ELSEVIER
Forest Policy and Economics 6 (2004) 229–241
Forest Policy and Economics
www.elsevier.com/locate/forpol

Norms from outside and from inside: an experimental analysis on the governance of local ecosystems

Juan-Camilo Cardenas*

Department of Economics, Universidad de los Andes, Carrera 1 No 18A-70 Bloque C, Bogota, Colombia

Abstract

Many forest ecosystems provide multiple goods and services to both local users (e.g. firewood, water) and to other external beneficiaries (biodiversity conservation, carbon sequestration). This calls for alternative approaches in the governance of these local ecosystems. Even if local users solve the commons dilemma they face regarding the optimal provision of the direct benefit, there might still be a need for introducing mechanisms that also address the externality that involves those outside of the group. This paper addresses the analysis of different types of mechanisms, endogenously emerged from groups vs. externally imposed to them, when facing the typical tragedy of the commons. During 2000–2002 we conducted a series of economic experiments in several rural communities in Colombia. The sub-set reported here of 53 sessions with 265 actual users of local ecosystems, were focused specifically on the effect of external and self-governing rules for inducing cooperative behavior within groups. A group extraction or 'commons' game was used to explore how rules, formal and informal, emerge and how individual behavior responds to regulatory mechanisms aimed at solving the dilemma. Three treatments were compared to a baseline design: Two external regulations (high and low penalties, and only 20% of the players monitored), and a self-governed system where individuals were allowed to have in each round a few minutes of non-binding face-to-face communication. Surprisingly, both external regulations generated very similar results regardless of the level of the penalty, and they induced behaviors very similar to those achieved by the self-governed treatment. The experimental results suggest that individuals do not seem to follow entirely the conventional economic prediction of a minimizer of expected costs of regulations against the benefits from over extracting the resource, and that humans can develop norms based on non-enforceable rules of cooperation. Instead, other elements related to social norms and subjective valuation of the benefits and costs of the regulations might be in play.

Keywords: Experimental economics; Commons dilemmas; Cooperation; Forest management; Regulations; Rules; Self-governance

1. Introduction: dilemmas in the management of local ecosystems

Forests produce and regulate water, offer raw materials for the logging industry, forages for feeding livestock, food and nursery services for coastal fisheries, nutrients recycling, firewood, habitat, protection against disasters, among many other goods and services (Costanza et al. 1997). Many of these services are enjoyed not only by the local users and residents within or next to the forested area but by other communities farther in space and time. Within the communities that use directly and indirectly the ecosystems there is a first dilemma to be solved, conventionally labeled as the 'tragedy of the commons', and

* Tel.: +57-1-339-4949x2473; fax: +57-1-332-4492.
E-mail address: jccarden@uniandes.edu.co (J.-C. Cardenas).

1389-9341/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.forpol.2004.03.006

studied widely since Hardin (1968) up to the present (Ostrom et al., 2002). There is a consensus now that self-governed solutions can emerge and succeed, but many factors regarding the institutional environment and the production function involved in the use of the commons affect the chances of success. There is another dilemma to be solved, that of other beneficiaries that do not live next to the ecosystem in terms of space and time and therefore who cannot easily participate in the decision-making and institutions regulating the behavior of those local users. The worldwide concern about preserving biodiversity is just one example of the problem associated with this second dilemma where external beneficiaries benefit or suffer the cost of decisions made by local users that depend on the extraction of resources. Society designs therefore rules and governance systems through the market, the state or the communities, to solve not only the group externality at the local users level, but also to transcend the local jurisdiction and bring upon the rights and needs of others farther in space and time.

To correct the social inefficiencies arising from local users using the resource and its effects on the welfare of these outsiders, external regulators or managers of these ecosystems can do mainly two things. One, to directly own and manage natural areas to guarantee the protection of biodiversity and other ecological functions. Also, secondly, they use mechanisms such as command and control and economic incentives to induce in local users a change in behavior that is better aligned with the local and social optimal solutions described above. These external regulators can be state and non-state agents and for both types their goal is to internalize the externalities imposed by local users' over-extraction of the resource on themselves and on outsiders. Notice that even in the case of state or private owners, for many forested areas of the world, the possibility of individuals extracting resources (e.g. logging, hunting) at levels that create social losses is still a problem due to difficulties in enforcing the property rights, particularly of access and appropriation of goods and services from the ecosystems.[1]

[1] In the case of political conflicts in ecologically valuable regions of the world, forest guards find it difficult to enforce perfect compliance of exclusion and extraction rules, and have to allow certain levels of entrance and extraction by local users, or in the case of corruption they choose deliberately to allow loggers to extract much higher amounts of resources.

In principle, the introduction of externally imposed regulations is supposed to induce a change the relative prices of the decision makers by increasing the private cost of over-extraction and therefore reduce the incentives for free-riding. However, regulations that need to be designed and enforced by external agents (e.g. the state) require a certain amount of resources and information that increase the social costs of enforcing them. Usually, it is the case that regulators have a rather limited amount of information about the individual behavior of users in order to apply instruments such as a fee on extraction by the regulated agents. Therefore, regulators usually evaluate their capacity of enforcing their rules to achieve the socially optimum behavior and design material incentives that change sufficiently the private costs or gains of the agents.

However, other types of non-material incentives are at play when individuals face a social exchange situation where there are externalities and effects of one's behavior on others' well-being. The last few decades of experimental and field research have converged to support the idea of humans having a utility function where various factors beyond the pure selfish material gains play an important role in economic behavior.

The case of groups facing the tragedy of the commons is only one of many cases where other-regarding preferences are critically determining individual behavior and social outcomes, as well as strategies the self-regarding individuals may play to increase the net present value of a series of cooperative interactions. Elements of altruism, fairness, reciprocity and reputation can play critical roles in affecting the weights that individuals put into the material costs and benefits from cooperating or defecting in a social dilemma (Ostrom, 1998; Bowles, 1998; Fehr and Gachter, 2000a; Fehr and Schmidt, 1999). These transformation of the benefits and costs of actions in individuals' preferences also play a role in the incentives introduced by regulations and sometimes can play unexpected roles in their net effect on behavior.

In Cardenas et al. (2000), we show for instance how a weakly enforced regulation can in fact crowd-out the group oriented strategies individuals are choosing in a common-pool resource game and reduce social efficiency to levels even smaller that those achieved under no external regulations. In such paper, we conducted a set of experiments in the field, similar to those reported here, where sessions with groups of eight individuals were facing a regulation based on a probability of being monitored of 1/16 and a fine that given the expected cost should increase social efficiency partially from the predicted symmetric Nash equilibrium towards but not quite the social optimum. Although the regulation performed quite well during the first rounds, it rapidly deteriorated because individuals were increasing their levels of extraction with a 15/16 probability of not being monitored, and thus negative reciprocity began to play an important role, inducing behavior that was less group oriented and more oriented to over-extracting. By the end of the experiments, the average player was making decisions much closer to the symmetric Nash equilibrium prediction than when the decisions were being made under a non-regulated environment. Meanwhile, those experiment sessions were individuals were allowed to have a face-to-face communication in every round, but were not permitted to introduce pecuniary incentives in their sessions, performed much better in terms of aggregate extraction and social efficiency. This paper is a follow-up to these findings but addresses among others the effect that the level of monitoring and the size of the penalty plays in behavior.

A further issue deserves attention due to its policy implications. Self-governed solutions by definition require less resources in the part of regulators and planners for their functioning, than externally enforced systems of rules. It might be the case that the resources contributed by the group members be as costly as resources arriving from outside of the community, but when states have limited funds and personnel, and when communities can derive other kind of gains from, say, participation in self-governing systems, such as increase in trust, social networks and ties, the comparison of externally imposed regulation systems to self-governance deserves also a policy level inquiry. The results here presented suggest that both types of systems can perform at similar levels in terms of their effectiveness in changing behavior under the same incentives from using local ecosystems but different public finance conditions.

The next section will present the model designed to study the behavior of the local users when facing both the group externality problem of over-extraction and the presence of different kinds of rules aimed at inducing an individual behavior that is socially desirable. Such a model was used to design and conduct a series of economic experiments in the field to explore the hypotheses offered by game-theoretical predictions about behavior of individuals under these environments of incentives and rules. The experimental results that follow will offer some lights about behavior and the effectiveness of externally and endogenously designed rules that in principle aim at similar socially efficient outcomes but in practice seem to have different kinds of (sometimes unexpected) effects. At the end, some reflections and conclusions will discuss the implications of a different approach to the problem of regulations and norms, both self-governing and externally imposed, to groups facing the dilemma of cooperation when managing local ecosystems.

2. An experimental design of the local commons problem

2.1. An analytical model of the resource and the users

The design is based on a simple model of a group of users of a natural resource who face a group externality, which will allow us to study the effects of regulations and enforcement of rules in these kind of dilemmas. In the experimental design, we frame the situation as one where a group of people can extract resources from the same source (experimental instructions and protocols are available from the author). Individuals derive part of their payoffs (direct benefits) from allocating effort into extracting a resource (e.g. logging or firewood) for which there is joint access by a group or community. They also see reduced their payoffs (indirect benefits) in the form of a public good from the negative externality that occurs as the aggregate extraction by the group increases, e.g. water quality or biodiversity losses that decrease because of over extraction from the common pool.

2.1.1. The non-cooperative game

Assume n players that benefit from the forest, and who have each the same maximum labor endowment of e_i units to allocate in extracting a particular resource. Player i's level of extraction x_i, where

$x_i \in (1,e_i)$[2], increases her payoffs at a decreasing rate (direct extraction benefits $= ax_i - \frac{1}{2}bx_i^2$, $a,b > 0$), while the aggregate extraction by the n players Σx_i ($i=1,n$), reduces i's payoffs (indirect benefits $= \Sigma(e_i - x_i)$, >0). The externality can also be described as a public good benefit from conservation, i.e. lack of extraction. Thus, player i's payoffs are:

$$\pi_i = (ax_i - \frac{1}{2}bx_i^2) + \alpha\sum(e - x_i) \quad (1)$$

For n players, and assuming symmetric endowments for all, $e_i = e$, we can rewrite Eq. (1) as Eq. (2),

$$\pi_i = ax_i - \frac{1}{2}bx_i^2 + \alpha ne - \alpha\sum x_i \quad (2)$$

If player i chooses x_i to maximize Π_i, the first order conditions that produce the optimal level of extraction x_i^{nash} are $\partial\pi_i/\partial\pi_i = a - bx_i - \alpha = 0$, which requires that:

$$x_i^{\text{nash}} = (a-\alpha)/b, \text{for } x_i \in [1, e] \quad (3)$$

For example, suppose values of $e=8$, $a=60$, $b=5$, and $\alpha=20$, $x_i^{\text{nash}} = (a-\alpha)/b = 8$. Therefore, from the standpoint of any player it would be a Nash best respond—and a dominant strategy, to allocate her maximum endowment of labor into extracting the forest. Later, we use these parameters, which allow us to create the environment of incentives we need for our experimental design.[3]

To produce the socially efficient outcome, we maximize the aggregate payoffs Eq. (4) and calculate the optimal level of extraction for the individuals, x_i^{so}.

$$\text{Max } W = \sum\pi_i = \sum ax_i - \frac{1}{2}b\sum x_i^2 + \alpha n^2 e - \alpha n\sum x_i \quad (4)$$

The first order conditions, $\partial W/\partial x_i = a - bx_i - \alpha n = 0$, require that:

$$x_i^{\text{so}} = (a-\alpha n)/b, \text{for } x_i \in [1, e] \quad (5)$$

For the same example parameters above, and for a group of $n=5$ players, such solution would require each player to allocate $(60-5*20)/5 < 0$. Since x_i takes only non-negative values—for purposes of framing in the experimental design, we have a corner solution at $x_i^{\text{so}} = 1$, i.e. all players should allocate a minimum of effort into extraction to produce the socially efficient outcome.

For these parameter values, we designed a payoffs table (see Appendix A) where columns represent player i's level of extraction, rows represent the rest of the group's aggregate extraction, and values in the cells are the earnings in one round for player i, based on this payoffs function and parameters. The exact same table is handed to the five participants in each group. Each should decide in each round the level of extraction $x_i \in (1,8)$, and the earnings can be then found after knowing the total group's effort extracting and looking at the respective column and row in the table.

2.1.2. External regulation of individual behavior

The challenge for the external regulator is to design an instrument that induces an individual behavior across players that produces the social optimum. However, a more realistic regulatory setting will involve a level of incomplete monitoring and therefore private information by the local users given that regulators face a costly enforcement of the instrument. Monitoring costs are high, and enforcement is even difficult in settings where political conflicts constrain the state to reach certain regions or ecosystems. Following the analysis of external regulation in Cardenas et al. (2000), we introduce in the problem a regulation in the form of a penalty f, externally

[2] We have eliminated in the action set the zero extraction option ($x_i^{\text{so}}=0$) to avoid possible conflicts in conducting these experiments in the field. Previous experiments and pre-testing exercises suggest that there are strong aversions by villagers towards prohibitions to use resources, which could create problems conducting the experiments with such an option. Interior solutions where $c^{\text{sopt}}>0$, such as used in Ostrom et al. (1994) and Cardenas et al. (2000) are another alternative, but we have decided here to maintain corner solutions for simplicity. There are no analytical implication of using such constrained action set of 1 to e units.

[3] The reason for such parameters was to construct a set of incentives where there were sufficiently clear and significant tradeoffs between self-oriented and a group oriented strategies.

imposed with certain probability P, to individual allocations above what the social optimal solution requires. The expected value of such penalty becomes a private cost for users and it is proportional to their level of extraction. By varying the probability of inspections times the fine or penalty we will test weak and strong enforcement levels. Notice that these regulations can take many forms in the field,[4] mostly through state governance systems of different types and levels, but in most cases involving a cost imposed to the resource user and a probability of monitoring and enforcement.

If we consider the penalty f and the probability of inspection P, following from Eq. (2), the new expected payoffs function for a player i is then:

$$\pi_i = ax_i - \frac{1}{2}bx_i^2 + \alpha ne - \alpha\sum x_i - Pf(x_i - x_i^{so}) \qquad (6)$$

which yields the first order conditions for an optimal solution: $\partial\pi_i/\partial x_i = a - bx_i - \alpha - Pf = 0$, implying that:

$$x_i^{nash-REG} = (a - \alpha - Pf)/b, \text{for } x_i \in [0, e] \qquad (7)$$

Suppose that for a weak enforcement case the probability of inspection is of $P = 1/5$ and the fine $f = 50$. In such case, the expected best response, in a symmetric Nash equilibrium, should be $x_i^{nash\text{-}REG} = 6$ units, which would only partially increase earnings and reduce extraction by decreasing in two units the individual extraction of rational players. In the case of a strong regulation for a fine of $f = 175$ points, we get $x_i^{nash\text{-}REG} = 1$ unit, which would achieve the social optimal solution by aligning the best response function with the socially optimal condition. These two levels of fines were tested in the field and compared to other non-pecuniary sets of incentives.

2.2. Experimental design in the field

The experiments were all conducted for groups of five players, in a finite repeated game of 20 rounds, divided in to two stages. The players' payoffs, according to the model above, increase with the individual's level of appropriation but decreases with the aggregate level of use by the group, following the incentives structure of a group externality dilemma. Throughout the game all decisions are made individually and privately and only the group outcome (total extraction by all five players) is publicly announced in each round. The first stage (rounds 1–10), for all groups, will be under a baseline treatment as a non-cooperative game, where each subject decides individually and privately her level of appropriation of the commons according to the payoffs incentives described before. In the second stage (rounds 11–20) a new institution is introduced in the form of a regulation aimed at improving social earnings.

2.2.1. Stages of the experiment (instructions available upon request)

The following stages were conducted for each of the sessions or groups.

Pre-game stage (instructions and practice rounds): Each of the experiments begins with the reading of the instructions to the group of five players, and the handing out of the following forms (available from author): the GAME CARDS where they write their choice, i.e. her extraction level, in each round; the DECISIONS RECORDS SHEET where they keep record of their choices and earnings; and the PAYOFF TABLE (see Appendix A). Once all questions from participants are clarified, the experimenter continues by conducting one round as an example, and at least one more practice round. After solving questions, stage 1 begins.

Stage 1 (Rounds 1–10): In stage 1 of the experiment each of the players must decide privately the individual level of extraction from the commons, and write it down in one yellow round card; the same information is also recorded in the blue records sheet. The monitor collects the five cards, adds the total extraction for the group, which he writes in the monitor's record sheet, and announces publicly such total. Each player must write the group's total, and by subtracting her individual extraction, she is able to calculate the payoffs for that round. She writes her total gains for the round and the experiment proceeds to the next round by filling a new round card. It was common information that round 10 was the final under such rules. Once they had finished calculating their earnings for round 10, they were told that the

[4] Forms of imposing such regulation cost include a fine proportional to the extraction level, confiscation of the equipment (e.g. chain saw, traps, fishing nets), or prohibition of extraction for a certain period of time.

rules of the exercise were going to change for stage 2 of the game. Also, they were never told in advance what the rules for the second stage were.

Stage 2 (New rule, Rounds 11–20): The second stage started by announcing that they will be playing for another 10 rounds under a new set of rules. This paper reports results for two different types of rules used in the stage 2, and a control baseline where we just tell them that the second stage would be run in the exact same form as the first one. The two types of new rules reported here are

i. a *self-governing mechanism* (face-to-face communication) in which we allow the five people to have a 3–5 min conversation before they make their decisions in each round; and
ii. an *externally enforced regulation* in which we as external monitors try to enforce a regulation based on a penalty proportional to the level of over extraction above the social optimum, as described in the analytical model described before, with a probability of being monitored of 1/5.

For the case of the face-to-face communication we started stage 2 by saying to the participants that in every round, and before they made their decisions, they would be allowed to have a 3–5 min discussion on anything they wanted about the development of the game and that no arrangements were allowed to redistribute earnings once the experiment had ended. However, they were told, decisions remained individual and confidential.

For the groups under the regulation treatments, the second stage started by the monitor explaining how they probably had noticed that the group could earn the maximum of points if every player chose a level of extraction equals to one unit (this information was not given to the communication groups though).[5] They were also told that for achieving such goal the monitor would choose randomly in every round one player and would verify her compliance with the stated rule. Had the player chosen a higher level of extraction, she would see her earnings reduced in \$50 (\$175 for the high penalty treatment) times the units of extraction above 1.

We also had control groups under a baseline treatment with no change in the rules for the second stage.

Exit stage (Calculate earnings, fill out survey): After all rounds from stage 2 end, the monitors calculated total earnings for each player by adding the column of round earnings and subtracting the cases where a fine was imposed. While the monitor made the calculations, the players responded the exit survey anonymously and in private. Then payments were made in cash to each player and in private, upon returning the filled survey.

The Table 1 summarizes the experimental treatments, the sample sizes and expected behavior according to the model and previous experimental evidence.

2.3. Sample size, predictions and hypotheses

Before describing the main results from the experiments with the villagers in the field, let us also review the game-theoretical predictions and some additional hypotheses for the different treatments used in the experiments. In general, conventional theory would suggest, following the game-theoretical analysis in the previous section that under the baseline treatment, and during the first 10 rounds (stage 1) all players by maximizing their own payoffs should follow their best response and therefore increase extraction up to 8 units. Secondly, under the face-to-face communication, such theory would also predict a similar result given that the group discussion is non-binding and promises to cooperate during the conversation would be considered as non-credible threats. However, experimental evidence has systematically shown that communication among players is a powerful device to construct trust and cooperation in these kinds of dilemmas (Ostrom et al., 1994). Finally, our external regulations, according to the analysis should induce a differentiated effect in behavior, with the low penalty treatment (XHL) providing an equilibrium at x=6 units, while the stronger high penalty one (XRH) inducing players to choose the social optimum strategy of 1 unit. The results reported here included 53 sessions with

[5] The reason for announcing this is to make sure that the players have a benchmark to compare to when facing a penalty if chosen for the inspection, and that the external policy is common knowledge. It was very clear in many sessions that by round 10 of the first stage such were the social optimum solution for many of the players. In no single occasion such solution was questioned, although we did allowed participants to make questions before stage 2 begun.

Table 1
Experimental design, sample size and treatments in stages 1 and 2

	Stage 1 (10 rounds)	Stage 2 (10 rounds)		Sample size	Predictions	
		New rule	(Rounds 11–20)		Sym.Nash equilibrium	Comments or experimental evidence
Baseline:						
(X) No communication or regulation	$X_1, X_2, X_3 \ldots X_{10}$	(No change-control)	$X_{11}, X_{12} \ldots X_{20}$	8 sessions 40 people	Xnash = 8	Baseline VCM and CPR experiments have shown a decrease in contributions or cooperation rates over rounds.
Non-pecuniary incentives: self-governance						
(CX-t) repeated communication	$X_1, X_2, X_3 \ldots X_{10}$	face-to-face Group Discussion before each round.	(CX-$_{11}$), (CX-$_{12}$)…(CX-$_{20}$)	13 sessions 65 people	Xnash = 8	Face-to-face communication has systematically showed effective results in similar experiments, despite the game theoretical prediction of its ineffectiveness due to the cheap talk hypothesis.
Pecuniary incentives: Mandatory fines for over-extraction						
(XRL) exogenous regulation (weak enforcement)	$X_1, X_2, X_3 \ldots X_{10}$	Inspection of 1 player in each round: P=1/5, f=\$50	$(X-R)_{11}, (X-R)_{12} \ldots (X-R)_{20}$	20 sessions 100 people	Xnash = 6	There might be a risk for crowding -out of group preferences after the regulation is imposed, due to imperfect monitoring.
(XRH) exogenous Regulation (Strong enforcement)	$X_1, X_2, X_3 \ldots X_{10}$	Inspection of 1 player in each round: P=1/5, f=\$175	$(X-R)_{11}, (X-R)_{12} \ldots (X-R)_{20}$	12 sessions 60 people	Xnash = 1	Less crowding-out expected as the expected penalty is considerably stronger.

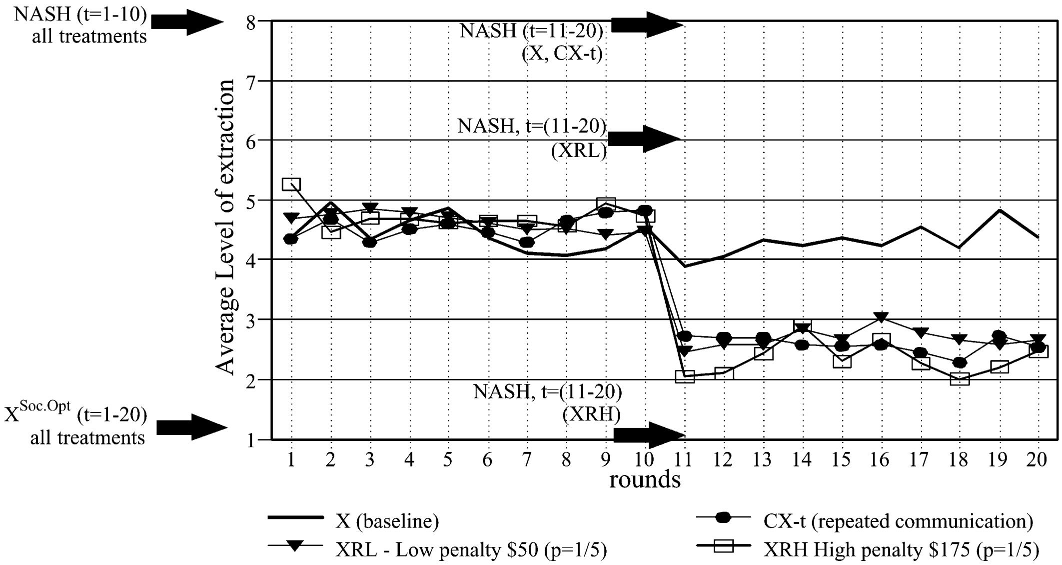

Fig. 1. Average of group extraction during stages 1 and 2 by treatment.

265 villagers as participants. All of them were paid in cash, individually and privately. Individual earnings averaged one to two minimum wage days of labor, compensating for their participation over some 4 h for a single session. In average our participants earned Col.$10 076 (S.D.=$3127) during the 20 rounds, which in average was approximately US$3.8. The minimum day wage in these rural areas was approximately Col.$8000 (US$3).

3. Experimental results

The following Fig. 1 summarizes the average behavior by our participants over time, and across treatments. The benchmarks represented by arrows show what the game-theoretical model predicts regarding the first 10 rounds, and then, for rounds 11–20, the shifts in behavior.

First of all, we observe as expected no difference across the treatment groups for the first 10 rounds and therefore the differences observed for stage 2 across treatments should not be the result of carry-on differential effects brought from the first stage but induced by differences in the treatment variable. Secondly, the first stage shows clearly that individuals in average do not converge to the maximum level of extraction, but choose in average a level between 4 and 5 units over time, and without a trend towards dissipation of rents in the commons. In fact less than 15% of choices during those 10 rounds correspond to x=8 units of extraction, with a rather flat distribution of choices by players. Overall, this pattern of partial cooperation during the first stage is very similar to the seminal work by Ostrom et al. (1994) where experiments were conducted with college students. The non-decrease in cooperation over time that is usually reported for linear public goods (Ledyard, 1995) might be explained by the non-linearity of the payoffs structure as one can observe also in the payoffs table. Further, the baseline treatment provides a stronger test bed for a non-decrease in cooperation under a non-cooperative game setting even after 20 rounds. The rationale for this argument is simple and can be appreciated in the payoffs table: as individual extraction increases, the marginal return from extracting individually does not justify the damage caused to others in the group providing a strategic incentive not to over harvest if one considers, as usually found in the literature (Bowles, 1998) that individual preferences might include the well-being of others through norms of fairness and reciprocity (Ostrom, 1998).

Some may argue that the subjects pool and the local context of the experiment might also explain this as the participants have a prior history of their other group members, and there are possible ex-post effects that players could consider when defecting or cooperating with their fellow neighbors.[6] Although this factor seems to play a role in the overall trends, it does not explain the steadiness in the aggregate and average individual levels of extraction. We replicated the same experiments with college students from Javeriana University (Colombia) and the results show a very similar but shifted average extraction towards slightly—but statistically significant—higher levels as reported in Cardenas (2003b), however, the levels of extraction of students did not show either a decrease by the end of the baseline treatments.

For the field sessions, under communication or the external regulations during the second stage, there was a clear change in individual strategies by most participants. However, the shifts show some results that are central to our discussion about institutional design of governance systems. Let us go in detail over the treatments.

Self-governance incentives: The group discussions under the repeated communication (CX-*t*) showed a clear change in the individual strategies and therefore in the group outcomes. All groups in average decreased their individual extraction to levels between 2 and 3 units, and sustained such extraction level over time. Recall that decisions under this treatment were still private and kept confidential by the experimenter. However, this result does not surprise the literature on the capacity of groups to device their own agreements to solve these externality problems. Face-to-face communication has been widely studied as a mechanism to coordinate the decisions within groups and the experimental evidence seems to reject the hypothesis of the 'cheap talk' argument in cases where the communication in group does not allow the players to introduce changes in the material payoffs structures (Marwell and Ames, 1980, 1981; Ledyard, 1995; Ostrom et al., 1994) shows that the simple communication among the group members affects their strategies and shifts the group outcomes towards higher social efficiencies. Empirical evidence about the potential for a long-standing system of self-governed institutions has been made best known by Elinor Ostrom's 'Governing the Commons' (1990) and further explored widely in the theoretical, experimental and empirical literature. Once again, it could be the case that the particular condition of villagers knowing each other and facing the possibility of ex-post interactions once the experiment ended might play a role in creating a different set of incentives for them. In fact, such incentives can work either way as communication involves also the possibility of bringing signals of less trustworthiness as the players detect different intentionalities and promises. For instance, real wealth distances among villagers could play a role in creating more difficult the achievement of a credible commitment towards cooperation, as studied in another set of field experiments (Cardenas, 2003a). Therefore, knowing each other and facing future interactions outside the lab does not necessarily imply that cooperation should be higher than for a university lab with randomly recruited students.

Pecuniary incentives: External regulation with imperfect monitoring. There is no doubt that the external regulations introduced for those groups in treatments XRL and XRH also induced a change in individual strategies. However, the effect does not follow the predictions regarding the expected costs of such regulations.[7] In fact there seems to be a very little difference across the two levels of the penalty. Although for all 1600 observations[8] combined for the 10 rounds, there is a statistically significant mean difference for Ho: Avg.X(XRH)−Avg.X(XRL), with a *P*-value=0.0006, such difference is of only +0.3447 units, while the theoretical prediction was of 6 units.

Therefore, we observe from the data that individuals within the high penalty XRH treatment extracted in average approximately 1.3383 units *above the Nash equilibrium prediction*, and individuals under the low penalty (XRL) extracted in average 3.317 units *below the Nash prediction* of 6 units, and approximately 2 units below the average extraction during stage 1.

[6] Thanks to the anonymous reviewer for bringing this issue up.

[7] While XRH players should expect a cost of \$175(1/5) = \$35 per unit of extraction above $X = 1$, players under the XRL treatment would face an expected penalty of only \$50(1/5) = \$10 from their earnings.

[8] 32 sessions × 5 people × 10 rounds.

Why such a small difference? A closer look at the data might help our understanding of behavior. Recall that for the case of the groups under the external regulation we explicitly announced the social optimum solution of $X=1$ unit, while the groups under communication were not given such information, although they were able endogenously to realize such norm. The following Fig. 2 shows the distribution of choices for all 10 rounds in the second stage, including the distribution for the baseline treatment during the same rounds.

The distributions are quite similar, and knowing that there was not a significant change over time during the second stage, as shown in Fig. 1, the aggregation of the 10 rounds provides a clear picture of the distribution of strategies. What we observe is a fraction of more than 40% of decisions equivalent to the social optimum, regardless of the pecuniary incentives to free-ride vs. the expected monetary cost of a regulation in the case of XRL and XRH. The remaining fraction of choices were distributed across the range of extraction, with approximately 30% choosing between 2 and 3 units of extraction -still close to a group oriented cooperative strategy, and a small fraction, maybe of 15% in levels of extraction according to the self-maximizing strategy. Thus, I would argue that a significant fraction of individuals were more responsive to the ‘norm’ of cooperation that was proposed externally than to the expected cost of the regulation. Some may debate on this and offer alternative explanations[9] such as a risk averse behavior on some individuals. Although it is difficult to test such hypothesis given that there are no measures at individual levels of risk aversion during the first stage to distinguish them from the rest of the group, it is interesting to note that assuming a random assignment of the fraction of more risk averse people in the XRL and XRH treatments, the effect of their behavior should have been stronger for the case of the higher penalties. However, the differences are very small.

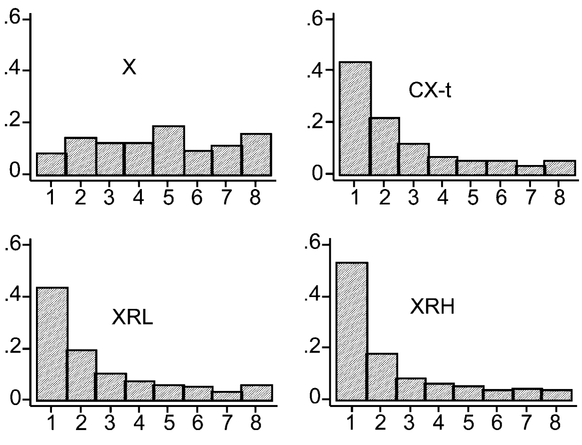

Fig. 2. Frequencies of individual decisions during stage 2 by treatment.

Furthermore, such group oriented response by a large fraction of players emerged in a very similar manner in the self-governed system based on the agreements that the different groups discussed. Basically, in all three cases a sufficiently high fraction of individuals followed the norm of only one unit extraction while a small fraction attempted the self-regarding strategy taking the risk of a pecuniary cost for the cases of XRL and XRH, or of a non-pecuniary cost (e.g. shame created by others in the following rounds) for the case of groups under communication.

4. Final discussion

The paper offers some lessons about the use of economic models to predict individual behavior by users of the goods and services from ecosystems, the use of experimental methods for enriching models, and even more so when brought to the field. In order to explore some, but not all, of the issues involved in governance of ecosystems, a simple microeconomic model was introduced to study the conflict between individual and group interests, and to study the effects of regulations with partial enforcement capacity. This model was applied to a series of economic experiments in the field and compared to the benchmarks of a social optimum and a Nash equilibrium based on self-regarding maximization of payoffs in a non-cooperative game setting. The experimental treatments, particularly of self-governing mechanisms vs. externally imposed regulations, offer some main lessons about governing from inside

[9] As suggested by an anonymous reviewer.

and from outside of the communities that use the local commons.

The possibility of these models replicating behavior of these individuals in their daily life when choosing the amounts of resources to extract such as water, firewood, fish or mussels needs to be considered with caution. Thus, a few words are worth mentioning regarding the external validity of these approaches. After the sessions were completed in a village, the research team invited the participants and other local people to discuss the preliminary results from the experiments with exactly this question in mind. It is the case that in virtually all villages our participants confirmed the similarities of the experience in the exercises and their daily decisions. Not much on the absolute values of resources, payoffs and trade-offs, during a short period of 20 decisions, but on the general conflict between the individual and the group interests, and on the marginal effects of introducing certain rules to change individual behavior, being these last two critical for inferring conclusions on the effects of different governing mechanisms for solving the dilemma.

The results suggest that we must pay more careful attention to the role that preferences play in human behavior when designing institutions, and also the capacity of individuals to device self-enforced mechanisms where trust and reciprocity create the possibility of reducing the probability of free-riding by others and therefore increase the personal material gains from cooperation. However, as Bendor and Mookherjee (1987) argue, when there are risks for collective action to fail because monitoring among group members is imperfect, the introduction of centralized mechanisms to control free-riding in the collective action situation might be desirable to combine the best of both centralized and decentralized worlds. Rossi and Warglien (2000) studied a similar situation in a Principal-Multi-Agent experiment where a boss (the principal) offers a share of the pie that a team of two workers (agents) have to produce through a game involving a prisoners dilemma. Their results show that as the share offered by the principal to the workers is smaller, higher rates of mutual defection occur among the agents and therefore a smaller pie is produced. Their results reject the Nash predictions that the Principal should not share with the two agents much of the pie produced, and that workers should not cooperate with one another. Further, fairness by the principal seems to induce cooperative behavior on the two agents. Fehr and Gachter (2000b), using a trust game setting with a Principal-Agent model of labor relations, provide evidence that when principals and agents face an incentive based contract to be enforced and which punishes defection, the voluntary rate of cooperation decreases as compared to games where no incentive contract is involved. The role that positive and negative reciprocity play in humans willingness to cooperate, these authors show, are critical in the design of incentives.

The compliance with a rule, even if externally generated, could be motivated by moral duties rather than to the calculations of an expected cost from non-compliance, at least at the levels of monitoring and penalties used in this study. Non-material costs that the participants may have included in their calculations, because of ex-post conditions in the game can be playing a role as discussed before. Thus, the design of instruments must pay more attention to non-pecuniary incentives and how social norms of behavior induced endogenously by groups or externally by formal institutions, can play an important role in economic decision-making. For instance, there is an increasing literature on the willingness of individuals to assume personal costs in order to punish anti social behavior even at inefficient levels but that could be interpreted as rational if one considers in the utility function a demand for punishment as discussed in Carpenter (2003) and reported also in experiments (Fehr and Gachter, 2000b). The participation of individuals in self-governed mechanisms that are seen as democratic and perceived as fair can contribute to maintain altruistic behavior (Fehr and Rockenbach, 2003) which one would assume to the case of any agreement emerging in the case of the face-to-face communication rounds as these were non-binding agreements due to the experimental design.

The policy implications that arise include the evaluation of the social costs of introducing external regulations that require monitoring and enforcing institutions and resources, against the resources that groups would endogenously have to provide to enforce their self-governing institutions. In the former case, once implemented, there are net transfer of resources flowing from the regulated group to the regulator when fines are eventually collected. In this case, there are net losses for the group while in the case of self-governed mechanisms, not only less financial resources are required, but the social costs assumed by the community can be assumed as contributing to other types of gains for the participants and the building and reinforcing of governance mechanisms that reduce social losses from opportunistic behavior.

Acknowledgements

Prepared for the 'INTERNATIONAL CONFERENCE ON ECONOMICS OF SUSTAINABLE FOREST MANAGEMENT' organized by the University of Toronto, May 2004. The author expresses his gratitude to a Research & Writing Grant from the John D. and Catherine T. Macarthur Foundation and a grant from the Network on Social Norms and Preferences headed by Herbert Gintis and Robert Boyd, for funding the field work, and to Ernst Fehr in particular who provided important insights for the experimental design; My gratitude also to the Santa Fe Institute for an International Fellowship and the School of Environmental and Rural Studies at Javeriana University (Colombia) during the time of the field work. Thanks to Maria Claudia Lopez, Pablo Ramos and Ana María Roldán for assistance in the field and in processing data. Diana Maya has provided important input and analysis of qualitative data. The guest editor and an anonymous referee provided excellent comments and helped improve this version greatly.

Appendix A. Payoffs table

Their effort extracting	My effort extracting									
Their total	1	2	3	4	5	6	7	8	Their total	Their avg
4	758	790	818	840	858	870	878	880	4	1
5	738	770	798	820	838	850	858	860	5	1
6	718	750	778	800	818	830	838	840	6	2
7	698	730	758	780	798	810	818	820	7	2
8	678	710	738	760	778	790	798	800	8	2
9	658	690	718	740	758	770	778	780	9	2
10	638	670	698	720	738	750	758	760	10	3
11	618	650	678	700	718	730	738	740	11	3
12	598	630	658	680	698	710	718	720	12	3
13	578	610	638	660	678	690	698	700	13	3
14	558	590	618	640	658	670	678	680	14	4
15	538	570	598	620	638	650	658	660	15	4
16	518	550	578	600	618	630	638	640	16	4
17	498	530	558	580	598	610	618	620	17	4
18	478	510	538	560	578	590	598	600	18	5
19	458	490	518	540	558	570	578	580	19	5
20	438	470	498	520	538	550	558	560	20	5
21	418	450	478	500	518	530	538	540	21	5
22	398	430	458	480	498	510	518	520	22	6
23	378	410	438	460	478	490	498	500	23	6
24	358	390	418	440	458	470	478	480	24	6
25	338	370	398	420	438	450	458	460	25	6
26	318	350	378	400	418	430	438	440	26	7
27	298	330	358	380	398	410	418	420	27	7
28	278	310	338	360	378	390	398	400	28	7
29	258	290	318	340	358	370	378	380	29	7
30	238	270	298	320	338	350	358	360	30	8
31	218	250	278	300	318	330	338	340	31	8
32	198	230	258	280	298	310	318	320	32	8

References

Bendor, J., Mookherjee, D., March 1987. Institutional structure and the logic of ongoing collective action. American Political Science Review 81 (1), 129–154.

Bowles, S., March 1998. Endogenous preferences: the cultural consequences of markets and other economic institutions. Journal of Economic Literature 36, 75–111.

Cardenas, J.C., Stranlund, J.K., Willis, C.E., October 2000. Local environmental control and institutional crowding-out. World Development 28 (10), 1719–1733.

Cardenas, J.C., 2003a. Real wealth and experimental cooperation: evidence from field experiments. Journal of Development Economics 70, 263–289 Elsevier Press.

Cardenas, J.C., 2003b. Bringing the Lab to the Field: More Than Changing Subjects Paper presented at the International Meeting of the Economic Science Association, Pittsburgh, June, 2003.

Carpenter, J. (2003) The demand for punishment. Mimeo, Department of Economics, Middlebury College.

Costanza, R., d'Arge R., de Groot R., Farber S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R.V., Paruelo J., Raskin R.G., Sutton P., van den Belt M. (1997). 'The value of the world's ecosystem services and natural capital'. Nature, 387, 15 May 1997.

Fehr, E., Gachter, S., Summer 2000. Fairness and retaliation: the economics of reciprocity. Journal of Economic Perspectives 14 (3), 159–181.

Fehr, E., Gachter, S., September 2000. Cooperation and punishment in public goods experiments. American Economic Review 90 (4), 980–994.

Fehr, E., Rockenbach, B. (2003) Detrimental effects of sanctions on human altruism, Nature, 422, 13 March 2003.

Fehr, E., Schmidt, D., 1999. A theory of fairness, competition, and cooperation. Quarterly Journal of Economics 114, 817–851.

Hardin, G., 1968. The tragedy of the commons. Science 162, 1245–1248.

Ledyard, J.O., 1995. Public goods: a survey of experimental research. In: Kagel, Roth (Eds.), Handbook of Experimental Economics. Princeton University Press.

Marwell, G., Ames, R., 1980. Experiments in the provision of public goods, II. Provision points, stakes, experience, and the free-rider problem. American Journal of Sociology 85 (4), 926–937.

Marwell, G., Ames, R.E., June 1981. Economists free ride, does anyone else?: experiments on the provision of public goods IV. Journal of Public Economics 15 (3), 295–310.

Ostrom, E., March 1998. A behavioral approach to the rational choice theory of collective action. American Political Science Review 92 (1), 1–22.

Ostrom, E., Gardner, R., Walker, J., 1994. Rules, Games and Common-Pool Resources. U.Michigan Press, Ann Arbor, pp. 1994.

Ostrom, E., T. Dietz, N. Dolsak, P.C. Stern, S. Stonich, E.U. Weber, (eds.) (2002) 'The Drama of the Commons'. Committee on the Human Dimensions of Global Change. National Academy Press. Washington.

Rossi, A., Warglien, M. (2000). 'An Experimental Investigation of Fairness and Reciprocal Behavior in a Simple Principal-Multiagent Relationship. Mimeo. 2000.