Group Performance and Individual Behavior with Endogenously Determined Common-Pool Resource*

Todd L. Cherry[a], Stephen J. Cotten[b], and Luke Jones[c]

29 March 2010

EARLY, EARLY DRAFT, PLEASE DO NOT CITE

Abstract

This paper considers the case of endogenously provided common-pool resources, in which users contribute effort to enhance the potential benefits of a common-pool resource. Though endogenously determined resources are common, experimental studies generally presume resources are determined exogenously. We develop a framework to explore whether the source of a common-pool resource influences the appropriation levels of the resource, while also investigating the potential of strategic behavior in the provision and appropriation of the resource.

*We would like to thank participants in the University of Tennessee Brown Bag Workshop for their helpful comments and insights, as well as the UT College of Business for their research support.

[a] Cherry (corresponding author): Department of Economics, Appalachian State University, Boone NC 28608-2051, phone: 828.262.6081, fax: 828.262.6105, cherrytl@appstate.edu

[b] Cotten: Department of Economics and Finance, University of Houston – Clear Lake, Houston TX 77058, phone: 281.283.3207, fax: 865.974.4601, cotten@uhcl.edu

[c] Jones: Department of Economics, University of Tennessee, Knoxville, TN 37996-0550, phone: 865.974.4193, fax: 875.974.4601, ljones54@utk.edu

1. Introduction

A *common-pool resource* is an impure public good characterized by rivalry, but non-excludability. Fisheries, forests, irrigation systems, groundwater basins, oil fields, and grazing areas are some of the most often cited examples. These resources are prone to overexploitation because it is difficult to limit the number of users or to limit the harvesting activities of existing users. The potential for overexploitation of common-pool resources, termed the *appropriation problem* by Ostrom, Gardner, and Walker (1994), has been a thoroughly harvested topic in economics. For example, Gordon (1954) showed that fishermen pursuing individual objectives will fish until average revenue equals marginal cost, implying a level of fishing that exceeds the social optimum. Similarly, Hardin (1968) described the "Tragedy of the Commons," using the example of a common grazing area that is overused as a result of its open-access nature.

In addition to the appropriation problem, users of a common-pool resource often face a *provision problem*: the task of creating, maintaining, or improving a common-pool resource (Ostrom, Gardner, and Walker, 1994). For example, users of a fishery might contribute to a project to build hatcheries to aid regeneration, or a group of recreational anglers may vote to increase the price of fishing licenses and use the generated revenue to restore aquatic habitats. While it is understood that users of a common-pool resource often face both the provision and appropriation problems (Ostrom, Gardner, and Walker, 1994), experimental investigations to date have examined these problems separately. Numerous experimental studies have contributed to a better understanding of the appropriation problem, ranging from early tests of Nash predictions (e.g., Walker et al., 1990) to explorations of behavior under various institutional rules (e.g., Ostrom et al, 1992; Ostrom and Walker, 1991). Likewise, a vast body of experimental literature has explored the provision of public goods. Marwell and Ames (1979 and 1991) first wondered how members of a group can act to maximize the collective interest when this conflicts with actions in their own self-interest, and economists have responded with an on-going line of research that has provided insights on the role of group attributes, public good properties and provision mechanisms (see Ledyard (1995) for a summary). Yet for all of the experiments examining common-pool resource appropriation and public good provision, these two strands of experimental literature have largely remained independent from one another.

One implication for the experimental research on common-pool resources is that appropriation concerns resources that are exogenously determined. By combining the provision and appropriation decision, we consider the case of an endogenously determined common-pool resource and investigate whether the origin of the resource affects the manner in which it is used. Theoretically, the origin of resources should not matter, but experimental research reports that behavior is often affected by the origin of the resource, and in particular that self-interested behavior increases when individuals must exert effort to secure resources (e.g., Cherry et al., 2002; Kroll et al., 2007; Harrison, 2007). This literature suggests that appropriative behavior of a common-pool resource may depend, at least partly, on whether the potential benefits from a resource are determined exogenously by nature or endogenously with effort.

A second implication is that linking provision and appropriation decisions creates a new framework to explore individual strategic behavior in social dilemmas. A growing literature continues to shed light on the role of negative and positive reciprocity in strategic environments. Andreoni et al. (2003) use a series of proposal-responder games to examine punishments and rewards jointly and separately. They report the potential of punishments or rewards from responders leads to higher offers from proposers, and that punishment is more effective than rewards. Sutter et al. (2006) explore the selection of institutional rules of punishment and rewards in a public goods game. They find that subjects prefer implementing reward mechanisms even though punishment is more effective in sustaining cooperation.

2. Theoretical Framework and Experimental Design

2.1 Theoretical Framework

Walker et al. (1990) established the baseline framework that is used in most common-pool resource experiments. In this framework, a group of (n) users plays a symmetric, non-cooperative constituent game where each user is confronted with *one* decision in each period: how to allocate an endowment between investment in a common-pool resource with exogenous productive capability and investment in a private alternative.

We extend this framework by considering endogenous enhancement (an increase in the potential return) of the common-pool resource. In our framework, each user faces *two* decisions in each period: first, each user decides whether to contribute some of her endowment toward the enhancement of the resource, and second, each user decides how to allocate the remaining endowment between investment in the common-pool resource and the private alternative.

At the beginning of each period group member (i) is endowed with (e) to be allocated between contributions toward enhancement of the resource (c_i), harvesting activity in the common-pool resource (x_i), and investment in the private alternative (z_i) (where c_i, x_i and z_i must be non-negative). The constraint for individual i in each period is then given by: $e \geq x_i + z_i + c_i$. Let the harvest function for the common-pool resource take the form of equation (1), where b is an exogenous functional parameter.

$$H\left(\sum_{i=1}^{n} x_i, S\right) = S\sum_{i=1}^{n} x_i - b\left(\sum_{i=1}^{n} x_i\right)^2 . \qquad (1)$$

The common-pool resource yields a harvest (*H*) that depends on aggregate harvesting activity $\sum_{i=1}^{n} x_i$ and on the stock of the resource (*S*)[1].

The individual return on harvesting activity (h_i) is the proportion of an individual's harvesting activity to the aggregate multiplied by the total harvest:

$$h_i = \left(\frac{x_i}{\sum_{i=1}^{n} x_i} \right) \left[S \sum_{i=1}^{n} x_i - b \left(\sum_{i=1}^{n} x_i \right)^2 \right]. \tag{2}$$

The private alternative yields a constant rate of return to investment, *w*, independent of the actions of the other group members, such that an individual's return from investment in the private alternative is given by $z_i w$.

The problem faced by each user in each period can be analyzed in two stages. In the provision stage of each period users simultaneously make decisions regarding the allocation of their initial endowments to contributions for enhancing the resource. In the appropriation stage, users simultaneously decide how to allocate their remaining endowments between appropriation from the common-pool resource and investment in the private alternative. We assume that users anticipate Nash behavior in the second stage of the game when making their decision in the first, so we solve backwards.

---

[1] The stock of the resource is an increasing function of aggregate contributions toward enhancement: $S\left(\sum_{i=1}^{n} c_i\right) = M + \left(\sum_{i=1}^{n} c_i\right)^{\beta}$. M is the exogenously specified portion of the resource stock, and β is an exogenous parameter for the returns to scale on contributions to enhance the resource ($0 < \beta < 1$). Thus, aggregate contributions affect the harvest function indirectly through the resource stock, increasing the rate of return on a given level of harvesting activity.

Appropriation Stage. In the second stage of each period, user *i*'s remaining endowment (e_i) is equal to the initial period endowment minus contributions in the first stage: $e_i = e - c_i$. Thus individual *i*'s second stage problem, taking $\sum_{\substack{j=1\\ j\neq i}}^{n-1} x_i$, $\sum_{\substack{j=1\\ j\neq i}}^{n-1} c_i$ and e_i as given, is to maximize individual payoff (π_i) over x_i:

$$\underset{x_i}{Max}\,\pi_i = w(e_i - x_i) + \left(\frac{x_i}{\sum_{i=1}^{n} x_i}\right)\left[S\sum_{i=1}^{n} x_i - b\left(\sum_{i=1}^{n} x_i\right)^2\right]. \quad (3)$$

Setting the partial derivative with respect to harvesting activity equal to zero and imposing symmetry yields the symmetric Nash Equilibrium in which each individual expends harvesting activity:

$$x^{NE} = \frac{(S - w)}{b(n+1)}. \quad (4)$$

Provision Stage. In the first stage, users decide whether to enhance the common-pool resource. We provide subjects with a proposed project, consisting of an exogenously specified target level of aggregate contributions[2] and a provision mechanism. We then allow the users to decide through the provision mechanism whether or not they realize the target level of aggregate contributions and associated resource enhancement.

---

[2] See Appendix A for a discussion of the aggregate contributions.

2.2 Experimental Design

Basics. All subjects were recruited from the undergraduate student population at the University of Tennessee. A moderator explained all instructions to the students as they followed along on their individual workstations[3]. Experimental earnings were denominated in tokens and were converted into $US at a common exchange rate at the end of the experiment. Subjects earned an average of $20 for a one-hour session.

Table 1 provides a summary of the experimental design. The experimental design consisted of four treatments; two baseline treatments and two provision treatments. In the baseline treatments subjects played *only* the appropriation stage. In the *standard baseline* the common-pool resource yielded the standard rate of return based on substituting $\sum_{i=1}^{n} c_i = 0$ into the stock variable. In the *enhanced baseline* the common-pool resource yielded the enhanced rate of return based on $\sum_{i=1}^{n} c_i = \sum_{i=1}^{n} c_i^{*}$. In the provision treatments we tested two provision mechanisms: a majority voting mechanism; and a provision point mechanism (PPM). The provision treatments included *both* the provision and appropriation stages. We ran one session for each of the baseline treatments, and two sessions for each of the provision treatments. Each session consisted of four groups of users in a partner design and lasted for twenty periods. A partner design was used for realism as a common pool resource is one that may be used over an extended period of time by the same population. Furthermore, it provides an opportunity to better

---

[3] The full instructions are available upon request. The experiment was programmed using Fischbacher (2007)'s z-Tree.

analyze coordination, as users may use different methods to coerce fellow group members toward the socially optimal provision and appropriation.

Subjects in the provision treatments were provided tables with both the enhanced and standard harvest payoffs (based on equation (1)) for every possible level of aggregate harvesting activity. Subjects in the baseline treatments were provided tables with *either* the enhanced or standard payoffs. Subjects were clearly informed on the relevant provision mechanism, the individual return to harvesting activity (equation (2)), the calculation of individual payoff for each period (in (3)), and the symmetry of the game. A short exercise was given to test student knowledge of the instructions, and students could not proceed until all questions were answered correctly.

Voting Mechanism. In the voting treatment, the outcome of the provision stage is determined by majority vote on a project, that if passed, would force each member to contribute an equal share of $\sum_{i=1}^{n} c_i^*$ to enhancing the resource. If a simple majority vote "yes," the project is approved and all members are compelled to contribute an equal share of the target level of aggregate contributions. The resource is developed and provides an enhanced return. If a majority of members vote "no," the proposal fails and members do not contribute any effort toward development. The resource remains undeveloped and provides the standard return, and subjects enter the appropriation stage with their full initial endowments.

In order to predict the result of the vote, we assume that subjects compare their Nash payoffs in the appropriation stage under the two possible outcomes of the vote in the provision stage. Our design is such that when each user provides an equal share of the target level of contributions, the increase in the Nash payoff from enhancing the resource exceeds the loss associated with a lowered second stage endowment. Thus, a vote of “yes” is a dominant strategy.

Provision Point Mechanism. The provision point treatment utilizes a provision point mechanism with no refund and no rebate (see McKee and Bagnoli (1991) as an example for further discussion); in this case the outcome of the provision stage is determined by whether or not aggregate contributions meet the target level of aggregate contributions $\sum_{i=1}^{n} c_i^*$. Users individually and simultaneously choose how much of their initial endowments to contribute toward enhancing the resource, and if the aggregate contributions are at least as large as the target level, the resource is developed and provides an enhanced return. If aggregate contributions exceed the target level, the surplus contributions are lost, subtracted from users’ initial endowments accordingly (no rebate) without providing further enhancement of the resource.

If aggregate contributions do not reach the target level, the resource remains undeveloped and provides a standard return. Any contributions made toward the unmet target provide no enhancement of the resource, and each user’s contribution is subtracted from her initial endowment before the start of the second stage (no refund). There exist two symmetric equilibria[4] in the provision point treatment, one in which every user contributes zero, and one in which the target level of aggregate contributions is exactly met (Cadsby and Maynes, 1999). We focus on these equilibria for our predictions.

Predictions. The parameters chosen for the experiment were $n=5$, $w=5$, $b=5/72$, $M=20$, and $\beta=1/2$. Each group member was endowed with $e=120$ tokens in all treatments except

---

[4] And multiple asymmetric equilibria (Cadsby and Maynes, 1999)

for the enhanced baseline[5]. Based on this parameterization of the experiment, the target level of aggregate contributions was $\sum_{i=1}^{n} c_i^* = 100$ tokens[6].

Theoretically predicted behavior in the provision stage is straightforward. If each user contributes 20 tokens in the provision stage, then based on Nash behavior, subjects stand to make 66.67% more in the appropriation stage if the resource is enhanced than if it is not enhanced[7]; so the incentives to enhance the resource are strong. In the voting treatment, all users should support the proposed project and the resource should be developed. Focusing on symmetric equilibria in the provision point treatment, theory predicts that either all users will choose to contribute zero tokens resulting in no resource enhancement, or each user will contribute 20 tokens and the target will be exactly met.

Given the predicted outcomes of the provision stage, predictions regarding the appropriation stage are based on the Nash equilibrium harvesting activity in (4). When the provision stage yields an enhanced resource, the Nash equilibrium harvesting activity is 60 tokens by each user, compared with the socially optimal[8] average of 36 tokens per user. If the resource is not developed, the Nash prediction of harvesting activity is 36 tokens per user, and the socially optimal is an average of 21.6. These predictions of 60 and 36 tokens also serve as the theoretically predicted outcomes for the enhanced and standard baselines, respectively.

All else equal, theory predicts the outcome in the appropriation stage to be neutral with respect to the existence of the provision stage. However, one could conceive that some users of

---

[5] Each subject was endowed with 100 tokens in the enhanced baseline. This is explained in greater detail later.

[6] Parameters were chosen so that 100 tokens would maximize the benefit of enhancing the resource if all subjects played the Nash strategy, assuming second-best optimization by a social planner.

[7] Assuming Nash behavior in each case, a participant would choose harvesting activity of 36 and earn 1,770 tokens in the standard-return case, and would choose harvesting activity of 60 and earn 2,950 tokens in the enhanced-return case – an increase of 66.67%.

[8] Socially optimal aggregate harvesting activity in the appropriation stage is derived by summing individual payoffs over *n* and maximizing the sum with respect to aggregate harvesting activity, taking contributions as given.

the resource might irrationally perceive the sunk cost of contribution, and attempt to "get their money's worth" by harvesting more in the appropriation stage than they would have otherwise. In order to evaluate whether the existence of a provision stage does in fact *not* matter for appropriation, we are able to cleanly compare appropriation in the voting treatment and the provision treatment[9] with the baseline treatments, for both successful and unsuccessful development of the resource[10]. Furthermore, we are able to compare provision mechanisms to examine whether one possesses a relative advantage over the other in terms of efficiency. A difference in efficiency may arise out the potential for asymmetry in the second stage endowment of the provision treatment. Theoretically, the second stage endowment should not affect appropriation as long as it is sufficiently high as to not constrain any subject from playing the Nash equilibrium; however, experimental evidence suggests that higher endowments may lead to more severe over-appropriation (Ostrom et al., 1994). Additionally, we are interested in how the success or failure of the project influences subject behavior both in the same period and over time, and how readily we are able to predict that behavior under alternative treatment conditions. Finally, we look for evidence as to the existence of different types of players as in Ostrom (2000).

Results

Table 2 provides the descriptive statistics of the appropriation decisions from the four treatments. First, comparing observed aggregate behavior with game-theoretic predictions, we note the mean individual appropriation across the enhanced treatments corresponds well to the

---

[9] A clean comparison for the provision treatment was only possible when the outcome of the first stage was one of the two symmetric Nash equilibria. In the event of any other outcome, subjects were left with second stage endowments that were inconsistent with the baseline treatments.

[10] Providing each subject with a 100 token endowment in the enhanced baseline simulated contribution and provided a counterfactual for the event of successful development in the provision treatments.

game-theoretic prediction of 60 units. In the enhanced baseline and voting treatments the mean harvesting activity is statistically equivalent to the Nash prediction, 59.29 units (p=0.488) and 58.52 units (p=0.153). In the enhanced voluntary PPM treatment, mean individual harvesting activity is significantly lower at 54.45 units (p<0.001). When the resource is undeveloped (standard), we observe that harvesting activity is greater than game-theoretic predictions across all treatments. Mean individual appropriation is 38.5 units in the standard baseline (p=0.075), 45.2 units in the voting treatment (p=0.088), and 39.35 units in the voluntary PPM treatment (p=0.090). When comparing mean harvesting activity across treatments, we see significantly lower appropriation levels when the voluntary PPM treatment yielded an enhanced resource relative to the other enhanced treatments (p=0.011). Across the standard treatments, we observe no significant differences in appropriation levels (p<0.222).

While harvesting activity at the aggregate level is quite similar across treatments, interesting results arise when stratifying the data by individual behavior in the provision stage. Returning to Table 2, two behavioral items stand out. First, in the voting treatment, members that voted in the minority exhibited statistically different harvesting behavior. Specifically, those that supported a failed vote to develop the resource exhibited significantly greater harvesting activity than the Nash prediction—54.6 vs. 36.0 (p=0.041), while those that opposed a successful vote appropriated significantly less effort than the Nash prediction—52.7 vs. 60.0 (p=0.005). Second, in the provision point treatment, members that cooperated in resource development by contributing 20 or more units exhibited significantly lower harvesting activity than Nash—52.1 vs. 60.0 (p<0.001).

These results suggest the presence of strategic reciprocity. When the majority voted against resource development, the members that voted in favor of development appropriated significantly more than those that voted against and more than the Nash prediction, which constitutes a form of costly punishment to the group. Members appear to have employed negative reciprocity to encourage fellow members to support the superior outcome of development. Note this is not the case in the voluntary PPM treatment. When resource development failed in this treatment, harvesting activity was similar across cooperative and non-cooperative members. However, strategic reciprocity does appear to show up in the voluntary PPM treatment, but members turn to positive, instead of negative, reciprocity. Specifically, when a majority voted for resource development, the cooperative members appropriated significantly less from the resource than the non-cooperative members. Thus, to encourage cooperative behavior in the provision stage, subjects appear to have used a stick in the voting treatment and a carrot in the voluntary PPM treatment.

The difference in behavior across the two treatments may result from the differences in equilibria. Recall, the voting treatment has one dominate strategy (vote yes), while the voluntary PPM treatment has two symmetric equilibria (contribute 20 and contribute zero). Achieving and maintaining the preferred outcome is more straightforward in the voting treatment, which may embolden members to use negative reciprocity. Conversely, the preferred outcome in the voluntary PPM treatment is more tenuous in the presence of a second, less beneficial equilibrium, which may cause members to opt for a carrot instead of a stick.

Reviewing the results from the final five periods indicates that groups in the voting treatments were able to achieve and maintain cooperation for the provision of resource development. During this period, groups successfully developed the resource in 100 percent of the cases. This was not the case in the voluntary PPM treatment, in which rates of cooperation and success in the final five periods were not different than observed in the first 15 periods.

Results indicate that subject choice of a carrot or stick depends on the clarity of the strategy, but also that a stick works well in the presence of a dominant strategy.

We follow these aggregate results with conditional analyses of individual decisions. A between-treatment analysis estimates the treatment effects on appropriation levels with the following model:

$$A_{it} = \alpha + \eta_{it} + \theta_{it} + \psi_t + \omega_i + \varepsilon_{it}, \qquad \text{i=1,2,}\ldots\text{N; t=1,2,}\ldots\text{T} \qquad (5)$$

where the dependent variable, A_{it}, denotes the i^{th} subject's appropriation from the resource in period t; η_{it} is a set of two indicator variables representing which treatment the i^{th} subject participated in (baseline omitted); θ_{it} indicates whether the resource is developed or not (=1 if developed; 0 otherwise); ψ_t captures time-specific effects on contributions, ω_i captures individual subject effects; α is the constant term and ε_{it} represents the contemporaneous error term.[11] In addition to a *pooled* model, we also estimate an *enhanced* and *standard* model, which clarifies any treatment effect specific to resource development.

Table 3 presents the estimated coefficients from (5). Conditional estimates confirm the initial impressions that harvesting activity is only marginally influenced when the common-pool resource is exogenously, rather than endogenously, determined. Across all models, estimates indicate that, relative to the exogenously determined resource baseline, appropriation was not statistically different when the resource was endogenously determined with the voting mechanism. Results however do find significantly lower appropriation levels when the voluntary PPM mechanism *successfully* developed the resource (p=0.011). The conditional

---

[11] Due to subjects participating in a single treatment, subject-specific heterogeneity is modeled as random effects

estimates corroborate the aggregate numbers that suggest the source of the common-pool resource has little influence on harvesting activity.

We turn to a within-treatment analysis to explore behavioral linkages between the provision of resource development and the appropriation of the resource by estimating the following model with data from the two endogenously determined resource treatments:

$$A_{it} = \alpha + \phi_{it} + \phi\delta_{it} + \theta_{it} + \eta_{it} + \omega_i + \psi_i + \varepsilon_i \qquad (6)$$

where the dependent variable, A_{it}, again denotes the i^{th} subject's appropriation in time t; ϕ_{it} captures whether subject i exhibited support[12] for resource development in time t; δ_{it} is an interaction variable that indicates whether the i^{th} subject's group developed the resource when the subject supported development; θ_{it} indicates whether the resource is developed or not (=1 if developed; 0 otherwise); η_{it} indicates whether the resource was endogenously determined by a vote or provision point mechanism (=1 PPM; 0 otherwise); ψ_{t} captures time-specific effects on contributions, ω_{i} captures individual subject effects; α is the constant term and $\varepsilon_{\mathrm{ij}}$ represents the contemporaneous error term. We estimate a pooled model that includes data from both the voting and PPM treatments, and two treatment-specific models that only includes data from that treatment. In the treatment models, δ_{it} is of special interest because it captures positive or negative reciprocity.

Table 4 reports the within-treatment panel estimates. Results from the pooled model indicate the members that cooperated in the provision stage (voting yes or contributing 20 or more units) exhibited significantly more harvesting activity in the appropriation stage. The specifications of the treatment-specific models isolate the appropriation behavior that corresponds to the possible strategic reciprocity identified in Table 2. In the voting models, the

---

[12] Support indicates a "yes" vote in the voting mechanism, or a contribution of at least 20 in the PPM.

estimated coefficient for ‘yes’ indicates that when the majority voted against resource development, the members that voted yes appropriated significantly more from the resource (p=0.069). Turning to the voluntary PPM model, the ‘yes’ estimate reveals, when the group successfully develops the resource, the members that cooperated by contributing at least 20 units exhibited significantly lower harvesting activity (p=<0.001). This provides conditional evidence that corroborates the aggregate results from Table 2, which suggest that subjects encouraged cooperative behavior in the provision stage with negative reciprocity (i.e., a stick) in the voting treatment and positive reciprocity (i.e., a carrot) in the voluntary PPM treatment.

Discussion

Previous research has examined provision and appropriation stages of common-pool resource games separately, because theory suggests the choice of appropriation is independent from the provision decision. Using laboratory evidence, we examine the possibility that behavior in the provision stage spills over to the appropriation stage. While we find only limited evidence that the provision mechanism affects aggregate harvesting activity, with the provision point mechanism resulting in closer-to-optimal levels of harvesting, we find interesting evidence that the structure of provision affects the nature of reciprocity in the appropriation stage.

When there is a dominant strategy in the provision stage, as in our voting treatment, those who follow the strategy punish those who do not by overharvesting the resource in the appropriation stage. When there are multiple equilibria, as in our provision point treatment, those who follow the socially optimal strategy attempt to entice those who do not by demonstrating their own willingness to cooprate through underharvesting the resource in the appropriation stage. This implies that individuals are more apt to punish (use the stick on) someone whose own welfare would be improved by compliance, while more prone to bribe (use the carrot on) someone for whom the decision is less clear.

While previous research has given subjects a choice of what institutions of reward and punishment they could use, or imposed it endogenously, there was no structured framework here. Even with no mention of rewards or punishments, subjects evolved carrot-or-stick mechanisms while trying to elicit cooperation in the appropriation of a common-pool resource. The behavior we observe is in line with the results of structured experiments (e.g. punishment is more effective than cooperation in achieving the desired outcome), but because we observe it with no framing, our results in some ways are more compelling.

References

Andreoni, J., Harbaugh, W., and Vesterlund, L. (2003) The Carrot or the Stick: Rewards, Punishments, and Cooperation. *The American Economic Review* 93(3): 893-902

Bagnoli, M., and McKee, M. (1991) Voluntary Contributions Games: Efficient private provision of public goods. *Economic Inquiry* 29: 351-366.

Cadsby, C. and Maynes, E. (1999) Voluntary Provision of Threshold Public Goods with Continuous Contributions. *Journal of Public Economics*. 71: 53-73.

Cherry, T.L., Frykblom, P. and Shogren, J.F. (2002) Hardnose the Dictator. *American Economic Review*. 92: 1218-1221.

Fischbacher, Urs (2007) z-Tree: Zurich Toolbox for Ready-made Economic Experiments. *Experimental Economics* 10(2), 171-178

Hardin, G. (1978). The Tragedy of the Commons. *Science* 162: 1243-48.

Harrison, G.W. (2007) House Money Effects in Public Good Experiments: Comment. *Experimental Economics*. 10(4): 429-437.

Kroll, S., Cherry, T.L. and Shogren, J.F. (2007) The Impact of Endowment Heterogeneity and Origin on Contributions in Best-shot Public Good Games. *Experimental Economics*. 10(4): 411-428.

Ledyard, John O., (1995) Public Goods: A Survey of Experimental Research, *The Handbook of Experimental Economics*, pg. 111-194, eds. John H. Kagel and Alvin E. Roth. Princeton University Press

Ostrom, E., Walker, J., Gardner, R. (1992) Covenants with and without a Sword: Self-Governance is Possible *American Political Science Review* 86: 404-417

Ostrom, E., Walker, J. (1991) Communication in a Commons: Cooperation without External Enforcement *Laboratory Research in Political Economy*, ed. Thomas R. Palfrey, 287-322. Ann Arbor: University of Michigan Press

Ostrom, E. (2000) Collective Action and the Evolution of Social Norms. *Journal of Economic Perspectives*. 14: 137-158.

Ostrom, E. (2006) The value-added of laboratory experiments for the study of institutions and common-pool resources. *Journal of Economics Behavior and Organization*. 61: 149-163.

Ostrom E., Gardner, R., and Walker, J. (1994) Rules, Games, and Common-Pool Resources. The University of Michigan Press. Ann Arbor.

Selten, R. (1971) A simple model of imperfect competition: where four are few and six are many. *International Journal of Game Theory*. 2: 141-201.

Sutter, M., Haigner, S., Kocher, M. (2006) Choosing the Carrot or Stick? Endogenous Institutional Choice in Social Dilemma Situations. CEPR Discussion Paper 5497, February 2006.

Walker, J., Gardner, R., Ostrom, E. (1990) Rent Dissipation in a Limited-Access Common-Pool Resource: Experimental Evidence. *Journal of Environmental Economics and Management*. 19: 203-211.

Appendix A

In order to specify the target level of aggregate contributions used in the experiment, we assume the position of a regulator attempting to maximize the sum of individual payoffs in a second-best scenario. We take the Nash behavior of users as given in the second stage and conditionally set the target level of aggregate contributions for the first stage optimally. Substituting the stock function *S* from (2) and the Nash Equilibrium individual harvesting activity x^{NE} from (5) into the individual payoff function in (4) and summing over *n* (noting that $e_i = e - c_i$) yields the regulator's second-best objective:

$$\underset{\sum_{i=1}^{n} c_i}{Max}\, w\left(ne - \sum_{i=1}^{n} c_i - \frac{\left(M + \left(\sum_{i=1}^{n} c_i \right)^{\beta} - w \right)}{b(n+1)} \right) + \left(M + \left(\sum_{i=1}^{n} c_i \right)^{\beta} \right) \frac{\left(M + \left(\sum_{i=1}^{n} c_i \right)^{\beta} - w \right)}{b(n+1)} - \left(\frac{\left(M + \left(\sum_{i=1}^{n} c_i \right)^{\beta} - w \right)}{(n+1)} \right)^{2} . \quad (5)$$

Equation (6) implicitly defines the solution, $\sum_{i=1}^{n} c^{*}(w,b,n,M,\beta)$, to (5) that serves as the target level of aggregate contributions for the experiment:

$$-wb\left(\sum_{i=1}^{n} c_i^{\;*} \right) n^2 - 2wb\left(\sum_{i=1}^{n} c_i^{\;*} \right) n - wb\left(\sum_{i=1}^{n} c_i^{\;*} \right) - 2w\left(\sum_{i=1}^{n} c_i^{\;*} \right)^{\beta} \beta n + 2\left(\sum_{i=1}^{n} c_i^{\;*} \right)^{\beta} \beta M n + 2\left(\sum_{i=1}^{n} c_i^{\;*} \right)^{2\beta} \beta n = 0 \quad . \ (6)$$

Given the target level of aggregate contributions $\sum_{i=1}^{n} c_i^{\;*}$, users decide through an exogenously specified provision mechanism whether or not the target level and associated resource enhancement are realized.

Table 1. Experimental Design

Treatment	Provision Mechanism	Provision Outcome	Initial Endowment	Individual Contribution	Remaining Endowment	Appropriation Stage
Baseline	Exogenous	Enhanced	100	none	100	Enhanced
		Standard	120		120	Standard
Voting	Majority Vote	Passes-Enhanced	120	20	100	Enhanced
		Fails- Standard	120	0	120	Standard
Provision Point	Provision Point	Met-Enhanced	120	≥ 20 (avg.)	≤ 100 (avg.)	Enhanced
		Not Met-Standard	120	<20 (avg.)	>100 (avg.)	Standard

Table 2. Mean Appropriation by Treatment and Provision Decisions

	All Periods		Last 5 Periods	
	Enhanced	Standard	Enhanced	Standard
Nash Equilibrium	60	36	60	36
Baseline	59.3	38.5	59.6	37.8
	(25.2)	(24.0)	(24.1)	(22.9)
	300	*300*	*75*	*75*
Vote	58.5	45.2	59.8	--
	(24.4)	(33.4)	(23.8)	--
	560	*40*	*150*	--
Voted Yes	59.9	54.6	60.9	--
	(23.8)	(31.9)	(23.0)	--
	452	*15*	*119*	--
Voted No	52.7	39.6	55.4	--
	(26.3)	(33.6)	(26.7)	--
	108	*25*	*31*	--
PPM	54.5	39.4	56.1	36.5
	(23.5)	(29.1)	(23.7)	(33.3)
	379	*220*	*105*	*45*
Contributed 20+	52.1	39.4	53.8	37.4
	(21.6)	(23.0)	(21.5)	(26.9)
	301	*109*	*83*	*17*
Contributed <20	63.7	39.3	64.4	36.0
	(28.2)	(34.1)	(29.7)	(37.1)
	78	*111*	*22*	*28*
Total	57.5	39.3	58.6	37.3
	(24.4)	(26.9)	(23.8)	(27.1)
	1239	*560*	*330*	*120*

Note: numbers on top, in parentheses and in italics represent the mean, standard deviation and number of observations for each cell.

Table 3. Resource Appropriation: Treatment Effects

	Pooled	Enhanced	Standard
Constant	38.19	55.65	40.36
	(0.000)	(0.000)	(0.000)
Vote	1.885	-0.108	1.63
	(0.192)	(0.949)	(0.695)
PPM	-2.114	-4.72	0.009
	(0.111)	(0.011)	(0.997)
Enhanced	15.84	--	--
	(0.000)		
χ^2	209.61	30.33	21.75
	(0.086)	(0.086)	(0.0000)
N	1799	1239	560

Notes: (1) dependent variable is the total amount appropriated
(2) estimation controls for individual and subject effects in each model

Table 4. Resource Appropriation: Within Treatment Behavior

	Pooled	Voting	PPM
Constant	41.10 (0.000)	37.55 (0.000)	42.39 (0.000)
Yes	5.84 (0.056)	12.11 (0.069)	-12.89 (0.000)
Yes-Passed	-6.75 (0.061)	-5.75 (0.407)	--
Yes-Failed	--	--	11.49 (0.007)
Enhanced	16.63 (0.000)	14.88 (0.002)	20.35 (0.000)
PPM	-4.90 (0.001)	--	--
χ^2	122.18 (0.0000)	56.12 (0.0001)	94.65 (0.0000)
N	1199	600	599

Notes: (1) dependent variable is the total amount appropriated
(2) estimation controls for individual and subject effects in each model