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HOW DO GROUPS SOLVE LOCAL COMMONS DILEMMAS? LESSONS FROM EXPERIMENTAL ECONOMICS IN THE FIELD

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Abstract. The use of experimental settings to observe human behaviour in a controlled environment of incentives, rules and institutions, has been widely used by the behavioural sciences for sometime now, particularly by psychology and economics. In most cases the subjects are college students recruited for one to two hour decision making exercises in which, depending on their choices, they earn cash averaging US$ 20. In such exercises players face a set of feasible actions, rules and incentives (payoffs) involving different forms of social exchange with other people, and that in most cases involve some kind of externalities with incomplete contracts, such as in the case of common-pool resources situations. Depending on the ecological and institutional settings, the resource users face a set of feasible levels of extraction, a set of rules regarding the control or monitoring of individual use, and sometimes ways of imposing material or non-material costs or rewards to those breaking or following the rules. We brought the experimental lab to the field and invited about two hundred users of natural resources in three Colombian rural villages to participate in such decision making exercises and through these and other research instruments we learned about the ways they solve - or fail to - tragedies of the commons with different social institutions. Further, bringing the lab to the field allowed us to explore some of the limitations of existing models about human behaviour and its consequences for designing policies for conserving ecosystems and improving social welfare.

Key words: co-operation, experimental economics, experiments, field experiments, collective action, common-pool resources, Colombia, reciprocity, trust, reputation, regulation, crowding-out, institutions, game theory.

Abbreviations: CPR - Common-Pool Resources.

1. Introduction

Technically, the question in the title is posed incorrectly, but with a purpose. Groups do not make decisions neither they solve problems. It are the individuals who make part of a group who solve or fail to solve problems through their individual actions. However, people use 'groups' or 'communities' as powerful devices and instances to design and enforce rules that solve the dilemmas they face. Individuals construct rules and norms for the groups they belong to, in order to solve the conflict between individual

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and social interests, and then they device ways of monitoring and enforcing them with various levels of success.

Belonging to a group means several things: it creates a sense of belonging, but it also creates the opportunity of free riding on the efforts and collective action achieved by the rest of the group. It means creating cohesion among a subset of people, but also means excluding outsiders of the benefits created by the co-operation emerging from such cohesion. It means accumulating key information about others in the group and build a history of their behaviour in the past (reputation building); which is key to trust others when contracts cannot be fully written and enforced, but also the reason to defect on them when their reputation forces one not to trust or co-operate.

Notice however that these implications of belonging to a group, can be easily associated to actual rural communities that use common-pool resources, and directly affect the way groups that use natural resources design their resource use and management rules. However, much of these issues are basically ignored or simplified in the arguments used by those arguing against community management of resources, e.g. Hardin's 'tragedy of the commons' (1968). Much of the arguments against a decentralised and self-governed solution predict that short-term sighted self-interested individuals would unconditionally over-extract a resource for which there is joint access, even if the users recognise that the aggregate outcome of such strategy is socially undesirable.

Since there is enough historical evidence that self-governance can emerge and be sustained (Ostrom 1990; Ostrom *et al.*, 1994; Berkes, 1989), and theoretical and experimental work are now exploring alternative models that also predict co-operation as an equilibrium (Axelrod, 1984; Ostrom, 2000), it should be worth exploring in more detail in the field why is it that a set of values, norms, and rules in a group can be designed, agreed upon and enforced endogenously, even if members have to bear a private cost, so that individuals shift their behaviour towards a collectively better outcome. In other words, it is now important to lower our analysis from the group to the individual level and explore the behavioural micro foundations of individuals that belong to a group and that face a dilemma such as using a CPR.

The approach here is to use the techniques of experimental economics (Smith, 1982, 1994) to observe in a more controlled setting how certain variables of the environment of incentives, or the institutions governing the behaviour of individuals affect the choices of people, and what the effects on the outcome at individual and group levels are. A very comprehensive survey of the literature on experiments that study the general problem of public goods (Ledyard, 1995) and where they include Common-Pool Resources as one type, concludes that there are strong evidences for both the arguments that people are willing to co-operate in these dilemmas, but also that people would free-ride on the co-operation of others, and that these opposite arguments ground their support on several weak and strong

variables that can be introduced in the lab that seem to explain the differences. For instance, when the interaction is repeated, or when face-to-face communication is allowed among the players, co-operation is more likely to emerge and be sustained despite the clear material incentives for free riding.

Furthermore, we brought the experimental lab from a university setting to the field and invited almost two hundred villagers to participate in different sets of experiments inspired, among others, on the CPR design by Ostrom *et al.*, (1994) which has become the baseline for experimental work on common-pool resources.

This chapter presents a subset of results from these experiments, regarding the general question of how people in groups attempt to solve commons dilemmas through self-governance, and how institutions surrounding the dilemma affect the effectiveness of such strategies. After presenting a general discussion of the problem, I illustrate the experimental design and the basic structure of the incentives that emulate a CPR or commons dilemma. The following section presents some of the relevant data regarding behaviour of the participants in the experiments and an analysis of some of the patterns and lessons that seemed to emerge regarding strategies to solve the dilemma by the different groups and under different institutions. The chapter closes with a set of conclusions at both the policy and the methodological level.

2. Research Context

An anecdote from the fieldwork may enrich the context. During the summer of 1998, at the exit of an experiment session in one of the three villages where the fieldwork was conducted, I informally interviewed a group of participants to a session where we wanted to compare the differences in behaviour when two different rules were introduced. A sub-set of groups were allowed to have an open and non-binding face-to-face conversation before each round of the game, while other groups, instead, faced an externally imposed regulation aimed at improving the level of individual co-operation through the imposition of an imperfectly enforced penalty on over-extraction of the commons. One of the participants mentioned how the game reminded her of a problem her father had in the past with his neighbour regarding the illegal shifting of their dividing fence during the nights. She described how her father never approached the authorities to denounce the problem, and rather got involved in several arguments and conversations with his neighbour until they figured out a solution. I asked why he did not approached the authorities, and she explained that even if he might obtain the just outcome of moving back the fence, and the neighbour to be found in violation of the law, he might have lost his neighbour forever.

The two neighbours now continue to talk to each other, and a probably better relation remains between them despite the impasse.

This story describes in several dimensions the policy and methodological lessons about commons dilemmas that this paper is about. Reciprocity, trust, information, repetition, are all concepts often ignored when designing policies to correct institutional failures arising from externalities. On the one hand, the role that external authorities can play in social exchange relations that involve non-anonymous and repeated interactions such as those in communities that use ecosystems or that face group externalities, has to be thought carefully. On the one hand, not all external interventions are costless and with perfect information, but in many cases may imply higher costs of enforcement than the social benefits they obtain. Further, such external interventions may transform the already existing system of informal rules and norms that constrain the behaviour of individuals in certain conflict situations, and thus transform the behaviour of individuals and outcomes in ways unpredicted and eventually socially sub optimal.

Methodologically, this story reflects one of the potentials of using this approach in the field as a participatory tool where researchers can generate processes of analysis by the participants and learn from their reinterpretation of their realities through the experimental design in which they participated. Much of the explanations and research hypotheses that were further tested with the experimental data were in fact derived from the collective discussions in community workshops conducted after some preliminary processing of the data from the sessions they participated in.

The mechanisms that people use through community governance to induce behaviours that better align the individual and collective interest are now being studied widely by different social sciences, and using methods that include deep case studies, statistical cross-section analysis of cases, theoretical modelling, agent-based simulations, and laboratory experiments. Keywords such as trust, reciprocity, reputation, altruism, bounded rationality, social capital, co-operation, all relate to these elements that emerge from belonging to a group and that if included in our models, can enrich the way we study the problem of managing the commons from a micro perspective.

Experimental economics has been applied widely for studying many of these issues, and in particular through the use of public goods and common-pool resource designs well surveyed by Ledyard (1995) and of which Ostrom *et al.* (1994) is of the most important and comprehensive studies on how groups show far richer behaviours and outcomes when facing a common-pool resource dilemma and a set of different institutions attempting to solve it. As a further extension, and given that so far most of the experimental economics evidence is based on using college students as subjects, I brought the economic laboratory to the field and invited actual users of CPRs to participate in these experiments, share their experiences and discuss the

results of the exercises they participated in. The lessons learned are reported in this chapter.

Within the context of a research collaboration between the Instituto Humboldt (Colombia) and the University of Massachusetts Amherst (USA), a group of faculty and fellows from both institutions designed during 1997 a strategy for training and research that included two workshops in Colombia during the summer periods of 1997 and 1998 where field practitioners and academicians from Colombia participated in a set of exercises applying novel tools from environmental economics, game theory and experimental economics to problems of conservation of biodiversity and other forest resources. During these workshops we pre-tested the tools that we later applied in the field, in three rural villages of Colombia for studying people's willingness to co-operate in conservation and the importance of different institutional arrangements for solving dilemmas of using ecosystems at sustainable rates.

In the first of the villages, Encino, located in the eastern Andean region, residents enter local tropical cloud forests to extract firewood, log timber on a small scale, and to hunt. Like all of the sites we visited, water for consumption and irrigation comes nearly untreated from local rivers. In the second case, in a basin between the villages of Circasia and Filandia in the Quindio coffee region in the mid-Andes the participants in our experiments were drawn specifically from a group of families whose livelihood is related to the extraction and processing of natural fibres from local forests. And thirdly, in Nuqui, located on the Pacific coast, villagers harvest coastal mangroves for firewood and other wood products, but their water comes from further inland, they face a similar dilemma because their exploitation of the mangroves for wood adversely affects coastal fish populations upon which they also depend. To sum up, the population from which the subjects for these experiments were drawn is of rural households that live in areas that depend heavily on local forests for wood products. In each location, exploitation of local forests affects another aspect of their livelihoods adversely: water quality in Encino and Quindio, and fish populations in Nuqui. Hence, the subjects face social dilemmas in their daily lives that are similar to the one we confront them with in the experiments. In each of the three settings, the participants generally knew each other well, having lived in the same village for most of their lives. Schooling, age and income levels varied significantly for the participants within each group. Most participants had fewer than 6 years of schooling, roughly half were between 30 and 50 years old, and all were 16 or older.

3. A Simple Household Model for Studying a CPR Dilemma

Most rural households derive their income and therefore much of their well-being from allocating their labour between different activities. In several

cases some of those activities involve the use of a resource from an ecosystem that on the one hand provides also other types of indirect use and non-use benefits (e.g. hydrological regulation, soil conservation) besides providing fibre, food or energy as direct uses; but on the other hand, many of these ecosystems present *de jure* or *de facto* property rights and enforcement rules that allow a group of users to extract from the same natural area.

We can describe such situation through a basic model of household's well-being as a function of using and benefiting from a nearby forest for which there is joint access to extract resources. In this model a household i's well-being depends on three arguments, namely, i) the negative group externality from the aggregate extraction of the forest (e.g. water quality externalities from deforestation), ii) its own extraction of resources from the forest which are either self-consumed or sold in the market, and iii) the income generated outside of the forest from the labour allocated in the next best alternative (e.g. wage labour, own land or others). Each of these components of income and well-being would ultimately depend on the allocation of i's effort (x_i) extracting resources from the commons, and the allocation of effort by the whole community of users ($\sum x_j$). Therefore, we can represent such well-being function as in equation [1]:

$$U_i(x_i, \sum x_j) = k[(q^o-(\sum x_j)^2/2) + (\gamma x_i - \phi\ (x_i)^2/2) + w_i \times (e-x_i)]^\eta \qquad [1]$$

where, x_i denotes the amount of time individual i spends collecting a resource (e.g. firewood) from the commons, and let w denote the prevailing wage for labour. Then, i's decision to provide $(e - x_i)$ units of labour to the formal sector yields a payoff of $w \times (e - x_i)$. Time spent collecting firewood from the forest yields a private benefit, which we assume takes the form $g(x_i) = \gamma\ x_i - \phi\ (x_i)^2\ /2$, where γ and ϕ are strictly positive and are chosen in part to guarantee $g(x_i) > 0$, for $x_i \in [0, e]$. The strict concavity of $g(x_i)$ indicates diminishing marginal private returns to time spent collecting firewood. And the group externality, e.g. the water quality, q as a quadratic function of the aggregate amount of time individuals in the community spend extracting resources, and expressed as $q(\sum x_j) = q^0 - (\sum x_j)^2\ /2$, where q^0 is interpreted to be water quality (or other biodiversity conservation benefits) in the absence of firewood extraction. Again these parameters are chosen in part to guarantee $q(\sum x_j) > 0$ for all feasible $\sum x_j$.

With such function, we assigned values to the parameters such that we could generate a payoffs structure clear enough that a social dilemma situation was created and therefore there was a conflict between the individual gains and the group gains. After the assignment of parameters, we created a payoffs table (see Appendix) which would be used to show the levels of payoffs for different combinations of extraction for one player and the aggregate. The cells inside the table are the net points of income as a function of the choice variable (time allocated exploiting the commons) and

the aggregate time allocated by the rest of the group also extracting it. In other words, the columns in the table are the choice variable (x_i), and the rows in the table are the sum of the other players in the group ($\sum x_{j,\ \text{where}\ j \neq i}$). Clearly from the table once can see that as i increases x_i her payoffs increase, but also as $\sum x_j$ increases i's payoffs decrease, emulating a social dilemma between individual and collective interests.

3.1. Experimental Design: the Basic Game and the Incentives

The basic experimental design used in the field presented people with the following simple decision problem. Every player of a group of eight people had a copy of the payoffs table (see Appendix) as the main decision making tool. Each player must choose in each of several rounds the 'months in the forest' as the decision to allocate time into extracting the resources from the commons, and represented in the table as the columns. The payoffs however depended on what the other seven players did (the rows in the table). The individual decision was always kept private and confidential, and only the sum of the eight decisions was announced publicly by the monitor in each round.

3.2. The Field Lab

All participants faced such decision for a first stage of several (between 7 and 10) rounds, and were never told of the exact last round to create an environment of more repetitive long term interactions. This way we created for the first stage an environment of a repeated non-co-operative game as a baseline. For the second stage we introduced a new rule in which the eight participants could have a 5 minutes open, non-binding, discussion about the game before each decision in the following 7-10 rounds. However, the individual decisions remained private and confidential. The following pictures show the set-up of our field lab in the two stages. In the first (Figure 1) we have a group of participants in the first stage making their decisions without any interactions with the rest of the group. In the second (Figure 2) a group is having a discussion right before making their next decision by turning to their own desks.

Each of the sessions lasted about 2 hours, including filling out an anonymous individual survey about their household, economic activity, and perceptions of several ecological and institutional problems. At the end of every session each participant was paid in cash according to his earnings. In average participants earned the equivalent of one to two minimum wage for one day of work. Also, a few days after the sessions in a village a community workshop was held to discuss with the participants the results of a preliminary analysis of the data.

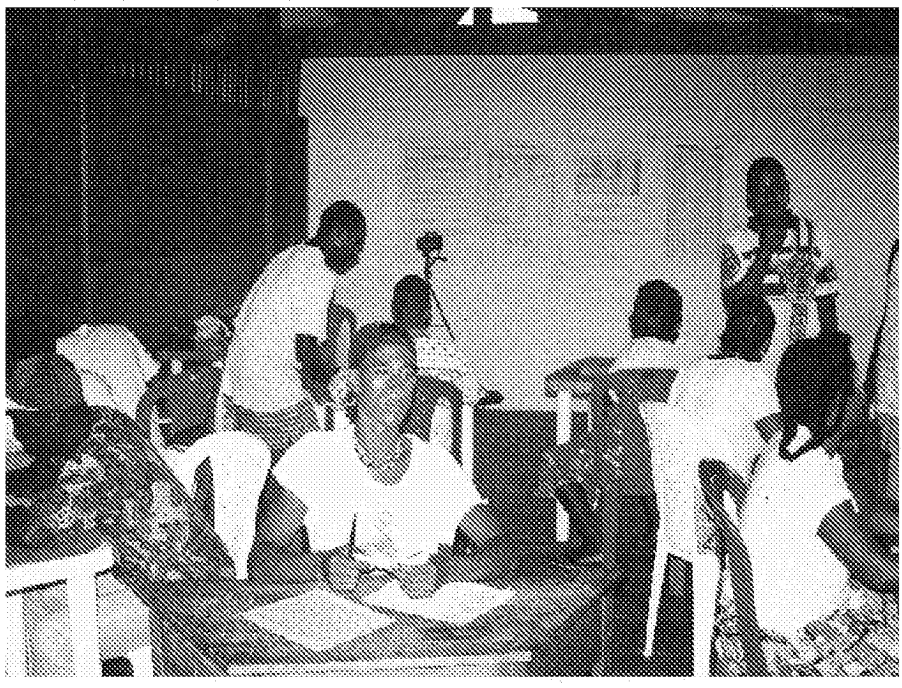

Figure 1. Group in stage 1 of the experiment where communication is not allowed.

Figure 2. Group discussion in stage 2 of the experiment.

3.3. INCENTIVES IN A NON-COOPERATIVE GAME SETTING (STAGE 1)

According to the payoffs from the table we can analyse in detail the incentives that each player would be facing in each round. Given that in terms of payoffs there is no carry-on effects from one round to the other, we can study the incentives for one round only as a non-co-operative game and therefore identify two key benchmarks for the analysis. There are, from a game theoretical point of view, two interesting solutions to the model described in equation (I). One, the social optimal, in which we maximise the aggregate points for the eight players as if they were a single decision making unit, and another in which each individual chooses a strategy in which she maximises her individual payoffs given what the other seven players do in the game, also called Nash equilibrium.

As in all commons dilemmas these two solutions to the problem do not coincide, and the latter implies a higher level of aggregate effort, and yields a lower payoffs for the group and individually, if we compare to the social optimal. It is straightforward from the payoffs table that when each chooses x_i=1 (i.e. $\sum x$=8) the group maximises earnings and each player can earn 645 points. However, notice what the incentives are for a specific player i when everyone else chooses x_i=1. Player i could earn, by choosing x_i=8, a much higher payoff, 891 points. If everyone then chooses the same reasoning, and there is no institution or rule that allows them to co-ordinate their actions, aggregate effort would increase up to the point where $\sum x$=48 (i.e. x_i=6). Such situation, a symmetric Nash equilibrium in game theoretical terms, would result from each individual maximising his own payoffs and assuming everyone else is doing likewise. At such point individual payoffs would only be 155 points and aggregate extraction of the commons would be much higher than in the social optimal solution.

Therefore, the challenge of an institutional arrangement would be to induce the each of the players to choose x=1, and achieve the maximum possible points for the group, given that each player has a clear incentive not to do so and free-ride on the co-operation of the others.

3.4. FACE-TO-FACE COMMUNICATION AS A CO-ORDINATING DEVICE (STAGE 2)

The second stage allows players to have an open conversation about the game. We are interested in learning from such conversations, and if they may have an effect on individual behaviour and group outcomes. However, it is not straightforward to predict the effect of such change in the rules. The notion of 'cheap talk' comes into play, given that for the second stage players do not face a change in the payoffs, and the communication rules do not change the feasible actions for the players nor they allow for any promise to transfer points after the game. Being non-binding, the communication would be innocuous here from the standpoint of the

conventional game theory and it would predict no change in behaviour by players after introducing the possibility of a conversation about the game. On the other hand, some may argue that other factors could play a role in creating an environment where the group outcomes matter also, besides the individual interest. Through a conversation, players can create conditions where co-operation is valued and free-riding is not, and they can point to the positive effects for everyone when the actions are co-ordinated, and point to the damages created by a player whose decisions are not aligned with the group interests. The field results in fact support the latter, and were consistent with similar experimental work in the lab (Ostrom *et al.*, 1994; Ledyard, 1995).

In fact most groups, if not all, after a few rounds of discussion in the second stage agreed that if each player chose a low level of 'months in the commons' they would all gain. Some groups rapidly identified that x=1 would create the first best solution to the problem. However, even if the conversation yielded an agreement that all players should choose x=1, the incentives not to do so and free ride instead remained.

Since we are including in the new stage the possible implications of the group agreement, let us think of this situation as a game where each individual plays against the 'rest of the group' and has the chance of co-operating and follow the agreement or to defect and increase x. In this game, the player has to make an assumption about the behaviour of the other seven players who can also co-operate or defect. The reason for this analytical simplification is to study the game from the standpoint of each player once an agreement has been decided in the discussion and each player has to make her private decision.

To simplify the analysis of the individual and group incentives, let us concentrate in the two benchmarks we have discussed and analyse them for second stage of the exercise. In the following 2x2 payoffs matrix we can model the decision that the row player i faces given what the rest of players could do in average (Table 1). The cells' values are the payoffs for player i and for the others' average respectively. Again, if all choose 1 month in the commons everyone would achieve a situation that is Pareto optimal and every player earns 645 points. If everyone chooses the symmetric Nash strategy (x= 6 months in the commons) group and individual earnings fall yielding a payoff of 155 points to each. However, for player i it is very clear that switching from x=1 to x=6, and assuming that the other seven players commit to the agreement, he could increase his payoffs from 645 to 836. Further, the other seven players' payoffs would be reduced only from 645 to 605 points, in the case that player i would care about the consequences of his actions to the others in his group. One more case deserves attention, namely the north-east cell, if compared to the Nash equilibrium where everyone chooses x=6. What would be the incentives for player i to unilaterally deviate from x=6 to x=1 if everyone else remains at x=6? Basically none, since i would see his payoffs reduced further from 155

to 135 and everyone else would gain by increasing theirs from 155 to 254. Notice then the difficulty of generating an institutional environment where players choose to co-operate and play x=1.

Table 1. The CPR dilemma as a 2x2 game.

		'Group's Avg' (Avg other 7 players)	
		X=1	X=6
Player i	X=1	(645 , 645)	(135 , 254)
	X=6	(836 , 605)	(155 , 155)

If we use the tools of game theory to analyse this game we would observe that given an agreement to co-operate and play x=1, player i's best response to such agreement is to play x=6 in either situation when the group's average is 1 or 6. Further, the other seven players as a decision making unit would still be better off by playing x=1, which would provide an extra incentive for player i to play such best response. The Nash equilibrium to such game would then be (x_i=6, and x_j=1 [where $j \neq i$]) and would be located in the south-west cell of the matrix. This equilibrium, again, assumes that the 'other seven players' act as a single decision making unit, and such assumption is supported mainly by the fact that the conversation induces a group oriented strategy in the group, and each player has the option of following it or not.

Notice however that such equilibrium is not socially optimal as the other seven players could be better off had they gained 645 instead of 605 points; and given that such gain (40 x 7) would compensate for the payoffs loss of 836-645=191 points by player i.

4. Field Experiments Results

As in most experimental evidence from the lab, the results from 10 groups (80 participants) who played in this Non-Communication/Communication design, the results show three major patterns. First, in the non-communication stage the individual behaviour does not approach in average the social optimal solution, neither they act as in the Nash strategy prediction. Second, there is a wide variation in the levels of social efficiency i.e. the actual gains as fraction of the group maximum at the social optimal, achieved across groups, as well as within groups. And third, the introduction of face-to-face communication does have a significant positive effect on individual behaviour and on group outcomes by inducing that in average players reduce their level of effort extracting the commons.

4.1. EXPERIMENTAL BEHAVIOUR

Tables 2 and 3 show the results for the ten groups by averaging the results for the last 3 rounds of each stage. For each group the Table shows the average X choice for the eight players, and the average payoffs earned at the end of each period. This table can illustrate the three points just made. The last row shows the average for all ten groups and one can observe that in average all groups improved their earnings. However a closer look at the groups clearly shows the variation and the effectiveness of the communication device in stage 2.

Table 2. Average individual choices (X) and avg. individual earnings (Y$) by period (Sorted by earnings at the end of communication).

Groups	Average last 3 rounds in each stage			
	End Stage 1 (rounds 6-8) (No communication)		End Stage 2 (rounds 17-19) (Communication)	
	X choice	Y$ earnings	X choice	Y$ earnings
CQS11	5,13	274,42	2,17	603
CQW41	3,04	527,75	2,88	547,17
CEW42	3,75	456,96	3,42	497,67
CES12	4,79	320,33	3,46	491,46
CNW41	5,42	244,67	3,42	490,5
CES11	3,88	441,08	3,67	467,5
CNS12	4,21	394,46	3,92	403,13
CNW42	4,79	319,58	4,33	383,88
CNS11	4,63	342,96	4,58	347,79
CEW41	4,19	402,13	5,75	187,63
All groups	4,383	372,434	3,76	441,973

Table 3. Changes in experimental social efficiency and actual economic context of participants.

Group	Social Efficiency (End of stage I)	Social Efficiency (End of stage II)	Change in Social Efficiency	% of players with extraction of resources as main occupation	% of players with land as main income source
CEW41	62.35%	29.09%	-33.26%	0.00%	87,50%
CEW42	70.85%	77.16%	6.31%	0.00%	75,00%
CES12	49.66%	76.20%	26.53%	0.00%	25,00%
CES11	68.39%	72.48%	4.10%	0.00%	50,00%
CNW42	49.55%	59.52%	9.97%	12.50%	25,00%
CNS12	61.16%	62.50%	1.34%	12.50%	37,50%
Avg 10 groups	57.74%	68.52%	10.78%	22.50%	37,50%
CNW41	37.93%	76.05%	38.11%	37.50%	25,00%
CNS11	53.17%	53.92%	0.75%	37.50%	50,00%
CQW41	81.82%	84.83%	3.01%	50.00%	0,00%
CQS11	42.55%	93.49%	50.94%	75.00%	0,00%
Coefficients of Correlation with % change in Social efficiency:				0,5732	-0,71560
(Pearson Correlation test) p-values:				0,0832	0,02000

4.2. CAN THE FIELD HELP SOLVE THE PUZZLES

The results above basically replicate most experiments using similar designs and where face-to-face communication is introduced. This provides some strength to the problem of internal validity of these methods when used in the field, but leaves open so far the same problem of why there is such wide variation across and within groups, despite the fact that the environment of rules and incentives is the same, and that the participants are chosen randomly from a population (in a village or in a university).

One of the reasons for bringing the lab to the field was to learn from the experiences of the participants when facing similar dilemmas in their actual life and environment. Not only through the participation in the experiment, but also through the participatory workshops we held, we could learn more about the factors that interact when groups of neighbours face a dilemma such as this.

One of the most interesting results from the interactive research with the participants was to observe how the familiarity they had with similar problems in the field was correlated with the way they attempted to solve the experiment's CPR dilemma, and how much they brought such information into the field lab. The more familiar the group was with problems of collective use of a mangrove, or extraction of firewood from a joint access forest or fishing, the more effective seemed to be the conversation between rounds. Since we had information about participants' economic activity, we tested statistically some of these possible relations. The following table illustrates the point being made. In this table we present for each of the ten groups the social efficiency achieved before and after communication was allowed, for the last three rounds in each stage. The I calculate the change in social efficiency from stage 1 to stage 2. The last two columns of the table show respectively the percentage of players in that group whose main economic occupation is extracting a natural resource, and the percentage of players whose main income source is working land (rented or owned). At the bottom I included the correlation coefficient with the Pearson test (p-value). The data show that groups composed of people more familiar with similar problems in reality gained proportionally more from the face-to-face discussion, and that groups composed of people more dependent economically on their own assets and private production, were less effective in the use of the group discussion.

We found other types of similar evidence that the actual context of the participants was associated with the behaviour and outcomes in the experiment. For instance, social distance and group inequality based on the economic wealth of the people in the group seemed to constrain the effectiveness of communication for this same sample of groups. Such relation is clear when one observes with detail the videotapes of several groups, and also was tested statistically with the data gathered by the experiment and the exit survey they filled (Cardenas, 2000a).

In another set of results from these experiments and reported elsewhere (Cardenas *et al.*, 2000) we also found key results that challenge the assumption that rules and regulations imposed from outside the communities will always produce the expected outcome even if well intentioned and aimed at producing a socially desirable outcome. In this subset of experiments we introduced a new rule, instead of allowing the groups to discuss, by which players should choose x=1 as the desired decision, and to enforce it we inspected in every round one of the eight players randomly. If the player did not comply with the rule, a penalty was imposed proportionally to the degree of non-compliance. With such expected cost to the well-being of each player, theory would predict a partial improvement away from the Nash equilibrium and towards the social optimal. However, the imposition of this regulation crowded-out the group oriented preferences that already existed before the rule, and promoted a more self-interested behaviour in the average player. As a result not only the groups in average achieved lower levels of social efficiency with the rule, but much lower levels than the efficiency achieved by the groups that were allowed to communicate.

5. The Lessons Learned

Elinor Ostrom's last decade of work has focused among other areas on the micro foundations of collective action, self-governance and CPR management institutions. This represents a step forward and a level down from her analysis of CPR institutions in her seminal book 'Governing the Commons'. Her work on experimental validation of theories about CPR dilemmas and her theoretical exploration of theories of collective action is opening a major area of work from the standpoint of the individual that belongs to a community and uses jointly with others a resource. Her presidential address to the APSA meeting (Ostrom, 1998) was a call for a new generation of models to explain collective action from the stand point of the rationality of individuals, and her recent paper in the Journal of Economic Perspectives (Ostrom, 2000) illuminates the path to respond to that call.

In her preface to the Spanish edition of 'Governing the Commons' recently published (Ostrom, 2000) she reflects on the previous ten years and summarises some of the key results from experimental evidence in the following manner: When users of a CPR are not allowed to communicate their individual behaviour will approach the predicted outcome by the conventional theory; When they can communicate, the collective results are substantially superior; When the payoffs are relatively low, face-to-face communication allows users to sustain levels of co-operation close to the social optimal; When payoffs are high enough, some users are tempted to break the agreements; the aggregate results are lower than those with lower payoffs; If given the opportunity to participate in costly monitoring and

the application of sanctions, users are willing to pay to punish defectors; When users discuss openly and agree on their own levels of extraction and their systems of sanctions, the level of non-compliance of agreements remains rather low and results approach the social optimal.

The micro foundations to understand why people in groups are willing to co-operate in a social dilemma like the use of a CPR, according to Ostrom (1998; 2000), can be studied through three key variables: *trust, reputation and reciprocity*, as the engines of co-operative behaviour.

These are powerful explanatory variables to why in average the participants to our field experiments were able to improve the individual and aggregate results via self-governance rules induced by the communication. However, the variation of the results is also related to the degrees of these three variables. Recall that for every group, the eight participants were members of the same community and therefore had a history of the others they were facing. The social closeness among participants could create higher levels of trust as they had a previous history of reputation of the others in a group. The economic dependence on activities based on using a CPR as compared to a private asset also affected the possibility of improving the group outcomes.

6. Conclusions

I have presented some of the results from the field experiments conducted in these three villages in Colombia. Other treatments and designs were also used but not reported here for space reasons. We also conducted a 600 household survey in the same villages and gathered information about people's willingness to pay and co-operate in undertaking different types of arrangements for managing their local commons (Cardenas, 2000b). The survey confirmed, using the conjoint analysis method, that rural people are willing to sacrifice individual income in order to maintain the capacity of ecosystems to provide multiple benefits, and that they value elements such as biodiversity and regulation of water as much as extractive benefits from these natural areas for which there is joint access.

The following list summarises the main lessons from the surveys and the set of experiments performed in the field during this study. Some results cannot be described in detail here due to space limitations, but are relevant to the question of this paper on how do people in groups solve these dilemmas.

- Users do recognise that ecosystems provide more than just short-term benefits from resource extraction, and value other indirect and non-use benefits. Further, they are willing to provide benefits to others outside the community, or to future generations as shown by the survey results.

- They use key tools of human behaviour for solving exchange with other humans, such as reciprocity (negative and positive), reputation, trust and fairness. The micro data from the experiments confirmed that in average players would reduce the 'months in the commons' if the average of the group reduced in the previous round, despite that the best response in terms of maximising payoffs would be the opposite. In the same manner, players in average increased extraction when the group in average had increased in the previous round. In the case of the household survey, respondents valued higher the scenarios where there was a higher fraction of respondents agreeing with co-operating with a specific project.
- They craft, through face-to-face communication, endogenous ways of enforcing rules and norms that align individual and collective interests, which sustain co-operation over rounds. The use of language and metaphors from their daily life and from similar dilemmas helped the groups to overcome the negative effects of not co-operating and also allowed them to identify and control free riders in their groups. The previous history they had of the others helped also to identify, despite that the experimental decisions were private, the most likely free riders.
- However, when confronted with external regulations, they can in fact deviate from a group oriented strategy and concentrate in an individually oriented behaviour, which affects social outcomes as predicted by conventional game-theoretical models. The negative reciprocity was greatly enhanced by this externally imposed institution as verified by the statistical analysis.
- They overcome certain limitations (e.g., asymmetries of payoffs and choices) by devising second-best solutions that increase social efficiency and equity despite the game theoretical prediction that called for an asymmetric solution.
- And when confronting a rather heterogeneous group in terms of wealth and social distance, they find it harder to implement and sustain mechanisms that increase social efficiency.

These results suggest at least three levels of implications. Theoretical, methodological and policy ones. In terms of contributing to the study of institutions that affect the use of natural resources by groups of users, I have shown how using tools from game theory and experimental economics, applied to the field, can complement the richness of participatory analysis of problems, and can provide a more tractable set of hypotheses and models.

Policy-making can also be enriched by loosening usually strong assumptions about people's behaviour regarding self-governance, free riding, and the use of instruments to solve dilemmas like these. The results from this study support once again that idea that the tragedy of the commons is not always the best prediction when a group has joint access to a resource; that people combine a series of information additional to the basic material benefits and costs of extracting the resource, such as certain shared norms

and values, and use mechanisms associated with the construction of social capital to govern their own dilemmas.

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Appendix. Payoffs table.

LOS MESES DE ELLOS EN EL BOSQUE	MIS MESES EN EL BOSQUE								
	0	1	2	3	4	5	6	7	8
0	619	670	719	767	813	856	896	933	967
1	619	669	717	764	809	851	890	926	959
2	617	667	714	760	804	845	883	918	950
3	615	664	711	756	798	838	875	909	940
4	613	660	706	750	792	831	867	900	929
5	609	656	701	744	784	822	857	889	917
6	605	651	695	737	776	813	847	877	905
7	600	645	688	729	767	803	836	865	891
8	595	638	680	720	757	792	824	852	877
9	588	631	672	711	747	780	811	838	862
10	581	623	663	700	735	768	797	823	846
11	573	614	653	689	723	755	783	808	830
12	565	605	642	678	711	741	768	792	813
13	556	594	631	665	697	726	752	775	795
14	546	583	619	652	683	711	736	758	776
15	536	572	606	638	668	695	719	739	757
16	525	560	593	624	653	678	701	721	737
17	513	547	579	609	636	661	683	701	717
18	501	534	565	594	620	643	664	681	696
19	488	520	550	578	603	625	645	661	674
20	475	506	535	561	585	606	625	640	653
21	461	491	519	544	567	587	605	619	630
22	447	476	502	527	548	567	584	597	608
23	433	460	485	509	529	547	563	575	585
24	418	444	468	490	510	527	541	553	561
25	402	428	451	472	490	506	520	530	538
26	387	411	433	453	470	485	498	507	514
27	371	394	415	434	450	464	476	484	490
28	355	377	396	414	430	443	453	461	466
29	338	359	378	395	409	421	431	438	442
30	322	341	359	375	389	400	409	415	418
31	305	324	341	355	368	378	386	392	394
32	288	306	322	336	347	357	364	368	371
33	272	288	303	316	327	335	341	345	347
34	255	270	284	296	306	314	319	323	324
35	238	253	266	277	286	293	297	300	300
36	221	235	247	257	265	272	276	278	278
37	205	218	229	238	245	251	254	256	255
38	189	200	211	219	226	231	233	234	233
39	173	184	193	201	206	211	213	213	212
40	157	167	175	182	188	191	193	193	191
41	142	151	159	165	169	172	174	173	171
42	127	135	142	148	152	154	155	154	152
43	113	120	126	131	134	136	137	136	133
44	99	106	111	115	118	119	119	118	115
45	86	92	96	100	102	103	103	101	99
46	73	78	82	86	87	88	88	86	83
47	61	66	69	72	73	74	73	71	68
48	51	54	57	59	60	61	60	58	55
49	40	44	46	48	49	48	47	45	43
50	31	34	36	37	38	37	36	34	32
51	23	25	27	28	28	28	27	25	23
52	16	18	19	20	20	19	18	17	15
53	10	12	12	13	13	12	11	10	8
54	6	7	7	7	7	7	6	5	4
55	2	3	3	3	3	3	2	2	1
56	0	1	1	1	1	1	0	0	0