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What do people bring into the game? Experiments in the field about cooperation in the commons

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Abstract

Experimental research has enhanced the knowledge acquired from theoretical and field sources of when and how groups can solve the problem of collective action through self-governing mechanisms. Widespread agreement exists that cooperation can happen, but little agreement as to how. As a first step, we propose that individuals may use three layers of information in deciding about their level of cooperation. The layers range from the material incentives of a specific production function and the dynamics of the game, to the composition of the group and the individual characteristics of the player. We use this framework to analyze data from a set of experiments conducted with actual ecosystem users in three rural villages of Colombia. Prior experience of the participants, their perception of external regulation, and the composition of the group, influence decisions to cooperate or defect in the experiment. Understanding the multiple information levels of a game as they affect incentives helps to explain decisions in collective-action dilemmas.

Keywords: Collective action; Cooperation; Experimental economics; Field experiments; Local ecosystems

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1. Introduction

The use of local ecosystems by human groups through different farming and extractive systems involves the resolution of collective-action problems due to (1) the nature of interactions between individuals and the ecosystem and (2) the nature of the institutions that govern the rights and duties of those affected by the goods and services provided by these ecosystems. Understanding how individuals within groups make decisions about using an ecosystem, and how self-governed solutions can emerge that enhance sustainable use, are both crucial to enhance policy analysis. The use of economic experiments for addressing these questions was initiated a decade ago (Ostrom et al., 1994). In this article, we take a further step and explore the possibilities of conducting these experiments in the field, with actual users of local ecosystems, in order to learn about their decision making in such settings.

Contemporary economic theory is one of the more successful, empirically verified, social science theories to explain human behaviour. It does best, however, in the settings for which it was developed – the exchange of private goods and services in an open, competitive market. When the goods involved are easily excludable, and individuals are interacting in a competitive market, theoretical predictions have strong empirical support. When the goods involved are not easy to exclude – public goods or common-pool resources, for example – empirical support for conventional theoretical predictions is much weaker (Camerer, 1997, 1998; Gintis, 2000). In a static setting, the conventional predictions are that individuals will not produce public goods and that they will overharvest common-pool resources. The evidence for both predictions is mixed (Ostrom, 1999).

In public good experiments, for example, instead of contributing nothing to the provision of a public good, as is predicted by neoclassical theory for individuals maximizing material payoffs, individuals tend to contribute between 40% and 60% of their experimentally-assigned assets in a one-shot game (Davis and Holt, 1993; Isaac and Walker, 1988b). In repeated games, the average level of contribution starts at around 50%. Without opportunities for communication, cooperation slowly decays toward the predicted zero level (Ledyard, 1995). With non-binding communication – cheap talk – subjects are able to sustain cooperation in public good experiments for long periods of time (Sally, 1995; Isaac and Walker, 1988a). Similarly, subjects in common-pool resource experiments approach near-optimal withdrawal levels when they are able to communicate, come to their own agreements, and use agreed-upon punishments if someone deviates from the agreement (Ostrom et al., 1994). Probably the clearest rejections of theoretical predictions have occurred in ultimatum and dictator experiments where first movers tend to offer second movers a far larger share of the bounty than predicted and where second movers (when given a chance) turn down offers that are not perceived, given the experimental conditions, as being fair (see Güth and Tietz, 1990; Roth, 1995).

Field studies also find that the theoretical prediction that users are trapped in inexorable tragedies (Hardin, 1968) are frequently not confirmed (Bromley et al., 1992; Ostrom, 1990), even though many examples exist of resources that have been destroyed through overuse. Attributes of resources and of participants have consistently been found to affect initial levels of organization (Gibson et al., 2000; Ostrom, 2001). Social scientists interested in human-resource dynamics face a major challenge to construct a behavioural theory of human behaviour that includes the classical economic model when applied to the exchange of private goods in full-information, market settings, but that assumes a wider range of motivations when individuals use resource systems that are non-private goods (Hirschmann, 1985). Given the number of variables involved, providing a framework for how they are interlinked is an important next step.

In this article, we take a small step in this direction. We speculate that understanding how individuals learn about and interpret the information potentially available to them in a particular situation is an important factor affecting their decisions. We thus offer a simple framework for studying how individuals gather information about the incentives of a situation, the context of the group in which they face the dilemma, as well as information about themselves. We posit that these layers of information are differentially invoked by the structure of a situation to inform the decision on whether to cooperate or defect when facing such options within a group immersed in a local commons problem.

We illustrate the usefulness of the framework to explain behaviour in a series of field experiments. Survey data collected from the participants after the completion of the experiments about their perceptions and values related to the layers of the framework enables us to explain a significant part of the variation in cooperation, as a function of variables associated with various levels of individual and group information in the game.

2. The layers of information that people bring into the game

Institutions as ‘‘rules of the game’’ transform key elements involved in the decision of an individual. Most of these elements enter the decision as information – or lack of it – about components of the game or other participants in the game. Individuals, by interacting with institutions, gather information by learning about others and their actions, and about the consequences of interacting within a specific set of rules.

Our framework, first proposed in Cárdenas (2000), combines inputs from Ostrom's (1998) behavioural model of collective action, from Bowles's (1998) arguments for a model of endogenous preferences, and from McCabe and Smith's (2003) cognitive model of social exchange (see Fig. 1). The arguments are associated with the specific kinds of information that are available to members from the same rural village who hold information about each other, and information about the context in which the social interactions happen in the experiment or in their daily decision making about resource use.

Ostrom (1998, 2000) argues that studying the context of a game is crucial because institutions affect individuals' decisions to cooperate by performing at least three key

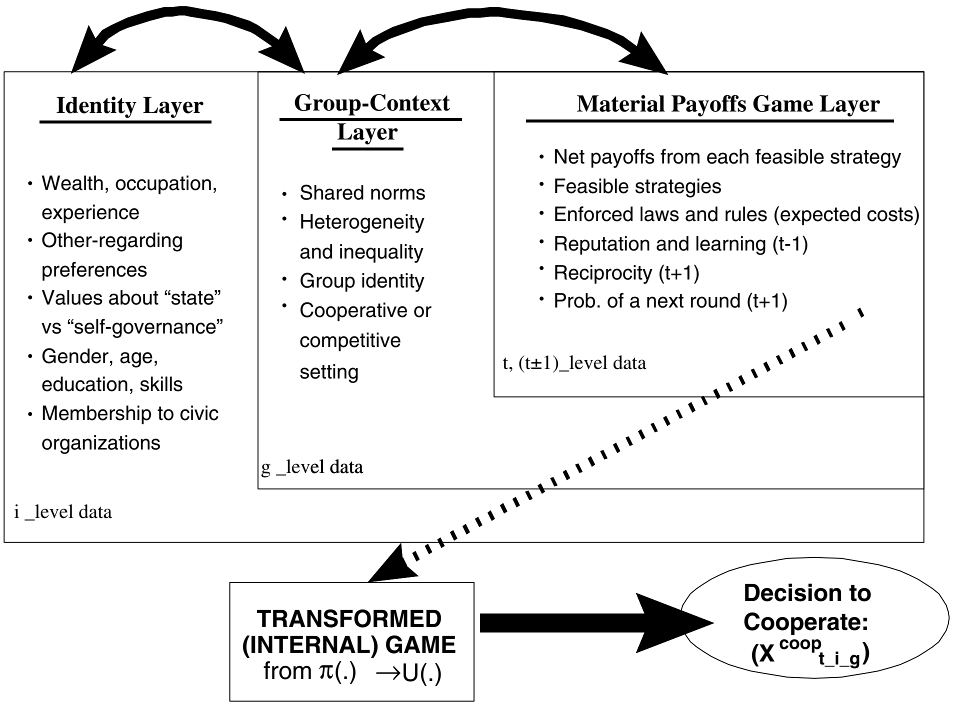

Fig. 1. Framework for the analysis of the levels of information for deciding to cooperate.

tasks. First, institutions reinforce social norms that are consistent with the rules. Second, they allow participants to gather more or less information about the behaviour of others. And third, they entitle people to reward and punish certain behaviours with material and non-material incentives.

The framework organizes the kinds of information that individuals may use in deciding whether to cooperate or defect in a collective-action problem. As a starting point, let us assume that an individual is facing a game with the characteristics of a particular collective-action dilemma. If all individuals playing the game only take into account their own net benefits when choosing their contributions, and take others' contributions as given, the game we have constructed has a material payoff structure where the unique Nash equilibrium strategy is for each individual to defect (the Nash equilibrium being the set of each individuals' contribution such that no individual has an incentive to change his or her contribution when others' contributions remain unchanged). On the other hand, all individuals could be made better off if each and every individual contributed and achieved at universal cooperation; this latter solution is referred to as the Pareto-optimal solution. In experimental games, it is frequently observed that a significant fraction of individuals (roughly half) start cooperating in these experiments (Ledyard, 1995). Arguments explaining this observation range from presuming a lack of learning and understanding of the game to inherited altruistic preferences of humans. The assumption that individuals engage in reciprocity is also offered as an explanation in repeated games. Information enables players to decide whether to trust the others in the group and cooperate, once they are aware that cooperation can achieve a superior outcome.

The framework we propose classifies the pieces of information that the players gather to explain how players may transform the material payoffs of an externally-defined game into an internal game. These data can be ordered in three layers of information, namely, the material payoffs game layer, the group-context layer, and the identity layer. We argue that players use these layers of information as sources for responding to basic questions. In regard to the material payoffs game, they want to know: What payoffs can I obtain from my actions and those of others in this game?, and What can happen in future rounds of this game? In regard to the group-context layer, they want to know: can the others in my group be trusted? In regard to the identity layer, they ask: do I care if I defect, cooperate, or compete?

Our framework implies that individuals try to gather and evaluate information about these three layers, depending on the game structure. Once the game involves repetition, non-anonymity, and externalities among players, net individual and group gains may be achieved from gathering additional information, even if costly, to construct a new internal game. The transformed game will then have a different set of payoffs, a different set of preferred strategies, and eventually, in light of the change of behaviour over time, a different set of Nash strategies. Depending on the initial distribution of intrinsic preferences and the information revealed, social dilemma games may be transformed into other games, such as an assurance game, with less conflict between individual and collective interest.

Given these possibilities, let us now look at the layers of information proposed in the framework.

2.1. The material payoffs game layer

In the first layer of information, the player observes the structure of material payoffs and feasible strategies for a one-shot game. The set of actions and payoffs will produce possible Nash equilibria, some of which may be more socially desirable than others. The valuation of the game at this layer is affected by common knowledge of the set of formal rules that are effectively enforced and that impose material costs or benefits on each decision. Therefore, the perceived game drawing on this information is in fact the one resulting after applying those formal rules and the material rewards, penalties, or restrictions that are fully enforced. Once the enforcement of rules suffers from any kind of transaction or enforcement costs, the other layers of information enter into play to affect the actual response to a certain formal but partially enforced rule.

Further, most social exchange relations of the collective-action type in the field involve a non-zero probability of facing the same counterparts in future rounds of the game. Axelrod's (1984) argument of cooperation emerging from self-oriented maximizers was based on such grounds. The likelihood that the same players meet in future rounds creates several effects in the dynamic game. Since players can learn and have memory, they can build a reputation and build a history of the reputation built by others. McCabe and Smith (2003), in their cognitive model, suggest a set of modules, one of which involves the process of goodwill accounting. Since the strategy of tit-for-tat produces strong results in the long run against most other strategies, the information that can be gathered about past rounds and the probability of future ones with the same players creates the conditions that are conducive for cooperation through reciprocity, including retaliation towards non-cooperators as a group selection mechanism. It is well recognized that in public good experiments with no possibilities for communication among players, contributions decrease over rounds. Players that start cooperating, but observe others free-riding, decrease their cooperation. This phenomenon of crowding-out of cooperative behaviour (see Cárdenas et al., 2000 for more details) will play a crucial role in the empirical results we present below. It may also explain why one observes cases in the field where initial cooperative efforts fail after a period of time because cooperators, frustrated by the initial free-riding of others, switch to non-cooperative behaviour. The argument behind the crowding-out hypothesis is that the intrinsic motivations (see Frey and Jegen, 2001, for a survey) can be crowded out by explicit incentives such as rewards or punishments; people's intrinsic motivations to engage for collective benefit may be redirected when explicit monetary incentives are introduced.

The time frame is also important. Isaac et al. (1994) explored extending the number of rounds in a linear public goods game from 10 to 40 and 60 rounds and show how, in 10 rounds, the percentage of contributions falls from 50% to less than 10%. When the game was run over 40 rounds, by the 10th round the percentage of contributions was 40% and fell to less than 10% only by the 40th round. When extended to 60 rounds, the same pattern happens: the percentage of contributions was 30% at round 40 and around 10% at round 60. This pattern would be consistent with the behavioural model of the rational actor of Ostrom (1998) where longer time horizons can contribute to the virtuous cycle of reciprocity, trust, and reputation that sustain cooperation.

2.2. The group-context layer

A second information layer is proposed that is based on the notion that a player's decisions are also influenced by recognizing specifically who the other players are in the transaction. Knowing who the others in a game are may trigger the possibility that the same players will meet in a future round of the game. The possibility of reciprocity and retaliation processes affects future outcomes. Second, an individual's own set of preferences may include caring for the well-being of certain others (relatives, friends, or neighbours), and knowing who is involved affects their valuation for the payoffs going to others.

For repeated games, evolutionary models, where the gains from cooperating or defecting may be affected by the frequency of cooperators and defectors in the group (Bowles, 1998), also provide grounds for this argument. The information a player has about the composition of the group will determine if there is sufficient trust among those involved to choose to cooperate for mutual gains. Thus, depending on the fraction of trustworthy and opportunistic types observed in a group, the player will have a better estimate of the likelihood of cooperation by others and therefore of the gains and costs of doing likewise.

Empirical evidence supports this. Group identity, group cohesion, and social distance have been shown to affect the likelihood that individuals cooperate. Lawler and Yoon (1996), for instance, show in a series of experiments how the level and equality of power among players increased the frequency of mutual agreements. Kollock (1998) provides data from a set of prisoner's dilemma experiments studying how group identity has a direct effect on cooperative behaviour. The behaviour of college students changed depending on the information they received about the other players (being from the same fraternity, from any other fraternity, from the same campus, from another campus, from the police department). Significant changes in behaviour were found to be consistent with the existence of strong in-group/out-group effects (see Orbell et al., 1988). Other non-experimental evidence might also support how group composition and context may determine cooperation. Alesina and La Ferrara (1999) show evidence from US survey data that the participation of individuals in social organizations and activities is higher for more equal and less fragmented localities in terms of race or ethnicity.

Accounting for the particular major of the student participating has also been a focus of attention. Early experiments in the 1980s asked whether economics majors showed higher levels of free-riding, with moderately strong results (Marwell and Ames, 1981; Isaac et al., 1985; reported in Ledyard, 1995). More recently, Cadsby and Maynes (1998) reported that nurses showed higher levels of cooperation than economics and business students in a threshold public goods game. These results would also be consistent with the work by Frank et al. (1993) on the behaviour of economics majors being closer to game-theoretical predictions. In another interesting study, Ockenfels and Weinmann (1999) found that East German participants behaved less cooperatively than West German ones in both public goods (10 rounds, 5-person) and solidarity (one-shot, 3-person) games.

We are not claiming that groups that are homogeneous and closed to their outside environment are always or, more frequently, prone to cooperation. Many other factors in the structure of the collective-action problem, and their relative position within that structure, can affect their willingness to cooperate. Further, different types of heterogeneity may foster collective action, meaning the homogeneity $\rightarrow$ cooperation relationship does not always hold. Some evidence indicates that groups that are closer to markets, and less homogeneous in race or cultural identity, can in fact show high levels of trust and cooperative behaviour. Our experiments suggest that heterogeneity in wealth and social position within a group imposes a barrier to finding self-governed solutions to the cooperation dilemma (see also Cárdenas, 2003).

Certainly, a long history of lack of cooperation within a homogeneous group can also impose a considerable barrier to future cooperation. Unfortunately, time frames of experiments are too limited to study such long-term processes.

2.3. The identity layer

In this third layer, the players store and process information about their own selves that may affect subjective payoffs and thus strategies chosen. Values internal to the player will increase or decrease the subjective payoffs from cooperating or defecting because of the existence of other-regarding or process-related preferences. This information is not necessarily invoked by a particular game. The information is already available. It is used depending on the externalities involved in the game. In the case of transactions under perfectly competitive markets where no externalities are involved, it is unlikely that the player will use this layer.

Positing this layer is consistent with Sen's (1977) rejection of egoism and opportunism as the *only* rationalities possible for humans. His discussion of behaviours based on sympathy – which is still based on an egoist rationality – may help to explain why we observe non-negative voluntary contributions in public goods. Also, inherently human traits such as reciprocal fairness (Fehr and Tyran, 1997; Kahneman et al., 1986) create behaviour that goes against the opportunist prediction. Falk et al. (2002) explore behaviour in the commons based on the theoretical model proposed by Fehr and Schmidt (1999). They include individual preferences based on reciprocity and fairness to explain the levels of cooperation in experiments where communication and informal sanctioning are introduced (see also Crawford and Ostrom, 1995). In their model, an individual's utility increases with material payoffs, but decreases with the level of disadvantageous or advantageous inequality in outcomes.

This identity layer is also quite important when imperfect information exists about the material game. The framing of the problem can induce the player to bring elements from prior experiences into the game. Games with the exact same objective structures produce different behaviour depending on the framing (Hoffman et al., 1996, 1999). Institutions in field settings can induce different preferences in the way that they frame a social exchange situation.

The two-way arrows above the layers in Fig. 1 suggest that cross-effects between layers might play a role as well. The conditions of one layer may reinforce or diminish the effect of another layer. Sally (2001) has proposed a formal model to introduce the concept of sympathy as a key to determining the willingness to cooperate by a player. He defines sympathy as the "fellow-feeling person i has for person j" and models it as a function of both the physical and psychological distances between i and j. His approach, using our framework, combines the last two layers in the sense that it involves information both about self and about the others when playing the game. In fact, Sally differentiates sympathy from altruism. He uses a reciprocity argument for the former, since persons will reduce their fellow-feeling for another when they feel they are being taken advantage of. In general, the importance of cross-effects among the factors that determine cooperation has been understudied, particularly in experiments.

2.4. Hypotheses about decision making using this framework

If the arguments presented above are valid, we could further explore why substantial differences are observed in behaviour, under the same experimental design, when comparing different cultures. For example, Henrich (2000) and Henrich et al. (2001) report on a series of ultimatum, public goods, and dictator games from field experiments with 15 small-scale societies in 12 countries. The behaviour under the same objective game varied with the culture of the group as well as with results obtained in experimental laboratories using American undergraduate students.

Individuals decide to gather information or not from added layers beyond the basic game layer depending on the overall structure of the game, including the payoffs, the feasible strategies, the other players, and the norms and rules that are shared by such groups. Bringing this information to the game depends on the ease and cost of gathering it. If players do not know who the others are in a group involved in a social dilemma transaction, the group-context layer is useless for them, unless this is inexpensive information to gather. If the player does not assume multiple rounds of the same game with the same players, there is no need to think about multiple time periods and implications related to reciprocity. In fact, Bowles suggests that "the more the experimental situation approximates a competitive (and complete contracts) market with anonymous buyers and sellers, the less other-regarding behaviour will be observed" (1998, p. 89).

A player might want to bring information from other layers into the game in cases where a transaction involves some kind of externality or interdependency not corrected in the basic game through enforceable rules and material incentives, and which usually affects the well-being of others in the group. A second reason for the player to search for information in other layers is the existence of asymmetric information and the costliness of writing and enforcing contracts. Many social exchange transactions involve some kind of private information that gives the player the possibility of deriving extra rents from the transaction. In common-pool resources, it would be very costly for other users or authorities to know the individual levels of appropriation that decrease the availability of the resource to others.

In summary, we suggest that when the game involves externalities and there are problems of asymmetric information among players, they will search for additional information from one or more of the three layers and use these to create an internalized vision of the game. Some will be more likely to cooperate because of this information, while others will be more likely to defect. The internal game values will be affected by their perception of self (identity layer), the information they gather about the other players (group-context layer), and the dynamic game conditions. The basic structure of the game in the static game layer alone will not provide the complete picture, but players may try to complement it with the other layers of information if they can.

3. Empirical evidence from field laboratories

The second and third layers – group-context and identity – are especially related to the kind of variables that are difficult to control in the regular experimental laboratory, as Ledyard (1995) pointed out. Experimenters usually try to downplay the importance of culture, beliefs, group identity, social context, and personal identity in their designed experiments. The importance of these factors in forming the context of the basic game gives support for the approach presented here, i.e., to bring the experimental laboratory to the field and enrich the analysis identified as important but difficult in the experimental literature.

An adaptation of the initial common-pool resource experimental design (Ostrom et al., 1994) was brought to three Colombian villages. All three rural communities had joint access to a resource and the respective groups all faced a common-pool resource dilemma. In one case, the shared ecosystem was a mangrove forest where they extracted mollusks, firewood, and fisheries. In another case, villagers extracted fibres from nearby forests for handcrafting activities and firewood, which affected the state of the forest and the conservation of water supply in the watershed. In the third case, the villagers obtained wild meat from hunting and firewood from the local forests. In all three cases, the forests were either state or private reserves, but exclusion was difficult because of weak state enforcement mechanisms and political conflict. In another study (Cárdenas, 2001), using part of the data reported here, it is shown how the actual experience (measured through labour allocated to the actual extraction of these resources) explains variation in cooperation in the experiments. Below we will explore how this and other factors associated with the individual, group, and village context can play a role in explaining experimental behaviour. Eventually, if the results are externally valid, this will increase our understanding of individual behaviour in collective-action situations.

Let us now focus on the experimental design. Fifteen sessions (groups), with eight people each, were conducted within the same basic design where players had to choose an individual level of effort represented by the "number of months" of extracting resources from a forest.

The baseline design of the field experiment is as follows. Participants were told that they would participate in a group of eight people in the same room, in a game where they had to choose privately the number of times (e.g., months per year) they would go to a forest to extract a resource (e.g., firewood). Their earnings from such a decision would depend not only on their individual extraction but also on the extraction levels that the other members of their group made in that round.

Participants could know the earnings in a round by looking at a payoff table where the columns represented the player's choice of "months in the forest", from 0 to 8 units; the rows of the table represented the sum of "months in the forest" by the other seven players of the group. The cells in the table had the monetary payoffs for such combination of one's choice and the sum of choices of the others in that group. The payoff function was constructed in such a manner that we created a typical common-pool resource dilemma where individual extractions increased personal gains, but aggregate extractions decreased everyone's gains. In each round, each player would learn from the experimenter the total extraction level by all eight players. From this, each could calculate their earnings by using the payoffs table. Detailed instructions (translation) and the payoffs table are contained in an earlier version of the paper (Cárdenas and Ostrom, 2004) or can be downloaded from http://isis.uniandes.edu.co/~jccarden.

The data used here consist of a set of common-pool resource experiments conducted in the summer of 1998, where roughly 180 *campesinos* participated in a series of repeated-rounds sessions under different treatments. We asked each participant to fill out a survey at the end of each session – information that we were able to link to their decisions in the field laboratory for the analysis of individual and group contexts.

The framing of the decision making was such that each participant had to decide how to allocate from zero to eight months for the purpose of extracting resources from a forest; as noted above, each participant's earnings increased with their own time in the forest, but decreased with the group's total time in the forest. The key payoff benchmarks were, first, the social optimum, where every player harvests from the forest for only one month, yielding Col$645 (US$0.50) in each round; and second, the Nash equilibrium, where everyone would harvest for six months yielding a suboptimal result of Col$155 (US$0.12) per round, i.e., around 24% of the maximum social efficiency possible. For 18 rounds, each participant would earn around Col$2790 (about US$2.15) if they followed the symmetric Nash equilibrium strategy. If all participants played the social optimum strategy, however, each could earn Col$11,610 (about US$8.90). [1] The daily minimum wage was around US$5.40 at the time for all three villages. Depending on the treatment, our participants each earned somewhere between US$5 and $7 for their participation, which was paid at the end of each session, in person and confidentially. They also received a show-up fee represented in certain items for their household with an average value of around US$2. Under these incentives, we expected participants to be compensated for their opportunity cost of coming to the sessions, which took about half a day total for each participant.

All 15 groups of eight people in the sample participated in a no-communication treatment for nine rounds, at which point they were told that a new set of rules was to be introduced in the game. Five of these groups, which we will label REG, were told after the first stage ended that an *external regulation* would attempt to improve the group's earnings, while the other 10 groups, which we will label COM, were allowed to have a *face-to-face group discussion* before each round to comment openly about the game developments. Each group, therefore, went through a no-communication stage to a single new treatment institution, but no group had to face both communication and regulation.

In the case of the external regulation design, the participants were informed *before* beginning the new stage that playing one month in the forest would yield payoffs at the social optimum and that to achieve such an outcome, an inspector (the

[1] The exchange rate at the time, 1998, was of Col.$1300 per US$.

monitor) would randomly audit players in every round with an individual probability of 1/16 of being inspected. If the player had chosen two or more months in the forest, he or she would have a penalty of Col$100 (about US$0.08) imposed for every unit in excess that would be subtracted from the final earnings. Those under the communication treatment were never told of the group optimum solution.

For purposes of the analysis of these experiments, we calculated the individual deviation from the predicted Nash strategy as a proxy for cooperation, and show its evolution for both treatments and the two stages in Fig. 2. During the first stage, behaviour in both the REG and COM designs is very similar, as expected, therefore lending support to the idea that the substantial differences in stage 2 can be attributed to the changes in the rules (external regulation versus face-to-face communication).

The difference in outcomes during the second stage of the experiment cannot be explained by the monetary payoffs alone. In the case of external regulation, the expected cost of violating the rules was intended to induce a partial improvement of social efficiency. An improvement did, in fact, happen in the early rounds after external regulation was introduced, but it gradually vanished. Selfish behaviour, along with an imperfect monitoring, created *more* overharvesting, even when compared to the rounds *prior* to the introduction of the rule. See Cárdenas et al. (2000) for further discussion of such regulations.

In the case of the groups under face-to-face communication, we found the results consistent with the earlier evidence in a university experimental laboratory (Ostrom et al., 1994). Despite being non-binding, face-to-face communication did create and sustain more cooperative behaviour in the average player, thus increasing social effi-

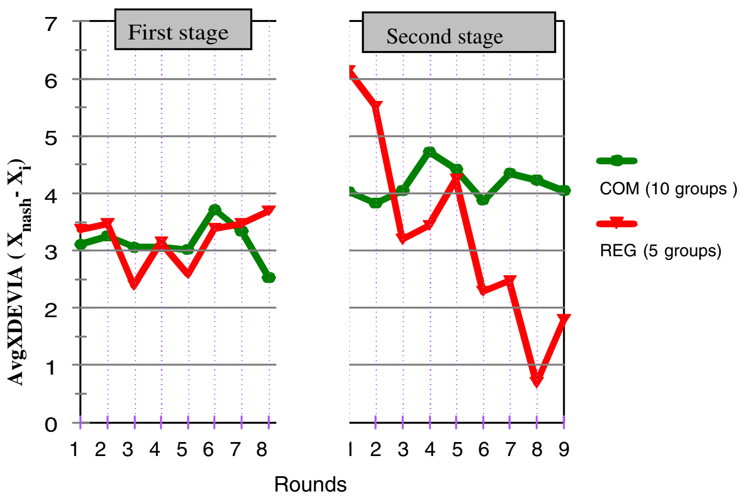

Fig. 2. Average deviations from individual Nash best-responses.

ciency. However, a wide variation in decisions across individuals deserves further exploration.

The survey at the end of the sessions included information about basic demographic variables such as gender, age, education; economic activities, assets, and occupation; as well as personal opinions about the role of government and community governance structures. In order to test for the combined effects of some of the factors discussed in the layers of the model, we used a regression analysis model in which we attempted to explain the individual level of cooperation in each round as a function of vectors of variables from all the layers, making use of the round-level data from the experiment, the individual-level data we gathered about the participants, and the construction of group-level data for each of the eight player groups. Thus, each observation in the regression corresponds to the decision by one player in a specific round of the game.

As the dependent variable of this multivariate analysis, we have again chosen to measure the degree of deviation from the predicted Nash strategy for each player as our measure of cooperation. We calculate this deviation, XDEVIA, as the difference between the Nash best-response for each level of aggregate extraction and the actual choice in that round; the closer the actual extraction to the Nash best response, the lower the degree of cooperation. Notice that the estimation of XDEVIA depends on the sum of months by the rest of the group, which each player did not know with certainty. We tested the estimations with two options yielding equivalent results: one using the sum of months in the same round, and one using the sum of months in the previous round.

The independent variables for the estimation were:

DELTAVG7: Change (average reduction) in "months in the forest" by the other seven players in the group, and calculated as the (Σ months by the other seven players in $(t-1) - \Sigma$ months in t), measuring the average intentions to cooperate by the rest of the group from the previous round.

ROUND: Round number. Accounts for the learning or adaptation processes in each treatment.

FINELAG: Fine in the previous round. The value of the variable is the size of the fine ($\$100 \times (X_{i,t-1} - 1)$) for those actually monitored, and it takes the value zero for those that were not monitored, in the previous round.

AVCOOPLB: Average number of days in non-paid labour contributed during last year by the group members: a proxy of "cooperative" behaviour in community projects. Survey based.

HHWEALT2: Player's household actual wealth based on land, livestock, and machinery holdings, valued at local prices and adjusted across villages. Survey based.

WLTHDS2A: Wealth distance, the absolute value of the difference between the player's wealth and the average of other seven player's wealth. Survey based.

WLT_DIS2: Cross-effect variable = HHWEALT2 × WLTHDS2A. Accounts for differences in the marginal effect of wealth distance for different social (wealth) classes.

BESTATE: A dummy variable, equal to 1 if individual believes that a "State" organization should manage the local commons from where they extract resources, and 0 otherwise. Survey based.

PARTORGS: Number of community organizations the player belongs to, such as school parents' association, cooperatives, and water committees. Survey based.

The sample size is in each case the number of decisions made during a set of rounds in a stage – starting at round 2 to allow for the dynamic effects – for all eight players and for all the groups under each treatment. Few observations showed missing data on the survey responses.

Table 1 summarizes the results of applying the estimation model using a simple "group fixed effects" estimator with an ordinary least squares procedure, to address the problem of independence of observations within groups. Individual fixed effects could not be used because of the sample size. Dummies for each of the groups were included in each estimation but not reported here.

The summary table of the estimated models is organized for each of the two stages: Stage 1 included data for rounds 2–9, where all fifteen groups faced the same baseline treatment. In Stage 2 (rounds 12–19), 10 groups (COM) had a face-to-face group discussion, while five groups (REG) faced the externally imposed and imperfectly monitored regulation.

The estimation results reflect how the layers of information of our framework explain part of the variation in decisions aside from the material incentives of the game within treatments. Recall that each group of eight people consisted of members of the same village. Therefore, a prior history existed of experience, reputation, and beliefs that could determine their willingness to cooperate with the other seven in their group.

With respect to the first level, where we account for the static and dynamic effects of the material payoffs game, we observe that reciprocity, expressed in the positive and significant sign of DELTAVG7, is confirmed for both treatments, COM and REG and across stages. A reduction (increase) in extraction by other players is followed by a reduction (increase) in one's own extraction. The effect is slightly stronger (negative reciprocity) in the regulation treatment, as a result of players being more responsive to average increases by the rest in the group. Negative reciprocity, caused by the external regulation, is what seems to crowd out the intrinsic motivation not to choose their best Nash response that seemed to exist prior to the introduction of the external rule. The slightly larger coefficient for DELTAVG7 in the second stage for REG shows that in this case each player was, on average, increasing their deviation from the Nash best response (in "months in the forest") by 0.37 units for each unit change in the average of the rest of the group. Notice the magnitude of the ROUND coefficient in the regulation treatment, compared with the COM groups with weak and insignificant results, suggesting how the COM institution sustained cooperation

Table 1
Fixed-effects with OLS estimation to explain deviations from the Nash selfish strategy as a function of the layers of information in Fig. 1. *P*-values for Ho: coefficient = 0 under coefficients

Dependent variable: deviation from the Nash strategy – a measure of cooperation	Variable	Stage 1: rounds (2–9)	Stage 2: rounds (12–19)	
Label		No-COMREG	COM	REG
Material payoffs game				
Intercept	INTERCEP	4.5314	7.1965	13.4518
		0.000	*0.000*	*0.000*
Average reduction by other seven players	DELTAVG7	0.3916	0.2472	0.3710
		0.000	*0.002*	*0.014*
Learning	ROUND	0.0015	−0.0549	−0.4233
		0.965	*0.102*	*0.000*
Fine in previous round	FINELAG	–	–	−0.0001
				0.935
Group-context layer				
Average labour contributions by group	AVCOOPLB	0.0401	0.0838	−0.1497
		0.488	*0.200*	*0.054*
Wealth distance	WLTHDS2A	0.1154	−1.6521	−1.8326
		0.712	*0.000*	*0.001*
Wealth × wealth distance	WLT_DIS2	−0.051	0.5371	0.5630
		0.963	*0.000*	*0.005*
Identity layer				
Individual's wealth	HHWEALT2	−.0784	−1.0181	−0.5625
		0.710	*0.000*	*0.117*
1 if "State should solve problem"	BESTATE	0.0612	−1.1979	0.5301
		0.762	*0.000*	*0.087*
Number of organizations participates in	PARTORGS	−0.1391	−0.1646	−0.7158
		0.133	*0.110*	*0.000*
Fixed effects (number of dummies)		15 groups	10 groups	5 groups
Sample size	N	856	677	340
R2 adjusted	ADJR2	10.64%	18.67%	49.45%
F-test *(p-value)*		6.09 *($p < 0.0001$)*	10.70 *($p < 0.0001$)*	28.47 *($p < 0.0001$)*

over time, other things held constant. These results strongly reject the free-riding hypothesis where the *i*th player should increase extraction as a best response to others decreasing it.

Laury and Holt (in press), focusing on the decay or sustained rate of cooperation in public good experiments, test a non-linear setting similar to our experimental design of a common-pool resource, and like us they observe that the rate of cooperation in the base line treatment (first 10 rounds) was constant – hence the zero coefficient for ROUND during this first stage. Other literature could also explain the rates of cooperation based on variables other than reciprocity, e.g., risk sharing and altruism (Fafchamps and Lund, 2003). It is certainly a major factor that gift-giving among members plays a fundamental role in the maintaining of social networks and the provision of public goods they provide. Our model here, however, does not technically reflect cooperative actions as gifts since this is not a zero-sum game. Choosing to reduce the number of months can produce higher private and group payoffs if others in the group cooperate. The significant and positive sign for DELTAVG7 confirms that players were responding reciprocally to the average extraction of the group regardless of the treatment, and not necessarily that they were altruistic in their decisions.

The result of the coefficient FINELAG deserves some attention, as it is statistically insignificant and close to zero. Players who were fined in the previous round were not responsive to such an incentive in the following period when compared with those not monitored. A close look at the data for those actually monitored shows no special pattern of increase or decrease in their extraction in the next round. Some players increased their extraction, perhaps perceiving a smaller chance of being monitored, while others did reduce their extraction. Recall, however, that these same players were on average responsive to the mean extraction of their group members in the previous round. This illustrates the weak effect of external regulation and the stronger effect of reciprocity.

AVCOOPLB measures the average level of actual labour contributions by the eight group members to community projects and is used as a proxy for the history of cooperation they may have with others in their group. Only during the second stage did this variable show a negative coefficient (p-value = 0.054) in the case of the REG groups, suggesting that a greater number of individuals in the group with a history of contributing to community projects was associated with smaller deviations from the Nash strategy in the experiment. No significant results were observed for this variable in the COM sessions, although it had a small positive sign consistent with the argument.

On the other hand, those players with higher levels of actual wealth (HHWEALT2) and wider wealth distance to the other players in the group (WLTHDS2A) seemed less willing to cooperate. This is consistent with the findings of Sally (2001), who suggests that sympathy – a key factor in cooperation – is a direct inverse function of physical and psychological distance between a person and others. The explanations emerge from a combination of "experience" in similar situations and the context of the group in which each player participates, particularly in terms of social distance. Thus, more homogeneous groups, and those whose players depend more on similar collective-action situations because of material poverty, show significantly higher levels of average cooperation.

Notice that BESTATE has opposite signs for the COM and REG data-sets, as in the case of AVCOOPLB, suggesting that under the external regulation, "state believers" will proportionally comply *more* with the rule, but cooperate *less* under the group communication environment. In the meantime, notice that for PARTORGS the signs are negative in both cases, which would be counterintuitive. However, its sign is larger and significant for the REG environment, which would be consistent with the effect of BESTATE and AVCOOPLB. Those that join community organizations seem to be less prone to comply with the externally-imposed rule in the experiment. Other demographic variables for the individuals showed no results that were significantly better estimators than these, including the individual value for labour contributed to projects (i.e., the individual value of AVCOOBLB).

It is worth adding some comments on the fact that during the first rounds of the game, except for the reciprocity DELTAVG7 variable, no other variable shows any relevance in explaining variation in behaviour, although the overall model has explanatory power ($p < 0.001$). It seems that the institution of no communication in the first stage (they were in fact sitting facing outwards in a circle) and the necessary learning in the early rounds to understand the structure of the incentives, did not allow players to use the other information about the group-context.

4. Conclusions

We have tested the proposed framework of the layers of information (material incentives, group-context, and individual characteristics) that people may use when facing these games through a common-pool resource experiment in the field, and have used information not only about the experiment incentives but also about the actual context and personal information of the players. A possible transformation of material payoffs into an internal subjective game through the use of information about themselves, their group members, and the incentives of the repeated game may induce cooperative behaviour as a rational strategy in a collective-action setting. Depending on the context and game individuals face, and whether the game is ongoing, if group communication is possible, and whether the others and their attributes are known to the players, players may use information from these layers to inform their decisions.

The field experiments we report on here allowed the subjects to use information from their own context and for researchers to examine the impact of this information on decisions. We found positive support for the arguments derived from our framework. It does appear that individuals may use diverse layers of information depending on the structure of a game and the context within which they are playing that game.

The use of experimental methods was enriched by having taken the laboratory into the field and invited actual users of natural resources to participate. This methodological approach, combined with survey data about the demographic and socioeconomic conditions of each particular participant and their group, has allowed us to enrich the experimental information and therefore to help explain the variation in cooperation levels across the same experimental design.

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