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Centralized and Decentralized Management of Local Common Pool Resources in the Developing World: Experimental Evidence from Fishing Communities in Colombia

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CENTRALIZED AND DECENTRALIZED MANAGEMENT OF LOCAL COMMON POOL RESOURCES IN THE DEVELOPING WORLD: EXPERIMENTAL EVIDENCE FROM FISHING COMMUNITIES IN COLOMBIA

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This article uses experimental data to test for a complementary relationship between formal regulations imposed on a community to conserve a local natural resource and nonbinding verbal agreements to do the same. Our experiments were conducted in the field in three regions of Colombia. Our results suggest that the hypothesis of a complementary relationship between communication and external regulation is supported for some combinations of regions and regulations but cannot be supported in general. We conclude that the determination of whether formal regulations and informal communication are complementary must be made on a community-by-community basis. (*JEL* C93, H41, Q20, Q28)

I. INTRODUCTION

In this article, we report the results of a series of common pool resource experiments conducted in three regions of Colombia that depend on small-scale fishing. Our field experiments were designed to investigate whether regulations imposed on a community to conserve a local natural resource complement nonbinding verbal agreements within a community to do the same in the sense that a combination of formal regulations and informal community agreements leads to greater conservation of a shared local resource than community efforts alone.

A large literature of experimental research from different disciplines has demonstrated the positive welfare effects of simply allowing subjects to communicate with each other in common pool resource settings.[1] Communication can be effective because it allows participants to (1) share information about the nature of the game, its incentives, and decisions that maximize group payoffs; (2) coordinate their actions and send signals about intentions; (3) express displeasure about undesirable or unacceptable outcomes; (4) reduce social distance among group members; and (5) punish uncooperative behavior, for example, by agreeing not to cooperate in future periods if total group harvest exceeds some threshold.

A smaller literature has looked at the effects of external regulations—fixed quotas with

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1. For recent reviews of the effects of communication in social dilemma experiments, see Shankar and Pavitt (2002) and Cardenas, Ahn, and Ostrom (2004).

ABBREVIATIONS

INCODER: Instituto Colombiano de Desarrollo Rural
WWF: World Wildlife Fund

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some exogenous enforcement apparatus—on behavior in experimental common property games. This literature suggests that regulatory controls on the use of common pool resources may not be as effective as one would hope. Ostmann (1998) finds that external regulation and enforcement financed by experiment participants only reduce harvests by a small amount relative to a regulation-free environment. Beckenkamp and Ostmann (1999) report that middle levels of sanction lead to a reduction in the exploitation of a common property resource, but higher sanctions can cause overuse because subjects may perceive the high sanction to be unfair. Cardenas, Stranlund, and Willis (2000) found that a quota supported by weak enforcement is effective in initial rounds, but as subjects realize the weak consequences of noncompliance, the effectiveness of the regulation quickly erodes. Ostrom (2000) discusses how enforcement of externally imposed rules may crowd out endogenous cooperative behavior, because it may discourage the formation of social norms to solve the dilemma, and at the same time may encourage players to cheat the system.

However, little research has been done to investigate the effects of allowing subjects to communicate under an external regulation in common pool resource experiments. We are motivated to pursue this line of inquiry because of our interest in the relationship between informal community efforts to conserve common property resources in the developing world and formal regulatory controls to do the same. Villagers in communities like those we visited typically interact and cooperate with each other on a variety of community issues. Thus, when examining the effects of external regulation on local natural resource use, it is unreasonable to expect that regulations would simply replace nonbinding agreements among community members. Even under government regulations, community members are likely to interact with each other and develop informal norms of behavior. The question that this article addresses is whether these informal norms and formal regulations are complementary institutions for conserving local common pool resources.

Whether communication and regulations are complementary has important implications for judging the effectiveness of government interventions in local common pool resource problems. Evaluating the performance of an intervention must be done in comparison to the performance of existing community conservation efforts and with the recognition that community members will likely continue to pursue informal norms of behavior when the regulation is in place. Moreover, since regulatory interventions are costly, they are only justified in locales where the regulations will complement existing community efforts.[2]

The same processes that make communication effective in the absence of regulatory controls may also serve to complement, and be complemented by, formal regulations. For example, communication can serve as a mechanism to socialize information about the efficiency-enhancing goals of a regulation and the formal consequences of noncompliance with the regulation. Similarly, a regulation can complement cooperative community efforts if it provides a signal of efficient individual behavior that can serve as a focal point for community interactions. Moreover, group communication and the enforcement of a formal regulation can provide complementary consequences for overexploiting the resource. That is, communication can support a weak enforcement apparatus by bringing social pressure to bear on individuals to achieve more efficient outcomes, and regulatory enforcement provides an explicit sanction for noncompliance that may be necessary to support informal verbal agreements.[3]

On the other hand, we recognize that certain kinds of group interactions could lead

2. Bischoff (2007) is the only other study of which we are aware that combines communication and regulation in common pool experiments. Bischoff's study differs from ours in several ways, but the most important difference is that he did not examine whether communication and regulations performed better than communication alone. In fact, he finds that external regulation with communication induced a greater level of cooperation than external regulation alone. Although this result is potentially important in some settings, it does not provide the comparison between communication under a regulation and communication alone that we feel is the most relevant comparison for evaluating the performance of regulatory interventions in local common pool resource problems.

3. Baland and Platteau (1996) provide a conceptual discussion of potential complementarities between formal and informal institutions for managing common pool resources in developing countries. They suggest that such complementarities between government and user groups or communities can be exploited in comanagement arrangements. Also see Bowles and Gintis (2002) and Bowles (2003).

to worse outcomes. It is possible that community members may implicitly transfer responsibility for resource management to the external authority. For example, group discussions may lead to a consensus that group members are in a game against the government, thereby shifting the focus away from the benefits of voluntarily coordinating actions. More specifically, communication could lead to a focus on the weak consequences of noncompliance with a regulation instead of reinforcing its welfare-enhancing objective.

We test for complementarities between formal regulations and informal nonbinding communication with a series of common pool resource experiments conducted in three geographically distinct fishing areas of Colombia. Although villagers in each of these areas depend heavily on the local fishery, these areas are different along several dimensions (which we discuss briefly in Section II). Rather than using a neutral frame, our experiments were explicitly concerned with extraction decisions from a common pool fishery.[4] Thus, our experimental design avoids the problem that individuals in different communities may approach a "neutral" or "decontextualized" experiment in different ways.[5] Each group of five subjects first played ten rounds of a baseline limited-access common pool resource game (without communication or regulation) and then ten additional rounds under one of five institutions: face-to-face communication alone, one of two external regulations alone, and communication combined with each of the two regulations. The two external regulations consist of an individual harvest quota that was set at the level that maximizes a group's payoff but differ with respect to the level of enforcement. In both cases, the level of enforcement was chosen to be rather weak because this is typical of regulatory control of natural resources in the developing world. We conducted the full set of experiments in each area to determine whether the results we obtained in one region were replicable in the others.

We find no statistically significant differences in individual harvest decisions across the regions in the first-stage limited-access game but significant regional variation in responses to the second-stage institutions. This suggests that the differences in responses to the second-stage institutions we observe cannot be due to regional variation in how subjects responded to the fundamental common property problem; rather, these differences must be due solely to variation in responses to the alternative institutions.

In all cases, the second-stage institutions were effective in reducing harvests from the limited-access baseline. Thus, if we were to judge the performance of each of the regulations with respect to the limited-access baseline, we would conclude that they were effective in each region although not equally so. Again, however, the appropriate comparison is between regulation combined with communication and communication alone, and a regulation can only be justified if it complements nonbinding communication. Our results suggest that the hypothesis of a complementary relationship between communication and external regulation is supported for some combinations of regions and regulations but cannot be supported in general. We find that external regulation complements group communication in three of the six possible cases. In two cases, regulation and communication together led to harvest decisions that were no different from those under communication alone. In the remaining case, regulation combined with communication actually led to greater harvests than communication alone, suggesting that the regulation crowded out cooperative efforts to conserve the resource.

II. EXPERIMENTAL DESIGN

Our experiments are based on the standard problem of individual harvests from a common pool resource by n identical individuals. We use a static model similar to that presented by Ostrom, Gardner, and Walker (1994), Falk, Fehr, and Fischbacher (2002), and an earlier model developed by Cornes and Sandler (1983). Individual i harvests y_i units

4. Within their recent taxonomy of field experiments, Harrison and List (2004) would classify our experiments as *framed field experiments* because they were conducted with a population of subjects for which the phenomenon of interest (behavior in a common pool fishery) is also an important element of the subjects' experiences.

5. See the Henrich et al. (2005) experiments across 15 small societies and the comments by Vernon Smith, Randolph Grace, and Simon Kemp (among others) in the same volume. The commentators questioned the neutral frame of these experiments because it could have been understood in different ways across the societies. Hence, the reported behavioral differences across societies could have been the result of different interpretations of the game instead of particular behavioral patterns in each society.

up to a capacity constraint $y_i^{\max}$. Units of harvest sell at a constant price p. The individual's harvest costs are $c(y_i + y_{-i}) + dy_i(y_i + y_{-i})$, where $y_{-i} = \sum_{j \neq i} y_j$ and c and d are positive constants. The individual has an endowment e_i. Thus, individual payoffs are

$$\pi_i = e_i + py_i - c(y_i + y_{-i}) - dy_i(y_i + y_{-i}), \quad \text{subject to } 0 \leq y_i \leq y_i^{\max}. \tag{1}$$

Maximizing π_i with respect to y_i yields i's Nash best-response function:

$$y_i(y_{-i}) = \min[(p - c - dy_{-i})/2d, y_i^{\max}], \tag{2}$$

provided that $p - c - dy_{-i} > 0$ for all feasible y_{-i}.

It is well known that pure Nash strategies result in inefficiently high harvest levels. A government authority that imposes and enforces an individual harvest quota could address this inefficiency. In this framework, inducing compliance is largely a matter of finding the correct expected penalty to reduce harvest levels to the efficient quota. However, this approach ignores other factors that may also explain individual compliance decisions. Of particular importance to us is how communication may work to support individual compliance with a formal regulation. Moreover, individuals may respond to the frame that a regulation provides, that is, that the quota provides a signal of efficient harvests, and the expected penalty signals that deviations from the quota may be punished.

Subjects were placed in groups of five and participated in a 20-period common pool resource game that was framed as a harvest decision from a shared fishery.[6] Each subject received an identical payoff table that was generated from a simple modification of Equation (1). The concept of zero harvest is very difficult to explain in the field because the participants depend so critically on their use of local natural resources. Therefore, individual harvest choices were shifted by 1 to range from 1 to 9. Accordingly, we modified Equation (1) by defining $\hat{y}_i = y_i - 1$ and created the individual payoff table from $\pi_i = e_i + p\hat{y}_i - c(\hat{y}_i + \hat{y}_{-i}) - d\hat{y}_i(\hat{y}_i + \hat{y}_{-i})$, with parameters $p = 116.875$, $c = 17.875$, $d = 2.75$, and $e_i = 900$.[7] The resulting payoff table used in the experiments is shown in Table 1. With these values, the standard symmetric Nash equilibrium is achieved when each individual chooses $y_i = 7$, while the group payoff-maximizing individual harvest is 2 units. In addition to deciding upon a level of extraction, y_i, in each round, subjects were also asked to state their expectation of the total extraction by the other four group members, $y_{-i}^e = \sum_{j \neq i} y_j^e \in [4, 36]$.[8]

Each group played a first stage with ten rounds of a typical common pool resource game without communication or external regulation (Limited Access); the second stage consisted of ten additional rounds under one of the following institutions:

face-to-face communication (Communication);

external regulation with a low penalty (Low Penalty);

external regulation with a medium penalty (Medium Penalty);

face-to-face communication with a low penalty and external regulation (Low Penalty/Communication);

face-to-face communication with a medium penalty and external regulation (Medium Penalty/Communication).

Each of the five treatments was repeated 12 times, with four groups in each of the three regions. In the three treatments that allowed communication, participants were free to discuss anything related to the experiment prior to making their harvest decisions privately in each round. For the four treatments that involved an external regulation, an individual harvest quota of 2 units (the efficient individual harvest) was imposed. To enforce the quota, each subject faced an audit probability of 10%.[9] If an inspection revealed that a

6. Assignment to groups was not completely random. We tried to ensure that relatives were in separate groups.

7. Experiment instructions are available upon request.

8. In a public goods experiment, Croson (2007) also asked subjects about their expectations about the choices of the other group members. However, she compensated them for more accurate predictions. In our experiments, subjects' earnings were based solely on their choices and not affected by their predictions of others' choices. Other studies that use the expectations about other group members' behavior include Bornstein and Ben-Yossef (1994), Komorita, Parks, and Hulbert (1992), and Yamagishi and Sato (1986).

9. To decide who in a group, if anyone, was inspected in a particular round, a ballot was chosen from a bag containing five ballots with the participants' numbers on them and five other blank ballots.

TABLE 1
Earnings Table

Level of Extraction of Others	My Level of Extraction									Average of the Others
	1	2	3	4	5	6	7	8	9	
4	900	996	1,087	1,172	1,252	1,326	1,395	1,458	1,516	1.0
5	882	976	1,064	1,146	1,223	1,295	1,361	1,421	1,476	1.3
6	864	955	1,040	1,120	1,194	1,263	1,326	1,384	1,436	1.5
7	846	934	1,017	1,094	1,165	1,231	1,292	1,347	1,396	1.8
8	829	914	994	1,068	1,137	1,200	1,258	1,310	1,357	2.0
9	811	893	970	1,042	1,108	1,168	1,223	1,273	1,317	2.3
10	793	873	947	1,016	1,079	1,137	1,189	1,236	1,277	2.5
11	775	852	923	989	1,050	1,105	1,154	1,198	1,237	2.8
12	757	831	900	963	1,021	1,073	1,120	1,161	1,197	3.0
13	739	811	877	937	992	1,042	1,086	1,124	1,157	3.3
14	721	790	853	911	963	1,010	1,051	1,087	1,117	3.5
15	703	769	830	885	934	978	1,017	1,050	1,077	3.8
16	686	749	807	859	906	947	983	1,013	1,038	4.0
17	668	728	783	833	877	915	948	976	998	4.3
18	650	708	760	807	848	884	914	939	958	4.5
19	632	687	736	780	819	852	879	901	918	4.8
20	614	666	713	754	790	820	845	864	878	5.0
21	596	646	690	728	761	789	811	827	838	5.3
22	578	625	666	702	732	757	776	790	798	5.5
23	560	604	643	676	703	725	742	753	758	5.8
24	543	584	620	650	675	694	708	716	719	6.0
25	525	563	596	624	646	662	673	679	679	6.3
26	507	543	573	598	617	631	639	642	639	6.5
27	489	522	549	571	588	599	604	604	599	6.8
28	471	501	526	545	559	567	570	567	559	7.0
29	453	481	503	519	530	536	536	530	519	7.3
30	435	460	479	493	501	504	501	493	479	7.5
31	417	439	456	467	472	472	467	456	439	7.8
32	400	419	433	441	444	441	433	419	400	8.0
33	382	398	409	415	415	409	398	382	360	8.3
34	364	378	386	389	386	378	364	345	320	8.5
35	346	357	362	362	357	346	329	307	280	8.8
36	328	336	339	336	328	314	295	270	240	9.0

subject's harvest exceeded 2, then that person incurred a financial penalty; the results of inspections were not made public. We examine two regulations that differ only in the level of the unit penalty for discovered harvests that exceeded the quota. For the Low Penalty and Low Penalty/Communication treatments, the penalty was 27 pesos per unit above the quota. We chose this penalty because the resulting expected marginal penalty is not high enough to change the pure Nash strategy equilibrium from the baseline Limited Access equilibrium of 7 units for each individual. Nevertheless, such a regulation might serve to reduce individual harvests because of the frame the regulation places on the experiment, in particular the signal of efficient choices and that deviations from the quota will be sanctioned. For the Medium Penalty and Medium Penalty/Communication treatments, the unit penalty was 165 pesos. The Nash strategy equilibrium with this penalty is 6 units for each individual. We chose enforcement strategies that were rather weak, at least under a conventional theory of regulatory enforcement, because this is likely to be a characteristic of

TABLE 2
Summary Statistics of Subject Characteristics[a]

Subject Characteristics	*N*	Caribbean	*N*	Magdalena	*N*	Pacific
Mean age (yr)	100	35.6	100	42.4	98	42.3
Mean years of formal education	97	6.3	100	4.7	93	4.7
Percent male	100	55%	100	83%	100	89%
Percent who have lived in the same community for 10 yr or more	100	78%	100	93%	98	95%
Percent for whom fishing is their main activity	90	69%	98	87%	98	94%

[a]*N* refers to the number of responses. There were 100 participants in each of the three regions.

most regulatory controls of resource use in the developing world.

In each round, subjects were asked to choose a harvest level. After all subjects made these decisions, the monitor collected this information and announced to the group the aggregate level of harvest for that round. With this information, individuals were able to calculate their individual payoffs from the level of total harvest by the others. Individual earnings ranged between 11,220 and 22,900 pesos, with an average of 15,240 pesos (about US$6.00 in 2004).[10] Earnings were paid in cash at the end of each experiment. Each experiment lasted about 3 h. Before each experiment began, instructions were read aloud by the monitor and several practice rounds that did not count toward final earnings were played to familiarize the participants with the experiments.

The experiments were conducted during the summer of 2004 in three distinct areas of Colombia: on the Caribbean Coast, along the Magdalena River, and on the Pacific Coast. A total of 300 individuals participated in the experiments, evenly divided among the three regions. Summary statistics of the subjects' characteristics by region are provided in Table 2. The Magdalena and the Pacific regions were roughly comparable across all five dimensions: the mean age was about 42 yr with almost 5 yr of formal education. Subjects in these two regions were overwhelmingly male fishermen who had lived in the same community for more than 10 yr. In the Caribbean, subjects were younger and more educated. There was also a more even gender distribution (55% male). Relative to the other two communities, a smaller majority of subjects lived in the same community for over 10 yr and earned their living primarily from fishing.

An important element of our design is that all treatments were conducted in each of the three regions. Our motivation for doing so was to examine whether the results we obtained in one region were replicated in the others or whether there are significant regional differences in outcomes. The three communities were chosen because they vary with respect to how formal fishing regulations and more informal community conservation efforts play a role in managing local harvests. We do not develop formal hypotheses about how community characteristics might affect behavior in our experiments, mainly because it is not possible to conduct rigorous tests of any such hypotheses with only three communities. In the next section, however, we do speculate about how the relative importance of formal regulations and informal norms in the three regions may be correlated with our experiment outcomes. Thus, a brief description of how the regions are different in this regard is appropriate.

Participants in the Pacific region, more specifically the Ensenada de Tumaco, are members of Afro-Colombian communities, the majority of whom live in collectively owned territories. In the Ensenada de Tumaco, 94% of the participants report that fishing, particularly shrimp harvesting, is their main livelihood. Compared to the other two regions, the government authority that is charged with regulating fisheries and other natural resources has a stronger presence in this region. Colombian fisheries are regulated by Instituto Colombiano de Desarrollo Rural (INCODER), a federal-level agency under the Ministry of Agricultural Affairs. INCODER enforces several regulations on the Pacific Coast, such as seasonal

10. Daily wages in the regions where the experiments were conducted varied between 10,000 and 15,000 pesos.

restrictions and the prohibition of certain methods of harvesting shrimp. In general, local fishermen in the Ensenada de Tumaco are aware of the regulations they operate under, and there is agreement among them about the need to regulate the shrimp fishery. Community-based organizations, as well as international conservation nongovernmental organizations, are also actively promoting the conservation of the natural resources of the region, in particular the mangrove forests. International conservation organizations are active here because they see this region as a threatened "hot spot" of biodiversity. Although it is impossible to say whether government regulations or community conservation efforts are more important in this region, it is true that formal regulations are more important in the Pacific than the other two regions.

The participants in the town of La Dorada, Caldas, and surrounding villages are part of a mostly white and mestizo population who harvest several species of fish from the Magdalena River and the adjacent lake, Charca de Guarinocito, in the interior of the country. Eighty-seven percent of the participants reported that small-scale fishing was their main economic activity. The presence of INCODER in this area is considered to be very weak—participants describe regulatory authorities as distant, with no involvement at all with the community. Nevertheless, most of the participants are aware of seasonal restrictions on harvesting certain species. International conservation organizations are not present in this area, but a local fishermen's association has been formed to manage the local fishery. In fact, about 20% of the Magdalena participants belong to this association, which has been actively designing and enforcing their own rules for fishing in the Charca de Guarinocito. Thus, compared to the other two regions, community conservation efforts are relatively more important in the management of the local fishery in Magdalena area than government regulations.

Participants in the Caribbean region, more specifically near the city of Santa Marta, are part of a multiethnic population of whites, mestizos, African descendants, and indigenous peoples. The proportion of participants in this region who reported that fishing is their main economic activity is significantly lower than in the other two regions (69%). Some of the other participants are small-scale fish buyers who then resell their product in Santa Marta. The rest are farmworkers. Generally, the participants did not know who had the authority to regulate the local fisheries. Although some methods of fishing are recognized as illegal, few other fishing rules, formal or informal, are observed in this region.

III. RESULTS

To test for possible complementarities between formal regulations imposed on a community to conserve a local natural resource and nonbinding verbal agreements to do the same, we estimate a random-effects Tobit model in which the individual's choice of extraction (or harvest choice), y_{it}, is constrained to lie between 1 and 9, inclusive:

$$
\begin{aligned}
(3) \qquad y_{it} = {} & \beta_0 + \beta_1 y^e_{-it} + \beta_2 \mathrm{Age}_i \\
& + \beta_3 \mathrm{Education}_i + \vec{\beta}_4 \,\mathrm{Period}_t \\
& \times \mathrm{Treatment}_{it} + \vec{\beta}_5 \,\mathrm{Region}_i \\
& \times \mathrm{Treatment}_{it} + \vec{\beta}_6 \,\mathrm{Group}_i \\
& + \nu_i + \varepsilon_{it},
\end{aligned}
$$

where subject $i = 1, \ldots, 300$, period $t = 1, \ldots, 20$, the individual random effects are $\nu_i \sim N(0, \sigma^2_\nu)$, and $\varepsilon_{it} \sim N(0, \sigma^2_\varepsilon)$ is the idiosyncratic error term.

The constant (β_0) captures individual harvests in the Limited Access, first-stage of the experiments. Using a similar model to Equation (3), but with Limited Access harvests interacted with regional dummies and period, we found no significant regional or temporal variation. This led us to eliminate these interactions in Equation (3), with the advantage of simplifying the interpretation of the constant. More importantly, it is particularly interesting that the Limited Access results are replicated in the three regions; yet, as we will see shortly, significant regional differences emerge when we introduce the new institutions in Stage 2. This suggests that any differences in second-stage results are attributable to regional interactions with the different institutions and not to regional differences in the way in which the subject pools responded to the fundamental common pool resource dilemma.[11]

11. Average harvests under Limited Access were always below the Nash equilibrium harvests of 7 units for each individual. Mean individual harvests for the ten periods of this stage of the experiments were 5.7 units. Average harvests were below Nash equilibrium predictions for each of the second-stage institutions as well.

To allow for the possibility that harvest choices might change over time and that this might vary across institutions, we interacted each second-stage treatment with period. The coefficient vector $\vec{\beta}_4$ reflects this interaction of the five Stage 2 treatment dummy variables with period. The results from estimating Equation (3) indicate that the time interactions with the Low Penalty and Medium Penalty treatments were jointly significant ($p = .00$) but the remaining interaction terms were not ($p = .48$).[12] For conciseness and ease of exposition, we eliminated the nonsignificant period interactions from the final model reported in Table 3. Note that the two period interactions are positive and of similar size for the Low Penalty and Medium Penalty treatments (0.06 and 0.11); these coefficients are statistically indistinguishable ($p = .40$). That these coefficients are positive indicates that harvest choices increased over time under a weakly enforced external regulation when the subjects are not allowed to communicate with each other. This is consistent with the findings of Cardenas, Stranlund, and Willis (2000) in similar field experiments.

We included several individual characteristics as independent variables. The variable Expectation of Their Extraction (y^e_{-it}) is what individual i indicated that she anticipated would be the total extraction of the other four group members in period t. The positive and significant coefficient ($\beta_1 = 0.12$) indicates that individuals' harvest choices tended to increase with their expectation of what others' harvest choices would be. This is inconsistent with individuals pursuing pure Nash strategies, but it is consistent with a strategy of conditional cooperation that others have found in social dilemma experiments (e.g., Fischbacher, Gachter, and Fehr 2001; Kurzban and Houser 2005). Note also that older participants tended to choose more conservative harvests but that more educated participants tended to choose higher harvests.

The model in Equation (3) includes fixed effects (the coefficient vector $\vec{\beta}_6$) for all (but one) of the 60 groups in our sample. For conciseness, these estimates are not reported in Table 3. We also estimated this model without these group effects; this had minimal impact on our coefficient estimates and no impact on any of our hypotheses tests or conclusions.

The last 15 variables in Table 3 (the coefficient vector $\vec{\beta}_5$) reflect the interaction of dummy variables for the three regions with the five Stage 2 treatments. Since the omitted dummy variable, captured by the constant, is the Limited Access treatment, the coefficients for these variables indicate the changes in individual harvests from Limited Access harvests

12. We use Wald χ^2 test for all hypothesis tests and report the p values.

TABLE 3
Random-Effects Tobit Estimation of Individual Harvests[a]

Variable	Coefficient
Constant	4.19*** (0.72)
Expectation of Their Extraction (y^e_{-it})	0.12*** (0.01)
Age (yr)	−0.01** (0.01)
Education (years of formal schooling)	0.07** (0.03)
Period × Low Penalty	0.06* (0.04)
Period × Medium Penalty	0.11*** (0.04)
Caribbean region (Car)	
Car × Communication	−0.63** (0.26)
Car × Low Penalty	−1.28** (0.62)
Car × Low Penalty/ Communication	−2.51*** (0.27)
Car × Medium Penalty	−2.84*** (0.62)
Car × Medium Penalty/ Communication	−0.67** (0.26)
Magdalena region (Mag)	
Mag × Communication	−1.57*** (0.26)
Mag × Low Penalty	−2.04*** (0.62)
Mag × Low Penalty/ Communication	−0.93*** (0.25)
Mag × Medium Penalty	−2.70*** (0.62)
Mag × Medium Penalty/ Communication	−1.53*** (0.26)
Pacific region (Pac)	
Pac × Communication	−0.55** (0.26)
Pac × Low Penalty	−3.17*** (0.63)
Pac × Low Penalty/ Communication	−1.84*** (0.27)
Pac × Medium Penalty	−2.96*** (0.62)
Pac × Medium Penalty/ Communication	−1.81*** (0.27)
N	5,780
$p > \chi^2$	.00

[a]The dependent variable is the individual's harvest (1–9, inclusive). The omitted treatment dummy variable is Limited Access. Fixed-effects estimates for each group are included but not reported. They are available upon request. Standard errors in parentheses.

*** denotes $p \leq .01$; ** denotes $p \leq .05$; * denotes $p \leq .10$.

for each second-stage institution in each region. Note that all these coefficients are negative and statistically significant. Thus, each second-stage institution was effective at promoting more conservative harvests than under Limited Access. Note also that there is much variation in the size of these coefficients across institutions and across regions. This variation produces the main results of our work.

As expected, the Communication treatment was effective in reducing harvests relative to Limited Access in all three regions, although the effect in the Magdalena (−1.57) was greater than those in the Pacific (−0.55, $p = .00$) and the Caribbean (−0.63, $p = .01$) regions. The Pacific and the Caribbean regions are not statistically different from each other ($p = .82$). This regional variation reveals differences in the ability of different groups to form and maintain nonbinding verbal agreements to conserve the resource.

Some care must be taken when interpreting the coefficients for the Low Penalty and Medium Penalty treatments. Since we have interacted these treatments with period and found that harvests increased over time, the coefficients for these treatments indicate the reduction in harvests from Limited Access only at the start of the second-stage treatment. However, since we are mainly interested in the regional variation in these treatments, our qualitative conclusions about this variation can be drawn from comparing the coefficients for Low Penalty and Medium Penalty for each region. Note the significant regional variation in the effects of the Low Penalty. In the Caribbean, the initial reduction in individual harvests (−1.28) was smaller than those in the Pacific (−3.17) and on the Magdalena River (−2.04). These regional differences are jointly significant ($p = .00$). On the other hand, note that the initial effects of the Medium Penalty are about the same level in each of the regions. Not surprisingly, there is no statistically significant difference in the effects of the Medium Penalty among the regions ($p = .76$). Somewhat surprisingly, the higher expected penalty under the Medium Penalty regulation did not always produce greater harvest reductions than the Low Penalty regulations. In the Caribbean, the Low Penalty yielded a smaller reduction in harvests than the higher monetary costs associated with the Medium Penalty (−1.28 vs. −2.84, $p = .07$), but in the other two regions, there was no difference in the effects of the two regulations (in the Pacific: −3.17 vs. −2.96, $p = .81$; in the Magdalena: −2.04 vs. −2.70, $p = .45$).

Why is there so much regional variation with the Low Penalty but none with the Medium Penalty? Both treatments frame the experiments by providing a signal of the efficient individual harvest and by punishing deviations from this choice, but the Medium Penalty regulation has a unit fine (actual and expected) for exceeding the harvest quota that is over six times that of the Low Penalty regulation. Moreover, the fine for noncompliance in the Low Penalty regulation is so low that, at least in theory, it should have no effect on harvest choices; yet in all regions, there was a statistically significant reduction in harvests with this regulation. Its effectiveness, therefore, must be largely due to the regulatory frame, not the expected marginal penalty. The regional variation in the effects of the Low Penalty suggests that reliance on a simple regulatory frame does not produce consistent outcomes. While the Medium Penalty regulation also provides signals of efficient harvests and sanctions for deviating from the regulatory quota, the stronger monetary incentive of this institution produced consistent reductions in harvests across the regions, while the weaker monetary incentive of the Low Penalty did not. Overall, then, our results suggest that institutions that rely on framing effects (Low Penalty) or social pressure (Communication) to reduce harvests will not produce consistent outcomes, while those that rely on a significant monetary incentive (Medium Penalty) will.

Now, let us turn to our main hypothesis that communication and regulation are complementary institutions. The villagers who were the subjects in our experiments cooperate with each other on a large number of community issues. Thus, it is likely that a regulation to control individual harvests from a local fishery would be implemented in communities that already communicate with each other about the fishery, as well as other shared concerns. To judge the performance of a regulatory intervention in such a community, it is appropriate for us to ask whether introducing a regulation complements existing community efforts but not vice versa. Let us say that communication and a regulation are complements if their combination produces more conservative harvests than communication alone.

Of the six combinations of regions and regulations, there are three such cases. Note from Table 3 that in the Caribbean region, the reduction of harvests in the Low Penalty/Communication treatment from Limited Access (–2.51) is greater than the reduction achieved by the Communication treatment (-0.63, $p = .00$). Thus, the Communication and Low Penalty regulations are complementary in the Caribbean.[13] The other two instances are in the Pacific region where the harvest reduction for both the Low Penalty/Communication (-1.84) and the Medium Penalty/Communication (-1.81) treatments is greater than for Communication alone (-0.55; $p = .00$ for both comparisons).

We also observe one case in which communication combined with a regulation actually led to worse outcomes than communication alone. When this occurs, the regulation crowds out cooperative efforts to conserve the resource. In the Magdalena region, the Low Penalty/Communication treatment produced a lower reduction in individual harvests than Communication (-0.93 vs. -1.57, $p = .07$). Finally, there are two instances in which the combined treatment had no effect relative to Communication. This occurred with the Medium Penalty/Communication treatment in the Magdalena region (-1.53 vs. -1.57, $p = .90$) and with this same treatment in the Caribbean (-0.67 vs. -0.63, $p = .92$).

We conclude, therefore, that the hypothesis that informal communication and formal regulatory structures are complementary is not supported generally. Of the six possible combinations of regions and regulations, we observe three instances in which a regulation combined with communication produced more conservative harvests than communication alone, one case in which a regulation actually crowds out communication, and two cases in which the combination of communication and a regulation did not produce a significant difference in harvests than communication alone. Although there are likely to be regions in which regulatory control of harvests from a common pool resource complements informal community efforts, our results suggest that such a relationship will not be robust across communities and regulations.

13. In fact, the reduction in the Low Penalty/Communication treatment also exceeds that achieved by the Low Penalty alone.

Our results beg the question of why different regions produce different results in the same experiments, particularly considering that the outcomes under Limited Access in all three regions were identical. As noted earlier, with only three regions, it is not possible to provide general explanations of how community characteristics affect behavior in our experiments. Nevertheless, let us speculate for a moment because an interesting mapping may exist between the relative importance of informal community efforts and government regulations and our experimental results. Certainly, this relationship is worth exploring with subsequent research.

Let us compare the Pacific and Magdalena regions. The subject pools in these two regions are very similar in terms of age, years of formal education, gender composition, and livelihood (Table 2). However, in the Pacific region, the federal regulatory authority has the strongest presence of the three regions and the participants in the experiments generally agreed about the need for such regulations. In contrast, federal regulators have little involvement in the Magdalena fishery; instead, a local fishermen's association plays a significant role in the management of the local fishery. Our results reveal that Communication alone was significantly more effective in the Magdalena region than in the Pacific region. Moreover, in the Magdalena region, the Medium Penalty regulation did not complement Communication and the Low Penalty regulation actually crowded out Communication. These results may be determined, at least in part, by the fact that the government's impact on the fisheries of the Magdalena region is low relative to local conservation measures. On the other hand, in the Pacific region, Communication alone was not very effective at reducing harvests in our experiments and both the Low Penalty regulation and the Medium Penalty regulation complemented Communication. It is possible that this is explained partly by the strong presence of the government in the fisheries on the Pacific Coast. Our experiment results in these two regions suggest the intriguing hypothesis that the relative importance of government regulations versus community conservation efforts in specific communities may be positively correlated with whether regulations complement group communication in experiments like ours.

The connection between the relative importance of regulations versus community efforts and the results of our experiments is not as clear in the Caribbean. In this region, there are both minimal regulatory pressure and the absence of clear community efforts to conserve the fishery. In addition, the subject pool in the Caribbean was significantly different from those in the Pacific and the Magdalena regions. In particular, fewer of the subjects earned their living primarily through fishing, and fewer lived in the community for over 10 yr (Table 2). With a less stable population that is less concentrated on fishing, it is possible that these subjects are less vested in the local fishery. This combined with little formal or informal control of local harvests may be the reasons for the weak mapping of the context of the subjects' lives into the experiment results.

IV. CONCLUDING REMARKS

The primary message of this work is a cautionary note concerning the performance of government interventions in small-scale resource industries in the developing world. Although each of the regulatory interventions we studied was effective at inducing more conservative harvests than under a limited-access scenario, this comparison is not the most relevant one for evaluating government intervention in common pools in the developing world. In most of these cases, regulatory interventions will be imposed on communities of resource users that already have informal norms about individual behavior in the commons albeit with widely varying degrees of success. Thus, the relevant measure of the performance of a regulatory intervention is not how it performs with respect to the theoretical limited-access situation but how it performs relative to existing informal conservation efforts that stem from communication and organization at the community level that may or may not continue once a regulation is in place. With regard to this comparison, we observe that regulatory interventions sometimes do more harm than good, are sometimes completely ineffective, and at other times enhance existing community efforts. Since regulatory interventions are costly, they are only warranted in those communities where there is a strong likelihood that the intervention complements existing community efforts.

Identifying these communities calls for more intense study of the determinants of community responses to regulatory intervention. Geographical variation in the effectiveness of regulatory interventions could reflect existing behavioral patterns under current regulations, relationships with government authorities, and patterns of cooperation among community members to conserve a local resource (Cardenas and Ostrom 2004; Henrich et al. 2004). Clearly, further research is needed to explore how community and individual characteristics can explain variation in the responses to alternative institutions. Obviously, this requires visiting many more communities than we were able to. Yet, a clearer understanding of the relationships between community and individual characteristics and behavior in common pool experiments would provide valuable information about exploiting possible complementarities between community-based initiatives and external regulations and thus help in the design of better policies to effectively and efficiently reduce overexploitation of common property resources in the developing world.

Finally, we think that our study highlights and clarifies the value of conducting framed field experiments. As we have stated several times, our broader interest is in the performance of regulatory interventions in small-scale resource industries in the developing world. Thus, rather than trying to address this issue with students in university laboratories, it is appropriate that we traveled to a developing country and conducted experiments that presented a common pool dilemma to individuals whose livelihoods are tied to a common pool resource. The advantage of such framed field experiments is that subjects bring a context from their daily lives that could influence their experiment behavior and that context is an important element of the question that is being addressed. The regional heterogeneity of the responses to the institutions we examined in our experiments drives our main result about the nonrobustness of a complementary relationship between communication and external regulations. If we had used university students, we would have run the substantial risk of missing the heterogeneity that is so obviously important in the field.

However, the heterogeneity we observe not only highlights the value of framed field

experiments but also implies that the field itself is a heterogeneous, and often challenging, place in a way that the laboratory is not. Indeed, our results are a cautionary tale for anyone who contemplates field experiments. If we had attempted to draw conclusions about the performance of regulatory institutions in small-scale fisheries in the developing world from experiments conducted in only one region of Colombia, the results would have been just as misleading as the results from the same experiments conducted in a laboratory with university students. Hence, the value of fieldwork like ours does not come from simply designing framed experiments to examine behavior by individuals who are intimately connected to the questions of interest, although in cases like ours this is surely important. Replication in as many of the relevant settings as possible is equally important.

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