cannot be controlled, the results suggest that repeated random allocation with output-sharing may be a successful management tool.

2. Output sharing as a CPR management instrument: Theory

Dasgupta and Heal (1979) specify a fishery model with a fixed number of harvesters, who can choose the number of vessels they wish to employ. Each harvester, or appropriator, imposes an external cost on rivals that can be both static and dynamic in nature (Brown 1974). The former reflects the opportunity cost of congestion, while the latter reflects the scarcity value of the resource. Static externalities represent a *crowding problem*, and dynamic externalities exist if current actions lead to higher future costs. The following model focusses on the static externality problem and uses total effort applied to appropriation from the CPR as the decision variable controlled by the potential appropriators. A solution to the fundamental problem of the commons can be achieved by organizing N potential appropriators into K output-sharing partnerships (Schott, 2002). Each partnership, or group, consists of $N/K = n$ resource users who make private decisions to allocate effort to appropriation, but who equally share output from the CPR.

In this environment, total system output is a function of the effort allocated by all individuals to appropriation from the CPR. This output function, $Y = y(X)$, is assumed to be twice differentiable with positive first and negative second derivatives. X is the total effort allocated to appropriation from the common pool by the N individuals and Y is the resulting system output.

The profit earned by individual i in group k is

$$^{k}\prod_{i} = w(e - {}^{k}x_{i}) + p(1/n)({}^{k}X_{g} / X)Y \tag{1}$$

where ${}^{k}x_{i}$ is the effort from individual i in group k, w is the opportunity cost of effort put into appropriating from the CPR, e is the individual's endowment of effort, and p is the price of a unit of output from the CPR.[1] Assume that $p = 1$ and that all individuals are endowed with the same amount of effort. Note that the kth group receives a share of the CPR output Y equal to the relative effort it exerts, ${}^{k}X_{g} / X$, and that this output is shared equally among the n members of the group.

In an environment with $K < N$ output-sharing groups for which the profit function (1) characterizes the individuals in each group, in an equilibrium

(i) there is not a unique value for ${}^{k}x_{i}$,
(ii) there is a unique value for ${}^{k}X_{g}$,
(iii) ${}^{k}X_{g} = {}^{l}X_{g}$ for all k, l, and therefore
(iv) ${}^{k}X_{g} = (X/K)$ for all k.[2]

When CPR profits are maximized

$$K = 1 + [(N-1)w/(Y/X)] \tag{2}$$

Because $w < Y/X$ when profits are maximized, $1 < K < N$.[3] This indicates that there is an optimal output sharing group of size greater than unity but less than all of the participants who are appropriating from the CPR. If this number of equal sized groups is created, the effort voluntarily put into appropriation from the CPR will result in the maximization of the aggregated profit of the appropriators.

The next section describes a laboratory environment which captures the theoretical model presented above. Two treatment variables are considered, group size and the group allocation.

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[1] This profit function is comparable to the profit function introduced by Ostrom *et al.*, 1994, and which is typically used in laboratory CPR settings.

[2] When $K = N$, ${}^{k}x_{i} = {}^{k}X_{g}$ is unique. The derivation of these results are presented in Schott *et al*. (2002).

[3] See Schott *et al*. (2002).

Twelve participants are assigned to groups of 1, 4 or 6 individuals. The groups members are either allocated randomly at the start of the first decision-round and remain together for 15 decision rounds or they are allocated randomly at the start of the first decision-round and reallocated randomly following each decision-round. Performance measures include system effort allocated to appropriation from the CPR, individual profit, and the distribution of profit among all appropriators from the CPR. The extent to which the Nash equilibrium predictions from the model are characterized by the data is also reported.

3. Experimental design, parameterization, and predictions

The experiment consists of one treatment in which there are no output-sharing groups, and four treatments in which output-sharing is done in groups of 4 or 6 and the groups are allocated as partners (they remain together for 15 decision round) or with random assignment (after each decision round the members of the groups are reassigned). Three sessions are conducted for each of the five treatments. This design is presented in Table 1.

Table 1. Experimental Design: Number of Sessions by Group Allocation and Group Size

Group Size	Group Allocation		
	No Output Sharing	Output Sharing: Partners	Output Sharing: Random Assignment
One-Person Groups	3		
Four-Person Groups		3	3
Six-Person Groups		3	3

Each session has 12 participants recruited from the general undergraduate population at McMaster University.[4] The participants received written instructions, which were read aloud to them by a monitor, prior to the start of decision-making. Participants make appropriation decisions over three practice periods before beginning the fifteen 15 decision rounds which contribute to their earnings.

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[4] No attempt was made to consider the sex, academic discipline, ethnicity or age of the participants as treatment variables. These nuisance variables were controlled by assigning participants to groups randomly. Participants were assigned to sessions according to their availability and the times at which they responded to our ads. Ads were posted on bulletin boards across the McMaster University campus and an ad was posted on the McMaster University Daily News website.

In the partners treatments the groups are reassigned after the three practice rounds. Appropriation decisions were made by entering a decision number through a computer keyboard. All of the information provided to participants regarding potential payoffs from their decisions and the decisions of others, and the feedback following decision rounds, were reported in a computer mediated environment (instructions and an example of a computer screen are posted at http://socserv2.socsci.mcmaster.ca/~econ/mceel/papers/schottapp.pdf in Appendices 1 and 2). Throughout a session participants had online summaries of their contributions, the average contributions of others in their groups, and the average contributions of others not in their groups. Communication among participants was not permitted (participants sat at workstations which were separated by partitions).

Participants have endowments of 28 tokens that they can invest in two markets. This is comparable to allocating effort across two activities. Market 1 yields a fixed return of 3.25 lab dollars (L$), and represents the opportunity cost of effort. The return from Market 2 depends on the total investment in this market by all twelve participants. This represents the return from investing effort into appropriation from the CPR. The participants are told that based on the total investment made by the twelve people taking part in the session a payout per token invested is determined. This payout is in lab dollars. Each group receives a payout equal to the tokens the group invests multiplied by the per token payout from Market 2. This group payout is divided equally among the group members to determine the individual's payoff. Each token an individual does not invest in Market 2 earns a payoff of L$3.25. The average earnings for a participant in this experiment was $23.69 (median was $23.87) for approximately ninety minutes in the laboratory (the range of payoffs was $18.89 to $39.76 with a standard deviation of $2.04).

The payoff described above is the same as that presented in equation (1) where

$$Y = 32.5X - 0.09375X^2 \tag{9}$$

Given the parameters $w = 3.25$, $e = 28$, $p = 1$ and the output function of equation (9), the first order conditions for individual profit maximization given by equation (4) yield the Nash equilibrium predictions presented in Table 2. For these parameters, four-person groups will yield the optimal appropriation from the CPR through voluntary allocations of effort and output-sharing. The theory offers no predictions with regard to the group allocations. For all hypothesis testing, the null hypothesis is that group allocation has no effect.

The effort predictions reported in Table 2 are unique system and group equilibria. Other than when the group size is unity, there are no unique *individual* equilibria for effort allocated to appropriation from the CPR. In the case of four-person groups, any combination of effort towards appropriation by a group that adds up to 52 tokens will result in a Nash equilibrium if the other two groups have each allocated 52 tokens towards appropriation from the CPR. Different allocations of effort within a group will result in different distributions of income among group members. Therefore, the non-existence of unique individual equilibria when groups of appropriators share output, makes the effect of group size on the distribution of income among appropriators from the CPR an empirical issue.

Table 2. Nash Equilibrium Predictions for System Effort per Period, Group Effort per Period, and Mean Individual Session Payoff by Group Size

	System Effort per Period (Tokens Appropriated)*	Group Effort per Period (Tokens Appropriated)*	Mean Individual Session Payoff in Lab Dollars
One-Person Groups	288	24	2175
Four-Person Groups	156	52	4216.88
Six-Person Groups	92	46	3736.7

* The maximum number of tokens that can be appropriated in any period is 28 for an individual and 336 for the system. System aggregate payoff is maximized when 156 tokens are appropriated.

4. Results

4.1. System Effort

The underlying model for this experiment provides unique predictions for system effort allocated towards appropriation from the CPR for each session. While there are unique predictions for group effort allocated towards appropriations, the observations from the laboratory sessions for groups are not independent observations. Accordingly, the analysis focuses on mean per period system effort by session, mean individual payoff by session, and the standard deviation of mean individual payoff by session.

Figure 1 provides a summary of the data from the fifteen sessions included in this experiment. The figure contains five time series of mean per period system effort by group size and by group allocation. When there is no output sharing (group size is unity), the predicted Nash equilibrium effort is 288. The time series in Figure 1 for this treatment appears to converge to the predicted effort over fifteen decision rounds. This is the outcome for the static CPR environment and is consistent with results reported by Ostrom, Gardner and Walker (1994) for CPR environments with eight appropriators. The result appears to be robust to increases in the number of appropriators.

With optimal effort toward appropriation of 156, too much effort is allocated. When output sharing in four-person groups is implemented, there is a noticeable reduction in the appropriation from the CPR, and this is consistent with the Nash equilibrium prediction of the model with output sharing. When output sharing in six-person groups is implemented, appropriation falls further, as predicted. The summary data in the figure suggest that group allocation does not have an effect on appropriation. The time series for groups of four are intertwined, as are those for groups of six.

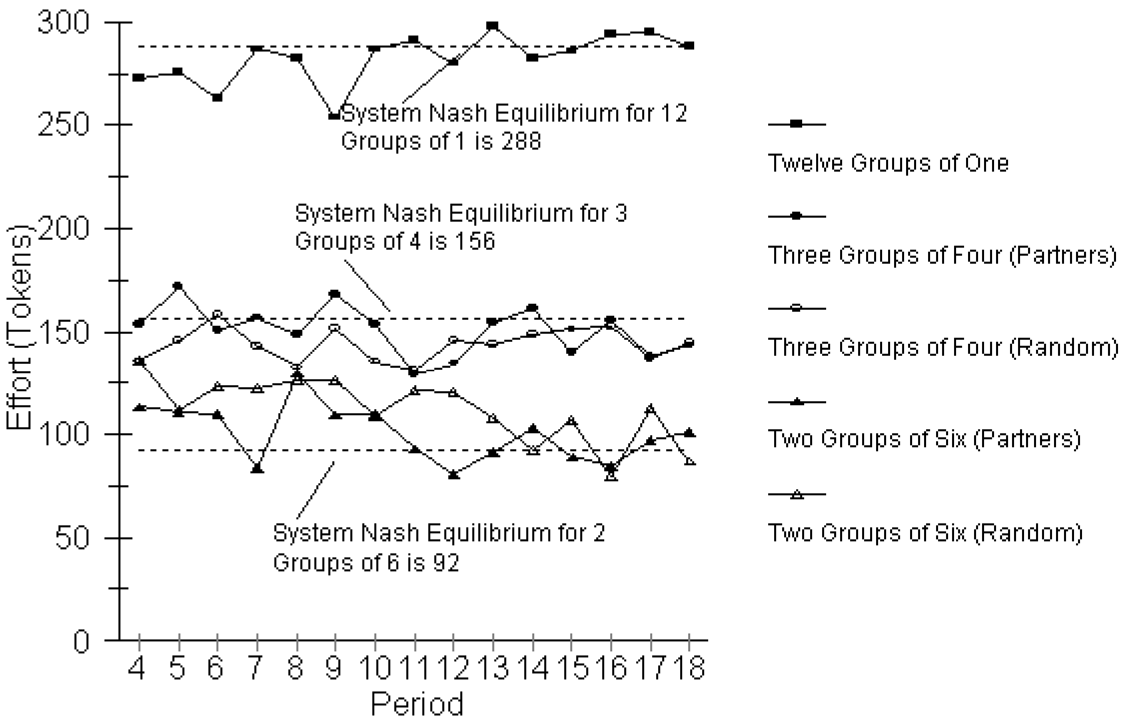

Figure 1. Mean System Effort by Group Size and Group Allocation

The decision-round data presented in Figure 1 are summarized in Table 3. This table is based on fifteen independent observations on the mean per period system effort. There is one observation for each session. Increasing group size clearly results in reductions in system effort to appropriate from the CPR. The data pooled across group allocations falls from 282 to 147 to 106 tokens as group size increases from one to four to six people. There is no noticeable effect of group allocation when the data are pooled across groups that share output (125 versus 128 tokens).

Observation 1. When group size is 4 or 6, it does not matter whether the members of the groups participate as partners or are assigned to groups randomly every period.

Observation 2. The system effort exerted when group size is 4 is less than when group size is six. This difference is statistically significant.

Support: The time series presented in Figure 1 suggest that the system effort differs by group size but that group allocation does not affect system effort. An exact randomization test using the three observations on system effort for each session with multiple-person groups (12 observations in total) does not permit rejection of the hypothesis that group allocation does not matter (p = 0.906), but does permit rejection of the hypothesis that group size does not matter (p = 0.002).

Observation 3. The system effort exerted when group size is unity is greater than when group size is four or six. This difference is statistically significant.

Support: The time series presented in Figure 1 dramatically shows the difference between the system effort when there are one-person groups relative to that from multiple-person group. Exact randomization tests for the difference between the means reported in the Group Totals column in

Table 1 yield p-values of 0.0119 when comparing system effort with one-person groups to system effort with either four-person or six-person groups.

Table 3. Per Period System Effort by Group Size and Group Allocation based on Session Data (standard deviations are in parentheses)*

	Group Allocation			
Group Size	No Output Sharing	Output Sharing: Partners	Output Sharing: Random Assignment	Row Totals
One-Person Groups	282.24 (3.59)			282.24 (3.59)
Four-Person Groups		150.42 (9.04)	143.82 (11.69)	147.12 (10.02)
Six-Person Groups		100.42 (2.93)	112.22 (22.27)	106.32 (15.60)
Column Totals	282.24 (3.59)	125.42 (28.04)	128.02 (23.51)	157.83 (68.03)

* There are three sessions for each treatment.

4.2. Payoffs to Participants in the CPR

In addition to knowing whether or not output sharing provides the appropriate incentives to correct the over-appropriation which characterizes an unregulated CPR, it is also important to know how the returns to the participants in output-sharing groups are affected. Adverse equity considerations could doom an economically efficient mechanism when the politics of implementation are considered. For the environment studied here, theory provides no guide to the effects output sharing will have on income distribution, although there are clear predictions on the effect on income itself (see the rightmost column of Table 2).

Figure 2 displays the distributions of session payoffs for individual participants by group size pooled across group allocation. Because there are 36 observations in the one-person groups and 72 observations in the four-person and six-person groups (36 with partners and 36 with random allocation), the distributions report the proportion of the individuals in the group which have a payoff in a particular range. The ranges are in increments of thousands of lab dollars. For example, an observation at L$3500 reports the proportion of all individuals with a particular group size that is in the range L$3500 through L$3599. Notice that there is no overlap between the distribution of payoffs to people in one-person groups (the conventional CPR environment) and the distributions to people in four-person or six-person groups.

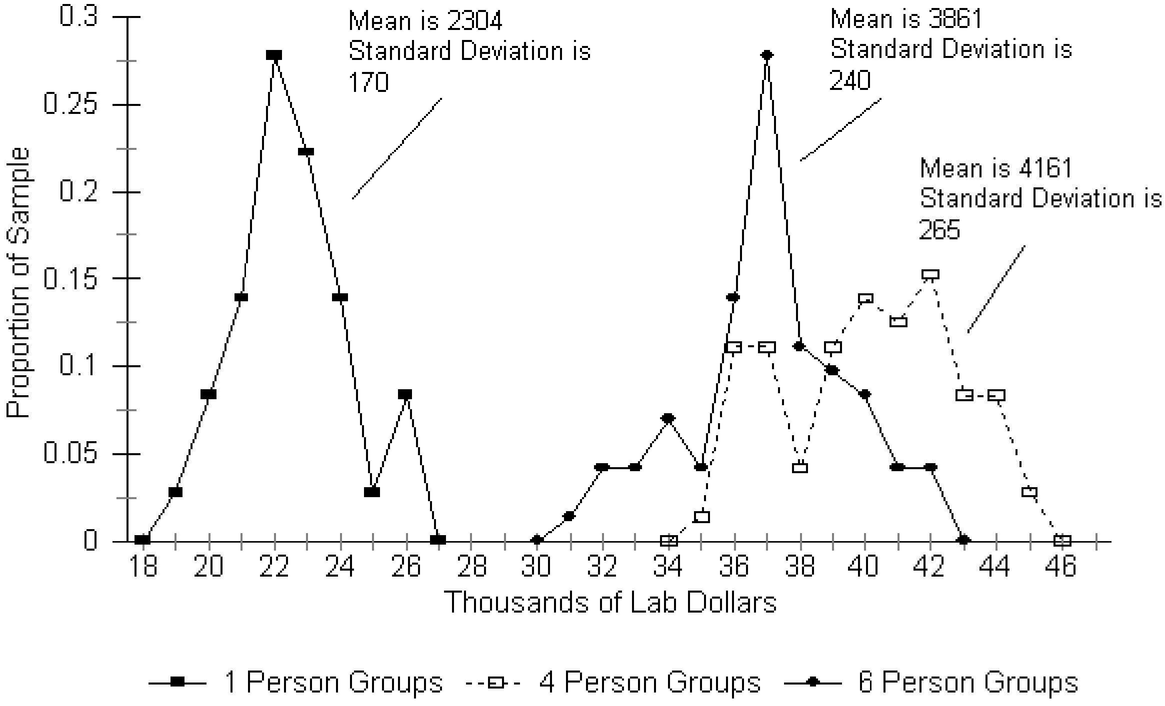

Figure 2. Distributions of Individual Session Payoffs by Group Size

Table 4 reports the mean individual payoff per session by group size and group allocation. This table is comparable to Table 3 which reports system effort. The number reported in the second row and the second column in Table 4 is the mean of three observations. Each observation is the mean session payoff of all individuals in one session in which the group size is four and the participants interact as partners. The row totals show payoffs increasing with the introduction of output sharing. Payoffs with the theoretically optimal group size of four exceed those with group size of six. For output-sharing groups, group allocation (partners or random) does not appear to have a substantial effect on payoffs.

Observation 4. When group size is 4 or 6, it does not matter to mean individual per session payoffs whether the members of the groups participate as partners or are assigned to groups randomly every period.

Observation 5. The mean individual per session payoff when group size is 4 is greater than when group size is 6. This difference is statistically significant.

Support: An exact randomization test using the three observations on mean individual per session payoff for each treatment with multiple-person groups (12 observations in total) does not permit rejection of the hypothesis that group allocation does not matter (p = 0.816) but does permit rejection of the hypothesis that group size does not matter (p = 0.002).

Observation 6. The mean individual session payoff earned when group size is 1 is less than when group size is 4 or 6. This difference is statistically significant.

Support: From Figure 2, the distribution of payoffs earned by individuals when group size is 1 is totally outside of the distributions of payoffs earned by individuals in groups of size 4 and size 6.

An exact randomization tests for the difference between the means reported in the Group Totals column in Table 4 yield p-values of 0.0119 when mean individual session payoffs for one-person groups are compared to mean individual session payoffs for either four-person or six-person groups.

Table 4. Mean Individual Payoff per Session by Group Size and Group Allocation (standard deviations of the session means are in parentheses)*

	Group Allocation			
Group Size	No Output Sharing	Output Sharing: Partners	Output Sharing: Random Assignment	Row Totals
One-Person Groups	2304.49 (103.93)			2304.49 (103.93)
Four-Person Groups		4170.40 (24.80)	4152.03 (39.83)	4161.21 (31.34)
Six-Person Groups		3814.99 (54.14)	3906.32 (197.45)	3860.66 (138.82)
Column Totals	2304.49 (103.93)	3992.70 (198.28)	4029.18 (185.31)	3669.65 (726.17)

* There are three sessions for each treatment.

These results are not surprising. They reflect the results for system effort described earlier. The results of particular interest, however, are those which reflect the effects on the distribution of income within groups. The distribution of income is measured here by the standard deviation of the payoffs to individuals in each session given group size and group allocation. The summary statistics are reported in Table 5. Although the conventional theory provides clear predictions with respect to the differences in effort and payoff across different treatments, there was not prediction associated with the distribution of income within treatments or across treatments.

The numbers reported in the first three rows and columns in Table 5 are each the means of three observations. Output sharing tends to increase the dispersion of incomes, but the distributions with the theoretically optimal group size of four are more disperse than those with group size of six. For output-sharing groups, group allocation has a substantial effect on the distribution of payoffs. The standard deviations of individual payoffs by session from the twelve sessions with output sharing permit the following observations:

Table 5. Mean Standard Deviation of Individual Payoffs per Session by Group Size and Group Allocation (standard deviations of the session standard deviations are in parentheses)*

Group Size	No Output Sharing	Output Sharing: Partners	Output Sharing: Random Assignment	Row Totals
One-Person Groups	143.49 (56.51)			143.49 (56.51)
Four-Person Groups		318.36 (5.08)	215.36 (47.33)	266.86 (63.94)
Six-Person Groups		253.86 (70.83)	143.07 (17.56)	198.46 (76.24)
Column Totals	143.49 (56.51)	286.17 (57.21)	179.22 (50.87)	214.83 (79.73)

(The header "Group Allocation" spans the columns No Output Sharing through Row Totals.)

* There are three sessions for each treatment.

Observation 7. With output sharing, payoffs of members of partnered groups tend to be more inequitably distributed than payoffs of members in groups to which individuals are randomly assigned period after period.
Support: The mean standard deviation of session payoffs in partnered groups is 286 tokens and that for randomly assigned groups is 179 tokens. These are significantly different (exact randomization test, p = 0.012).[5]
Observation 8. With output sharing, payoffs of members of four-person groups tend to be more inequitably distributed than payoffs of members of six-person groups.
Support: The mean standard deviation of session payoffs in four-person groups is 267 tokens and that for six-person groups is 198 tokens. These differences, however, are not significant (exact randomization test, p = 0.124).
Observation 9. While payoffs are more equitably distributed within one-person groups than within output sharing groups (143 versus 233 respectively), the differences are most pronounced between one-person groups and partnered groups and one-person groups and four-person groups.
Support: The mean standard deviation of session payoffs in one-person groups is 143 tokens and those for the partnered groups and four-person groups are 286 and 267 tokens respectively These are significantly different for the former (exact randomization test, p = 0.024) and marginally significant for the latter (exact randomization test, p = 0.072). The differences between the mean

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[5] This difference does not disappear when the standard deviations are normalized by dividing them through by the mean individual payoff by treatment.

standard deviations of session payoffs in one-person groups and those for randomly assigned groups and six-person groups are not significantly different (exact randomization tests, p = 0.404 and p = 0.286 respectively).

At first it may be surprising that payoffs are more inequitably distributed in the partnered groups than in the randomly allocated groups. But recall that when you are in a partnered group, you can behave strategically. There is not a unique individual Nash equilibrium for participants in output-sharing groups. If you can get others in your group to increase their effort, while you reduce yours, you can increase your payoffs. This incentive to behave strategically in order to benefit from your partners' increased appropriation does not exist in the environments with one-person groups or with multi-person groups in which individuals are randomly assigned. This shows up in the data. The standard deviations of individual payoffs by session in randomly assigned groups are lower than in partnered groups, regardless of group size.

5. Summary and Discussion

The objective of this experiment was to evaluate the incentives induced by introducing a countervailing externality as an mechanism for correcting the misallocation resulting from the congestion externality common to CPR environments. The theoretical development of this approach predicts that increasing the size of the group within which output-sharing is imposed will lead to lower system effort. This means a reduction in over-appropriation. There is an optimal group size, for which the congestion externality is precisely offset by the shirking externality introduced by output sharing. If a regulator could discover this optimal group size for a CPR that is being over-exploited, the imposition of output-sharing would lead to efficient exploitation of the CPR.

The induced incentives were evaluated in a laboratory environment, comparable to a CPR environment, in which human participants made appropriation decisions. Group size and the characteristics of the group allocation were varied across sessions in a two-by-two factorial design which created four treatments. A fifth treatment, the baseline CPR environment was also created. In this treatment there was no output sharing.

The results of fifteen laboratory sessions, involving 180 participants, strongly support the theoretical prediction that introducing output sharing will reduce appropriations from the CPR and that increasing group size will reduce appropriations. The data appear to be organized well by the Nash equilibrium predictions from the theoretical model. Whether participants are in output-sharing groups whose membership changes before each decision round or are in groups whose membership is constant over fifteen decision rounds has no significant effect on appropriation.

The data show that introducing output-sharing increases individual payoffs and results in greater mean payoffs with four-person groups than with six-person groups. This is consistent with the theory. What the theory provides no guidance for is how the distribution of income will be affected by the introduction of output sharing. In the baseline CPR environment the distribution of payoffs, as measured by the standard deviation of payoffs to all participants in the CPR, becomes less equitable with the introduction of output sharing. Given output sharing, payoff distributions become less equitable as we move closer to the optimal group size. Group allocation is not immune to a distribution effect. When group membership is reassigned randomly each period, income distribution is more equitable than when group membership is unchanged period after period. This latter result may be consistent with strategic behaviour in partnered groups which cannot be conducted effectively in groups whose members are randomly reassigned each decision round.

Recognizing that output sharing does induce the appropriation behaviour that the theory predicts makes output sharing worth considering as a management instrument. Its imposition does require acceptance by the people who will be regulated. The promise of increased payoffs may help implementation, in spite of the potentially increased dispersion of payoffs. While the use of output sharing may be an effective tool for managing a CPR if participants are unable to communicate, the impact of communication has not yet been evaluated.

Table 6. Per Period Group and System Effort with Individual or Group Optimization

Members in Group	Group Effort with Individual Optimization	System Effort with Individual Optimization	Group Effort with Group Optimization	System Effort with Group Optimization
1	24	288	24	288
4	52	156	78	234
6	46	92	104	208

Note: All of these values are Nash equilibria for the particular group sizes and optimization contexts. The allocation of effort that will maximize system profits occurs when the system effort is 156.

Consider a CPR such as an inshore fishery.[6] The people appropriating from the fishery live in several communities along the coastline that defines this fishery (imagine a large bay which defines the fishery and villages scattered along the coastline). With partnered groups, output sharing could be implemented by identifying groups as sets of coastal communities. With random groups, output sharing could be implemented by randomly assigning people to groups and then reassigning them to groups at the start of each "appropriation" period. Using the parameters introduced in this paper, Table 6 shows the equilibrium predictions for effort from Table 2 along with the equilibrium predictions associated with an environment in which the people *within* output-sharing groups make collective appropriation decisions which they can enforce. The effect of this communication and collective decision-making is to reduce the countervailing shirking externality that made output sharing work so well in the absence of communication.

Think of the twelve participants in this CPR environment as representing six communities with two people in each community. A four-person output-sharing group would consist of a pair of communities. A six-person output-sharing group would consist of a trio of communities. As an example, consider the case of four-person groups. These could be output-sharing groups, who are

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[6] This is not an open access environment. The only people using the inshore fishery, if it is a common pool resource, are members of a well defined set of individuals. To them, this resource is a common pool of fish.

able to communicate among themselves, or these could be communication groups. In the former case, if they can enforce a group optimal appropriation of effort through communication, the prediction in Table 6 may characterize this environment. This would not be a strong endorsement of output sharing. In the latter case the output-sharing groups would be randomly assigned at the start of each "appropriation" period, but the communication groups remain constant. Our theory does not help us predict how communication among these groups will affect appropriation. If this sort of communication does not reduce shirking, then it may be possible to implement output sharing in the presence of communication and successfully increase payoffs to appropriators from the CPR. There is evidence in Kinukawa *et al.* (2000), within the context of a voluntary contribution game, that this sort of *partial* communication will not reduce shirking.

While the theory that pits shirking against over-appropriation behaviour as a regulatory instrument is intriguing, it is necessary to identify the extent to which its predictions will be reflected by individual behaviour. Aspects of the naturally occurring environment, such as communication among participants, are difficult to capture with the theory, but can be implemented in controlled laboratory settings. This is the direction in which research on output sharing as a regulatory mechanism should go.

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