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Quota Compliance in TURFs

An Experimental Analysis of Complementarities of Formal and Informal Enforcement with Changes in Abundance

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Abstract

We explore the effects of different enforcement mechanisms, including formal (external), informal (local), and both together, on individual compliance behavior under a system of territorial use rights in fisheries (TURFs). Our design considers different stock abundance levels and the effect that such differences may exert on extraction decisions and compliance behavior. The analysis is based on a framed field experiment conducted with artisanal fishers in central-southern Chile. Our results indicate that, regardless of the level of biological productivity within the managed areas, the combination of formal and informal enforcement mechanisms reduced individual extraction and transgressions with respect to formal enforcement. However, in the case of abundance, the use of a combination of enforcement mechanisms did not accomplish more than informal enforcement alone in reducing individual extraction and transgressions. We also found that while the formal (external) enforcement tends to complement the informal enforcement mechanism, it may also crowd out efforts from the group to control peers under low biological productivity. We discuss the policy implications of our results for the proper design of TURFs-based fisheries management.

Key Words: economic experiments, enforcement, compliance, abundance, territorial use rights

JEL Codes: Q48, H23, Q53, H31

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Oscar Santis and Carlos Chávez*

1. Introduction

The use of decentralized fisheries management systems based on property rights is gaining support among fishery managers. These systems offer the opportunity for more efficient management of fisheries, from an economic as well as ecological perspective. In the context of artisanal fisheries, one such system includes creating and allocating Territorial Use Rights in Fisheries (TURFs). Under a TURFs system, rights to manage and exploit natural resources in a defined geographical space can be assigned to individual agents, organized groups of individuals or coastal communities (Charles 2002; Christy 1982; Wilen et al. 2012). In any system based on property rights, overharvesting is one of the most critical aspects. To minimize overharvesting, the design and implementation of TURFs must properly address the identification and delimitation of users, decisions related to rules of use, and the problem of enforcing regulations, among other issues (Wilen et al. 2012).

Under a TURFs management regime, user organizations are responsible for defining an exploitation plan, identifying operational rules, restricting harvest, and defining monitoring and enforcement strategies. However, the state can still play an important role in the system's implementation and functioning, especially when the TURFs regime is introduced in coastal fisheries where property rights have never been in place. To our knowledge, and perhaps surprisingly, the interaction between the state and organized users in solving these management problems remains unexplored in the literature. How do the efforts of users holding TURFs rights to restrict harvest work together with similar efforts by the external authority? What are the consequences in terms of individual extraction behavior related to the presence (or absence) of control by these entities, self-governing groups, and the external authority?

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This work presents the results of an economic field experiment designed to explore the effects of applying different enforcement mechanisms – formal (external), informal (local), and both together (co-management) – to individual compliance behavior under a system of territorial use rights in fisheries (TURFs). Our design also considers different stock abundance levels under exploitation and the effect that such differences may have on extraction decisions and compliance behavior. The field experiment was conducted with artisanal fishermen living in central-southern Chile, who are members of organizations exploiting benthic resources under TURFs regulation.

There is an increasingly large literature which analyzes the conditions under which local communities are able to successfully manage a resource (for instance, Ostrom 1990; Ostrom and Walker 1991; Ostrom et al. 1992). The possibility and consequences of non-compliance in fisheries has been considered in the existing literature since the seminal work of Sutinen and Andersen (1985); for a review of this literature, see Nostbakken (2008). However, the interaction in terms of monitoring and enforcement by both the users and central authority – either as a general question or in the context of TURFs – has not received much attention and relevant questions remain unexplored.

Our analysis is based on the design and application of a framed field experiment composed of six treatments, divided into two scenarios of abundance: high biological productivity (abundance) and low biological productivity (scarcity) of a target species. For each scenario of abundance, three treatments are considered: first, a formal enforcement (external enforcement) mechanism is applied. Second, an informal enforcement (local enforcement) mechanism is considered. Third, a combination of both mechanisms is applied. This is an exploratory study. Our primarily purpose is to measure the effects of different enforcement mechanisms on harvesting and compliance decisions.

Our experiment considers exogenous variation in a resource's availability. The motivation for this aim is twofold. First, there is empirical evidence of high spatial heterogeneity in terms of biological productivity; one example is the case of the Chilean TURFs (Orensanz et al. 2005; González et al. 2006; Cancino et al. 2007; Aburto et al. 2013). Second, the existing literature provides evidence on the potential consequences of levels of resource abundance on extraction decisions and transgressions by subjects, based on several experimental designs in common property resource (CPR) games (Blanco et al. 2011; Maldonado and Moreno-Sánchez 2009; Osés-Eraso and Viladrich-Grau 2007; Osés-Eraso et al. 2008). Some experiments have focused on exploring users' responses to exogenous changes in the availability of CPR. For instance, Osés-Eraso and Viladrich-Grau (2007) observed that the extraction level decreases when a common resource is scarce. By contrast, in a similar design, Blanco et al. (2011) found that users reduced extraction when the stock moderately decreased (i.e., a couple of rounds). However, extraction immediately increased when the resource was reduced to a size at which it could be completely depleted. Others have considered situations in which the changes in abundance are endogenous (e.g., Cárdenas et al. 2013; Osés-Eraso et al. 2008; Moreno-Sánchez and Maldonado 2010). For example, Cárdenas et al. (2013) explore the consequences of heterogeneous agents and endogenous stocks in a series of field experiments for fisheries, water irrigation, and forests. The design of each resource considered different sets of regulations faced by subjects. In the case of fisheries, they found a decrease in stock over time and observed that, once a low stock level was achieved by the group, recovery efforts were not successful. In addition, Osés et al. (2008) study the appropriation strategies in common pool resources wherein extinction is a credible threat. Their results show that initial resource scarcity limits appropriation by inducing an initial caution among users that persists throughout the game, indicating that subjects restrain their appropriation strategies when scarcity increases. However, this concern for resource scarcity is insufficient to prevent resource depletion.

The existing literature using experimental methods has also addressed the possibility of complementary relationships between formal regulation and informal mechanisms to reduce over-exploitation and induce natural resource conservation. Velez et al. (2010) discuss the results of field experiments designed to test for the possibility of a complementary relationship between communication and formal regulation to conserve a natural resource in a community (i.e., nonbinding agreements). These experiments were conducted in different regions of Colombia. The primary conclusion from this work is that the hypothesis of a complementary relationship between formal regulation and informal communication depends on the specifics of the regulation being introduced and also on the regions/communities where they are imposed. More recently, Lopez et al. (2013) reported their results from conducting standard public good games experiments on the Pacific coast of Colombia. The framed field experiments were designed to examine impacts from the introduction of external public regulations on community enforcement efforts (i.e., monitoring and sanctioning). The main result of this work is that formal government regulations are complementary to informal community efforts. Although the introduction of external regulations resulted in a reduction in sanctioning efforts from individual subjects, contributions and earnings were higher in the presence of government control than in the case of pure peer monitoring and sanctioning. Moreno-Sánchez and Maldonado (2010) investigated the effects of internal communication, external regulation, and the interaction between internal regulation and non-coercive authority intervention – they call this co-management – on fishermen's extraction decisions. They found that co-management exhibits the best results, in terms of both reduction in extraction and the resource sustainability of a CPR in protected areas.

In our study, levels of individual harvesting for all studied treatments are close to the predicted Nash equilibrium rather than the social optimum in both abundance and scarcity scenarios. The strategy of co-management, which relies on informal enforcement in combination with formal enforcement, presents the greatest decrease in levels of extraction and transgression compared to the use of either formal or informal enforcement alone.

With respect to the behavior of fishermen, there are significant observed differences when fishermen face abundance and scarcity scenarios. In situations of abundance, with quota enforcement, fishermen reduce extraction, presenting lower levels of extraction and transgression. Under situations of scarcity, however, even when fishermen reduce extraction, they present higher transgression and extraction levels than in scenarios of abundance, with extraction levels above the Nash equilibrium. Furthermore, we found that subjects are willing to impose sanctions on peers, even at a cost to themselves, as part of an informal enforcement mechanism.

This paper is organized as follows. Section 2 includes a brief description of the Management and Exploitation Areas of Benthic Resources (MEABR) in Chile. Section 3 presents the main hypotheses we wish to assess through our economic experiments in the field. Section 4 contains a description of the experimental design and procedures. Section 5 presents the results from the application of field experiments involving fishermen who belong to MEABRs in central-southern Chile. Finally, in Section 6, we present the primary conclusions of our work.

2. System of Territorial Use Rights in Chilean Fisheries

One example of a TURFs system is the Chilean Management and Exploitation Areas of Benthic Resources (MEABR), which was implemented in 1997. Under this system, exclusive rights of use and exploitation of benthic resources are assigned in five-mile coastal strips reserved for artisanal fisheries to legally establish organizations of artisanal fishermen (Gelcich et al. 2010; González 1996).[1]

MEARBs can be requested by artisanal fishing communities that establish a legal organization (e.g., union, trade association, cooperative or indigenous community) and present a project proposal of exploitation and management that must include a base situation study in which the existing benthic resources in the area are described in terms of species, quantities, and location, as well as a management and exploitation plan (MEP) specifying a set of actions intended to guarantee the sustainable management of the requested area. The MEP includes an area's initial characteristics and the benthic resource extraction plan, which specifies harvesting periods and techniques (Sobenes and Chávez 2009).[2]

The MEABR is controlled on the basis of a total allowable catch (TAC) quota, which consists of a fraction of the total number of mature available individuals of the species (mainly abalone) in the area. Consequently, every year, organizations that have been assigned MEARBs must hire university services or registered consultants for follow-up studies, on the basis of which admissible catches are defined for the species that the government will authorize according to conservation and sustainability criteria (Gelcich et al. 2006; Gelcich et al. 2010; Sobenes and Chávez 2009).

Monitoring and enforcement to deter illegal extraction in MEARBs are carried out in two ways: firstly, by the government through the maritime authority, the Chilean Navy (i.e., external or formal enforcement); and secondly, by fishermen who belong to these organizations (i.e., internal or informal enforcement), in a process that includes patrolling the areas to detect poachers and imposing sanctions according to their regulations and MEP. Organizations'

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[1] According to the Undersecretary of Fisheries (SUBPESCA), by March 2013 there were 773 management areas in the country, of which 512 have been assigned. There are also 354 MEARBs in progress. In the Biobío Region, where this study takes place, 76 management areas have been established to date, of which 56 have been assigned. There are also 24 MEARBs in progress. The Biobío Region has an area of 26,391.17 ha (23% of the national total). It is one of the 15 regions that are political-administrative divisions of the country. The Biobío Region is located in central-southern Chile bordering the El Maule Region to the north, the La Araucanía region to the south, the Republic of Argentina to the east, and the Pacific Ocean to the west.

[2] The main objectives of assigning a MEARB are: (1) to conserve benthic resources and protect the sustainability of artisanal fisheries; (ii) to maintain or increase the biological productivity of benthic resources; and (iii) to encourage and promote participatory management (SUBPESCA 2000).

monitoring activities usually involve either hired guards or members who take monitoring shifts themselves. However, while these strategies might discourage non-compliance by organization members, they are not effective in deterring transgressions by non-member fishermen who encroach on the organization's assigned territory. This shortcoming may be due to the absence of support from governmental authorities in charge of monitoring or the fact that fishermen's organizations lack legal tools to impose sanctions on transgressors who are not members of the organization in charge a given area (San Martín et al. 2010).

The MEARB system can be considered successful, especially in comparison to the predecessor regime and to sites that currently have unrestricted access.[3] Several studies have identified benefits following the introduction of the MEARB regime (Rosas et al. 2014). First, from a biological perspective, the introduction of the MEARB has assisted in the recovery of benthic resource stock, especially in the *loco* (abalone) fishery. Second, the regime has also improved economic performance in terms of prices and the per capita income of artisanal fishermen. Third, the system has had some positive impacts at the organizational level, allowing for decentralized management, including a decision-making process that largely takes place at the local level (Castilla et al. 2007; Gelcich et al. 2010; and San Martín et al. 2010).

Unfortunately, the MEARB system has not been exempt from problems (Aburto et al. 2013; San Martín et al. 2010). Early applications of the MEARB system were primarily focused on more productive areas with commercially attractive species, gradually reducing free access zones.[4] Perhaps more importantly, illegal harvesting has been reported as a problem of increasing concern to MEARB organizations, causing a decline in the levels of benthic species stock, as well as an increase in the administrative costs faced by the organizations, which must consequently devote more resources to monitoring their areas. Furthermore, the detection of illegal activities has also been a source of increasing tensions and conflicts, even escalating to

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[3] Before its collapse in the late 1980s – almost certainly due to overexploitation – the *loco* (abalone) fishery operated under an open access regime. Under this regime, fishermen had no incentive to cooperate, and short-term individualism prevailed. For a review of the systems that operated prior to the introduction of the MEARB regime, see Gelcich et al. (2010).

[4] Gelcich et al. (2005) carried out an assessment of the policy of assigning rights of territorial use, analyzing the statements of fishermen themselves, in order to understand both impacts and consequences of this policy. Thus, among fishermen, some negative perceptions toward a TURF system have been found, especially because open access places (i.e., historical territories) are increasingly scarce and overexploited. Among fishermen's organizations, these conditions tend to create negative perceptions and to justify illegal harvest.

violent encounters among fishermen's organizations and even between members of a given organization (Gelcich et al. 2005; González et al. 2006; Marín and Berkes 2010; and Schumann 2007).[5]

The areas in which our experiments were conducted are all under the MEARBs regime. In each of the communities we visited, there was at least one MEARB currently operating; thus, all fishermen who participated in the experiments were members of unions or cooperatives which operate benthic management areas.

3. Individual Compliance Behavior and Hypotheses

To examine the harvesting and compliance decisions of artisanal fishermen, we consider a risk-neutral fisherman who operates together with other fishermen in extraction activities of a common pool resource.[6] The model that we present directly follows the one proposed by Cárdenas (2004) and then extended by Moreno-Sanchez and Maldonado (2010), who included a resource stock factor to allow for dynamic analysis. The analysis considers the following scenarios: (i) absence of both quota regulation and enforcement mechanisms; (ii) quota regulation and the presence of external enforcement by governmental authority (formal enforcement); (iii) quota regulation and internal control by the artisanal fishermen's organization (informal or local enforcement); and (iv) quota regulation and the presence of both formal and informal enforcement mechanisms, representing enforcement by both the authority and the artisanal fishermen's organization.

3.1 Common Pool Resources

The model considers that the net benefits obtained by a fisherman depend on extraction level (x_i) and the available stock of the resource (S). Aggregate extraction by all fishermen

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[5] Incidents are usually reported in the local media. The two most severe incidents on record include one which occurred in 2007 when an encroacher was murdered by a patrolling fisherman in Maullín, near the city of Puerto Mont. A recent event occurred in February 2014 when a new patrolling boat was attacked and crashed into by another boat, causing injuries to two people.

[6] Our conceptual analysis of extraction and compliance choices assumes that individuals are risk neutral. If individuals are risk averse, then a given enforcement effort should produce more compliance (i.e., less violation) than expected. Moreover, as we show in this section, all individual decisions on extraction (and compliance, in the case of external regulations) are based, at the margin, on the benefits and costs involved, including the value of resources extracted, costs of extraction, availability of the resource, and enforcement parameters (e.g., monitoring and penalties).

reduces individual profits, i.e., there is a public good benefit from conservation. By following Moreno-Sánchez and Maldonado (2010), fisherman *i*'s individual benefit is given by:

$$\pi_i = px_i - \frac{\beta x_i^2}{2S} + \alpha \sum_{j=1}^{n} (e_j - x_j); \quad i, j = 1, \ldots, n. \tag{1}$$

where *p* represents the price level of the resource, x_i is the individual harvest level, *S* represents the stock level of the resource, *β* is a technical parameter associated with the harvest cost, e_i is the maximum feasible level that a fisherman can extract and *α* represents the effect on individual benefits of a change in the availability of the resource.

Considering a fixed number of fishermen that we denote n and assuming that they have symmetrical endowments of e_i (that is, $e_i = e$), if fisherman *i* chooses x_i to maximize π_i, we can obtain the first-order condition that characterizes the individual's optimal extraction level (see Cárdenas 2004). Considering a Nash equilibrium of a game with symmetric endowments, the first-order condition allows us to obtain the extraction equilibrium (x_i^{nash}), which is given by:

$$x_i^{nash} = \frac{S}{\beta}(p - \alpha) \tag{2}$$

Assuming that $p > \alpha$, then $0 \leq x_i \leq e$.

To obtain a comparison pattern with the predicted individual behavior, we characterize a situation in which fishermen select levels of individual extraction that maximize social or group welfare. To optimize the social welfare of *n* fishermen, the sum of payments is maximized and the socially optimal extraction (x_i^{social}) is calculated. This is:

$$\max \{x_1, \ldots, x_n\} \; W = \sum_{i=1}^{n} \pi_i = p \sum_{i=1}^{n} x_i - \frac{\beta}{2S} \sum_{i=1}^{n} x_i^2 + \alpha n^2 e - \alpha n \sum_{i=1}^{n} x_i \tag{3}$$

The set of first-order conditions for this problem defines the optimal extraction levels, according to Equation (4), as follows (see also Cárdenas 2004):

$$x_i^{social} = \frac{S}{\beta}(p - \alpha n) \tag{4}$$

Assuming that $p > \alpha n$, then $0 \leq x_i^{social} \leq e$.

From the previous results, it can be observed that $x_i^{nash} = \frac{S}{\beta}(p-\alpha) > x_i^{social} = \frac{S}{\beta}(p-\alpha n)$, which indicates that the socially optimal extraction level will always be lower than the resulting Nash equilibrium of the non-cooperative game for *n* >1.

3.2 Formal and Informal Enforcement

To incorporate the effect of external enforcement, we consider a regulatory system which applies to fishermen operating under TURFs. The regulation consists of the following instruments: (a) total allowable extraction quota (and its corresponding allocation at the individual level), (b) surveillance activity to detect quota transgressions, and (c) the imposition of a penalty in the case of a detected transgression. We assume that the regulator determines the quota at its socially optimal level $\left(x_i^{social}\right)$. We denote the probability of detection θ and a penalty per infraction unit that is constant and equal to *m*; that is, the penalty is constant per unit of violation, i.e., it increases linearly with the extent of the violation. Every time that *m* and θ are positive, the Nash strategy in this context will be lower than that which prevails in the absence of regulation. In this case, we can write the payment function in Equation (1) as:

$$\pi_i = px_i - \frac{\beta x_i^2}{2S} + \alpha ne - \alpha \sum_{j=1}^{n} x_i - \theta m\left(x_i - x_i^{social}\right) \quad (5)$$

For this case, the first-order condition that characterizes the optimal extraction level is:

$$\frac{\partial \pi_i}{\partial x_i} = p - \frac{\beta x_i}{S} - \alpha - \theta m = 0$$

which defines the extraction level, according to the following Equation (6):

$$x_i^{nash\_externa} = \frac{S}{\beta}(p - \alpha - \theta m) \quad (6)$$

Assuming that $p > \alpha + \theta m$, then $0 \leq x_i^{nash\_externa} \leq e$.

Under the assumption of risk neutrality and properly selecting *m* and θ, it is possible for the regulator to induce individual extraction strategies, consisting of the previously determined level in a social optimum.

Our analysis also considers the possibility of only informal control associated with peer monitoring activity. To incorporate the effect of internal enforcement, we consider an informal enforcement mechanism enacted by fishermen with TURF. Our analysis in this case considers a combination of an exogenous total allowable extraction quota (and its corresponding allocation at the individual level), local (informal) monitoring, and costly sanctioning by peers. We consider a situation in which the regulator sets the quota at a socially optimal level at which it is expected that rational individuals will not carry out a punishment because doing so is costly. However, as described by Cason and Gangadharan (2012), there are theoretical motivations and laboratory observations that suggest that subjects, even at personal cost, will impose sanctions (*Homo reciprocans*). Based on these arguments, sanctions can therefore be expected. Individuals should thus anticipate sanctions by adjusting their extraction decisions to reflect the social optimum.

In our research, the informal enforcement mechanism allows people to punish non-cooperative behavior, even if punishing implies a cost for the punisher, thus allowing for a decrease in the overexploitation of common pool resource; this outcome has been observed in several studies involving peer punishment (Yamagishi 1986; Ostrom et al. 1992; Fehr and Gächter 2000). In this regard, Fehr and Gächter (2000) stated that the possibility of punishment causes an increase in cooperation levels because potential free riders face a credible threat. When subjects have the opportunity to punish, they do so even if it is expensive for them or even if the punisher can expect no future material benefits.

Finally, we consider the joint presence of formal and informal enforcement. In this case, we combine the previously described mechanisms. When formal and informal treatments are implemented, the expected result is the same as with the formal treatment because it is expected that rational individuals do not want to carry out costly punishments. However, as mentioned before, there are experimental and theoretical arguments that predict the imposition of sanctions even if this is expensive. Such arguments would imply better compliance results than those from the formal treatment alone.[7]

[7] Based on an analysis of results from an experiment that combines both formal and informal mechanisms, carried out among shellfish collectors in a community in Costa Pacifica in Colombia, López et al. (2013) found that the combination of enforcement efforts by the community and the government generates almost perfect contributions to public welfare. However, in other investigations in which it was expected that the imposition of formal regulations would improve social welfare, the results suggested that these regulations could be counterproductive, degrading cooperative behavior and promoting more selfish behavior (Cárdenas et al. 2000; Vélez et al. 2010).

4. Experimental Design and Procedures

4.1 Experimental Design

We framed the field experiment as a harvest decision for Chilean abalone.[8] This harvesting decision is familiar to experimental subjects, who in their daily lives often make plans for harvesting (both as individuals and as part of the organization). The experiment was designed on the basis of work by Cárdenas et al. (2000), Cárdenas (2004), and Murphy and Cárdenas (2004).[9] Every subject had a harvest capacity of 8 units of abalone (whole numbers). The benefit from extraction depends on the individual decision as well as on group-level extraction. The parameters used to calibrate benefits and expected penalties for quota violations are presented in Table 1. With these values and using Equations (2), (4) and (6), we calculated the expected results and profits for extractions in each case. Expected results in terms of extraction units and experimental points are summarized in Table 2. The payoff schedules vary with the level of resource abundance (see the payoff tables in the appendix for the case of high and low stock levels).

The predicted Nash equilibrium for the baseline – a CPR treatment – is 6 units in the case of high biological productivity and 3 units in the case of low productivity. In the case of formal (external) enforcement, the Nash equilibrium is expected to be 4 units for high biological productivity and 2 in the case of low biological productivity. Finally, the socially optimal level of extraction is 2 units for high biological productivity and 1 unit for low biological productivity (see Table 2).

In our experiments, subjects face two stages. In the first stage, which is called the common pool resource baseline, individuals freely selected harvest levels in the absence of quota limits and enforcement. In the second stage, a quota regulation was introduced and one of the

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8 Chilean abalone or *loco* (*Concholepas concholepas*) is one of the main benthic resources exploited by artisanal fisheries along the Chilean coast, and has a high commercial value. The resource is subject to administrative measures including biological and extractive bans and size restrictions. Since 2003, the extractive ban has excluded MEARBs that are already established or are about to be established. Artisanal fishermen usually sell abalone to intermediaries or directly to representatives of processing plants.

9 Applications and later adaptations of this design are presented in Lopez (2004), Vélez et al. (2006), Vélez et al. (2010), and Moreno-Sánchez and Maldonado (2010). Our design for informal treatment follows previous work by Soest and Vyrastekova (2006), Moir (2008), and Cason and Gangadharan (2012).

three enforcement mechanisms under consideration was applied. As mentioned before, formal enforcement (external enforcement), informal enforcement (local enforcement), or a combination of formal and informal enforcement (co-management) was introduced. Specifically, under the formal (external) enforcement treatment in the second stage, after making harvest decisions, subjects were audited with a known predetermined exogenous probability. If the level of harvest chosen was higher than the individual quota, the subject was fined according to a linear penalty function (the penalty is constant per unit of violation; that is, it increases linearly with the extent of the violation).

Under the informal (local) enforcement mechanism, individual decisions were collected and presented to the group, maintaining individual decisions anonymously. Each individual then had the opportunity to impose a per-unit of violation penalty on his/her peer in the group at a personal cost. The set of penalties in this case included four options, and each individual could select one of the amounts, taking into consideration relevant personal costs. Finally, under the treatment that considers both enforcement mechanisms together (co-management), subjects were audited with a given probability after making harvest decisions. Conditional on detection, the linear penalty was imposed and individual extractions were presented to the group. Each member then had the opportunity to apply a penalty at a personal cost. Each subject participated in both stages, including both the baseline and one of the enforcement mechanisms.

4.2 Experimental Procedures

The experiment was applied to artisanal fishermen belonging to an organization that participates in the MEABR system in the Biobío region in central-southern Chile. A total of 180 artisanal fishermen were recruited from the following communities: Dichato, Cocholgüe Caleta Grande, Cantera (Tumbes), San Vicente, Lo Rojas, Laraquete, Llico, Los Piures, Puerto Yana, Puerto Sur (Isla Santa María) and Puerto Norte (Isla Santa María). The experiments were applied between December 2012 and February 2013.

In experimental sessions, the joint exploitation of Chilean abalone was considered, similar to real situations faced by participants on a regular basis. Participants were randomly allocated into 36 groups of 5 members. In the first stage, each group played 10 rounds of CPR baseline. In the second stage, each group played 10 rounds of one of the enforcement treatments (i.e., formal/external, informal/local, or both combined/co-management). Before the first round of each stage, subjects had the opportunity to communicate. This condition promoted discussion within the group for a maximum of five minutes before participants made an extraction decision, and no agreements about point or profit transference could be made after the session was over.

As mentioned before, in the case of the CPR baseline – the first stage – with high productivity, the Nash equilibrium strategy would be to harvest 6 units in each round. If each group member harvests 6 units, they all receive 680 extraction points, and no one has an incentive to either increase or decrease their harvest decisions. However, the social optimum is reached if each member harvests only 2 units, which would give each of them 840 extraction points. In the low-productivity case, the corresponding values are 3 and 1. Each individual decided how much to extract and submitted his/her decision to one of the study's facilitators using a decision card. The facilitator then calculated total extraction for the group, which he/she announced to the group so that individuals could calculate the points made in the round according to a payoff table which corresponded to high or low biological productivity.

In the second stage, one of three different treatments was used, i.e., formal (external), informal (local), or combined treatments. The formal treatment means that each player in the high productivity case is supposed to harvest only 4 units, while the total allowable catch level for a group is 20. Each member can extract more than 4 units; however, there was a 20% risk that exceeding the level would be detected and, if so, the subject would be punished with a 200 point deduction for each unit exceeding 4. Hence, the Nash strategy is to harvest 4 units. Every individual facing this treatment decided how much to extract, submitting his/her decision to the research facilitator on a decision card. The facilitator then calculated the total extraction for the group, which was publicly announced so that every individual could calculate the points earned in this round according to the payoff table. Every fisherman was aware of other group members' extraction decisions, which were announced anonymously by the facilitator. Subsequently, fishermen were audited according to the monitoring probability, and were subject to a constant fine per unit in cases of extraction above individual quota levels. Anonymity was maintained when audit results were announced; only the number of inspected subjects and inspection results were indicated.

In the informal treatment, each group member was told that there was a total allowable catch (TAC) quota and that they could receive equal shares, i.e., 2 in high productivity and 1 in low productivity. If someone exceeded the individual quota, the other members could allocate punishment at the end of the round. To that purpose, individual extractions were announced, maintaining decision anonymity. Subjects were able to allocate 54, 36, or 18 punishment points per unit of violation at a personal cost of 18, 12, or 6 points. These values were selected based on a 3 to 1 ratio of the penalty to the cost to a member who punishes. This relationship has been extensively used in the literature on punishment related to the public good (Cason and Gangadharan 2012; Gächter et al. 2008; Gächter and Herrmann 2011).[10] In the informal treatment with high and low productivity, the Nash strategies are to extract 4 and 2, respectively, taking into account an unlikely situation in which no one imposes costly sanctions upon their peers.

In the combined treatment, after harvesting decisions were made, the formal and informal enforcement mechanisms were both present. These enforcement mechanisms were implemented as previously described (see the set of instructions in the appendix). Table 3 presents a description of the experiment's application.

Materials were handed out to participants during the sessions to assist them in making decisions. The materials included a payoff table – which was the same for everyone – pens, decision cards and decision sheets, among other materials. In addition, flipcharts and boards were used to present instructions. A laptop was used to enter the fishermen's decisions to calculate their profits.

In each session, a lead researcher participated, accompanied by three facilitators. At the beginning, the researcher explained the process and how to use the materials, utilizing practice rounds to clarify doubts. Control questions were asked to determine whether the fishermen were ready to start.

Each experimental session lasted about two hours and thirty minutes. At the end of the session, a survey was carried out so that the research team might proceed privately with the cash payment.

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[10] The total per unit of violation penalty imposed on the fishermen who deviated from the quota under the informal (local) enforcement treatment is the sum of penalties imposed by four other fishermen (i.e., a participant could punish all other members in the group), with the possibility of a maximum of 216 points in the case when the penalty corresponded to 54 points (i.e., a value close to the 200 point formal treatment) and a minimum of 0 points in the case of no penalty.

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5. Results

In this section, we present the results of our fieldwork. Table 4 presents the summary demographic statistics for the 180 fishermen who participated in the experiment. The subjects were mainly male (83%), with an average age of 44 years and seven years of formal schooling on average. The average number of people in participants' households was four. The majority of participants indicated that they were the main contributor to their family income (76%), with monthly incomes for the family group in the range of 100,000 to 200,000 Chilean pesos (US $211-US $422).[11] Approximately 39% of the participating fishermen have incomes in this range, followed by 35% with incomes lower than US $211. Only 6% of the interviewees had incomes above US $844. As for primary fishing activities, 45% of the participants are divers, 32% are fishermen, 17% are collectors, and 6% are boat owners.

Subjects who participated in experiments were paid US $5 for showing up on time and earned more money for their participation in the session. Each session was composed of the two stages previously described (10 rounds of the baseline, plus 10 rounds of any of the three enforcement mechanisms). Total payments in the low biological productivity treatments fluctuated between 6,338 Chilean pesos (US $13) and 15,554 Chilean pesos (US $33), with an average payment of 12,842 Chilean pesos (US $27). The standard deviation was 786 Chilean pesos (US $1.6). In the high biological productivity treatments, individual total payments ranged between 12,728 Chilean pesos (US $27) and 17,129 Chilean pesos (US $36), with a mean value of 15,384 Chilean pesos (US $33) and a standard deviation of 786 Chilean pesos (US $1.6).

The means of extraction decisions were analyzed according to the treatment (i.e., formal, informal or combined enforcement), for the cases of high and low biological productivity (see Figures 1, 2a, and 2b).

The results obtained under the condition of high biological productivity (Figure 1) suggest that, for the baseline (first stage), the average extraction decisions were relatively stable, without evidence of statistically significant differences between groups (see Table 5). This is expected because the groups were randomly formed and identical experiments were carried out in the first 10 rounds. Similar results were obtained for levels of extraction under low biological productivity (see Figure 2a and Table 5).

[11] Amounts were calculated considering exchange rates reported for the months of the study (December 2012-February 2013). Average exchange rate for this period was $1 USD = $474 Chilean pesos.

Another result worth mentioning is that, even though the mean values of extraction do not reach the predicted Nash equilibrium (i.e., corresponding to 6 units under high biological productivity and 3 units under low biological productivity), they were closer to the Nash equilibrium than to the social optimum (i.e., corresponding to 2 units under high biological productivity and 1 under low biological productivity). See Figures 1 and 2a, first stage.

The results of the second stage (rounds 11-20), in which a quota regulation with formal, informal, or combined enforcement mechanisms was implemented, were as expected: there were significant reductions in extraction levels compared to the extraction observed in the baseline (first 10 rounds). This was the case for both high and low levels of biological productivity.

In the case of high biological productivity under the formal (external) enforcement treatment, the average level of extraction was approximately 3 units (Table 6), i.e., approximately one unit above the allocated quota (individual quota = 2) and one unit below the expected extraction for this treatment (4 units). In the informal (local) enforcement treatment, the average level of extraction was 2.4 units (Table 6), i.e., above but close to the allocated individual quota. In the case of the combined formal and informal enforcement treatment, an average of 2.3 units was reached (Table 6). The results of non-parametric tests performed under the high biological productivity case suggest that there are differences between the level of extraction under the combination of formal and informal enforcement mechanisms vis-a-vis the situation when only formal enforcement is in place. Furthermore, we also observe no differences between the extraction decision under the combination of enforcement mechanisms and the informal enforcement alone (see the upper section of Table 6). [12]

The results of the low biological productivity case are presented in the lower part of Table 6. In this scenario, we observe that, for the formal enforcement treatment, the average level of extraction was 2.7 units. This outcome is 1.7 units above the allocated individual quota (individual quota = 1) and 0.7 units above the expected extraction for this treatment (expected

[12] Because of the potential problem of performing a non-parametric test using non-independent observations, we also conducted it by generating one observation per individual in a given treatment; that is, in the alternative test procedure, each observation was obtained as the mean extraction by each subject over the 10 rounds played in a given treatment. The results for the second stage under high biological productivity do not change. However, we found some differences between the tests performed in the second stage under the low biological productivity scenario. The most significant difference is observed when comparing the treatment that uses the combination of formal and informal enforcement to the treatment that uses only formal enforcement under low biological productivity (see Table 6, last column).

extraction = 2). Moreover, the average extraction level in the informal enforcement treatment under the low biological productivity scenario was 1.9 units, i.e., 0.9 units above the quota allocated (individual quota = 1), and 0.1 units below the expected extraction (expected extraction = 2). In the case of the combined formal and informal treatment, an average of 2.5 units was reached under the low biological productivity scenario, i.e., 1.5 units above the expected extraction (expected extraction = 2).

We also performed a non-parametric test to explore differences in extraction under the low biological productivity scenario between formal, informal, and combined enforcement mechanism treatments. The results of the test, which was performed twice, are not conclusive. When the test is performed using non-independent observations, however, we are able to conclude that extraction under the combined formal and informal enforcement treatment differs from the extraction observed when either formal or informal enforcement is used alone. We conclude the opposite when the test is performed using one observation per subject, obtained by averaging the extraction decisions by each subject over the 10 rounds (see Table 6). This latter result is highly influenced by a small group of subjects who belong to a specific community. Furthermore, unlike the case of high biological productivity, the treatment which combines formal and informal enforcement mechanisms did not produce the lowest level of extraction under the low biological productivity scenario. Therefore, we decided to explore these results in more depth. After a closer look at subjects' individual characteristics, we realized that those who participated in the experiments in one of the communities differed from the rest of the subjects in the sample in several respects. Perhaps the most important observed difference is that, for most of the subjects within this specific community, fishing was not reported as the main economic activity and was instead considered a complement to agriculture and livestock husbandry. In addition, this sample was composed entirely of an indigenous community, which was unlike the other communities in the sample.

After considering the results described above, we decided to conduct a regression analysis with the individual harvesting decision as the unit of observation. We proceeded to estimate a Tobit econometric model to evaluate the effects of treatments on extraction decisions. The model was chosen because of the characteristics of the dependent variable (harvest) in which individual extraction is censored by the values of 1 as a lower limit and 8 as an upper limit. We estimated the model separately for high biological productivity and low biological productivity scenarios. Specification of the estimated equation is the following,

$$x_{it} = f(ENFOR\ TREATMENT_{it},\ INDIVIDUAL\ CHARACT_{it}, OTHER\ CONTROLS) \qquad (7)$$

where x_{it} is the extraction level of individual i in round t. The independent variables considered herein are classified into three groups, including enforcement treatment (*ENFOR* TREATMENT), individual characteristics (*INDIVIDUAL CHARACT*), and other controls (*OTHER CONTROLS*).[13]

The first group of variables includes *FORMAL_HIGH* and *FORMAL_LOW*, which are dummy variables equal to 1 if the treatment is formal (external) enforcement under the high biological productivity or low biological productivity scenarios, respectively; *INF_HIGH* and *INF_LOW*, which are also dummy variables equal to 1 if the treatment is informal (local) enforcement under the high and low biological productivity scenarios, respectively; and *FORMAL+INF_HIGH* and *FORMAL+INF_LOW* which are, respectively, dummy variables taking a value equal to 1 if the treatment is a combination of formal and informal enforcement under high or low biological productivity scenarios. We use these last two variables as a base for comparison.

The second group of variables includes: age of the individual in years (*AGE*), a dichotomous variable to control for an individual's gender (*GENDER*), a dichotomous variable indicating whether the individual is a member of an indigenous community (*LAFKENCHE*), years of schooling (*YEARS-SCHOOLING*), number of household members (*NMEMBERS*), a dichotomous variable indicating whether the income of the individual is the main source of income for his/her household (*MAIN_INCO*), an indicator of whether the individual is the owner of a boat (*OWN_BOAT*), and an indicator of whether the individual is the owner of fishing gear (*OWN_GEAR*). We also include a dichotomous variable indicating whether the main activity is fishing (*MAIN_ACT_FISH*) and a countable variable indicating a range for the level of income from 1 (lowest) to 5 (highest) (*INCOME*).

The third group of variables includes a dichotomous variable indicating whether the individual agrees with a regulation that includes a quota for extraction (*AGREE_QUOTA*) and a dichotomous variable indicating whether the organization to which the subject belongs has currently implemented a surveillance/patrolling system (*SURVEILLANCE*).

The econometric results are presented in Table 8. To evaluate the robustness and stability of estimated parameters of interest, different specifications were estimated for each scenario of biological productivity. The results with respect to our variable of interest indicate that, under the

[13] The details of the construction of independent variables are presented in Table 7.

high biological productivity scenario and holding everything else constant, the level of individual extraction is higher under the formal enforcement mechanism used alone than under the combination of formal and informal enforcement. However, we do not find that the combined enforcement treatment reduces extraction compared to informal enforcement under the high biological productivity scenario.

The results of the regression analysis for the low biological productivity scenario suggest that, when controlling for indigenous community membership, under both formal enforcement and informal enforcement, the level of individual extraction is higher than under a treatment in which both enforcement mechanisms are used in combination.

Additionally, with respect to the use of enforcement by fishermen, although the imposition of penalties on quota violators is expensive for both punisher and punished, penalties were used in all groups in which this treatment was applied, except in one group with co-management in an abundance scenario. Thus, lower extraction levels were obtained than with formal enforcement. We further explored the data related to punishment that was collected during the experiment. This analysis suggests that punishment tended to be used more frequently but was less effective in a scarcity scenario than in resource abundance.

Table 9 presents the results when participants were given an opportunity to sanction peers under the treatments of informal enforcement and co-management for both scenarios of biological productivity. Under both informal and combined enforcement, fishermen made use of the sanctioning opportunity more frequently during the scarcity scenario than during the abundance scenario. This result holds not only for the frequency of sanctioning peers but also for the level of sanctions imposed. Furthermore, under the scenario of high biological productivity, the willingness to punish peers was greater under co-management than under informal enforcement alone. By contrast, under the scarcity scenario, we observe less propensity to sanction peers under co-management than under the informal enforcement mechanism alone. These results suggest that, while formal enforcement tends to complement informal enforcement, it may also crowd out efforts by the group to control peers under low biological productivity.

Our results suggest that a hybrid of formal and informal regulation may induce more compliance and do a better job of improving natural resource conservation than either formal or informal regulation used separately. The existing literature has offered a number of possible explanations for why the combination of formal and informal regulation may work, as in our case. Frey and Stutzer (2008) discuss the role of environmental morale and environmental motivation in individual behavior from the point of view of economics and psychology.

Environmental morale and motivation affect individuals' behavior as users of common-pool resources. Intrinsically motivated people voluntarily contribute to public environmental goods, at least if others also contribute, and are willing to bear the costs to punish fellow citizens who do not cooperate. Frey and Stutzer (2008) contend that a crucial question is how intrinsic motivation and internalized norms are influenced by extrinsic motivation. For example, if a norm is internalized, sanctions are internal and result in feelings of guilt, reduced self-respect and other negative self-evaluations, which could operate as additional deterrence mechanisms.

Communication is a precondition for reciprocity via learning about and acknowledging the duties and responsibilities of other people. Experiments show that communication systematically increases the intrinsic motivation to cooperate. In our research, all treatments encourage communication before the first round, which we expect to strengthen intrinsic motivation and internalization of the norm; thus, informal enforcement (in which members both communicate and participate in decision-making) is expected to achieve lower extraction and transgression levels in comparison to formal enforcement. However, the fact that a combination of formal and informal enforcement has better compliance results could be explained by the notion that subjects understand that this combination is necessary, i.e., they see it as an effective co-management strategy and not as two separate regulations. As suggested by Cárdenas et al. (2000), government regulations, along with the efforts of local communities through active communication at the local level, might avoid inducing more self-interested behavior.

6. Conclusions

We explore the effects of applying different enforcement mechanisms on individual harvest and compliance behavior under a system of TURFs using field experiments from behavioral economics. We evaluate the effect of formal (external), informal (local), and combined formal and informal enforcement on extraction decisions under different scenarios of biological productivity within managed areas.

Our results indicate that, for all treatments, the levels of individual harvest are significantly different with respect to the predicted Nash equilibrium, although they are closer to this equilibrium than to the social optimum in both abundance and scarcity scenarios. Moreover, we found differences related to extraction (and compliance) under different scenarios of resource availability. Harvesting levels are below the Nash equilibrium under the CPR baseline treatment, formal enforcement, informal enforcement, and combined formal and informal enforcement in the case of a high biological productivity scenario. In contrast, in a scarcity scenario, all treatments present extraction levels above the Nash equilibrium, except in the case of the informal enforcement treatment. Our findings are consistent with Blanco et al. (2011), Maldonado and Moreno-Sánchez (2009), and Moreno-Sánchez and Maldonado (2010). Individual extractions under the CPR depend on the level of resource availability. Specifically, when resource levels are low enough to jeopardize resource conservation, individuals' behavior seems to consistently result in an intensification of extraction.

These results provide evidence that, regardless of the level of biological productivity within managed areas, the combination of formal and informal enforcement mechanisms was more effective than formal enforcement alone in reducing individual extraction and transgressions. However, in the case of abundance, we did not find that co-management produced better results than informal enforcement. Consequently, these results indicate that the presence of the government through formal (external) enforcement could be more relevant in cases of low biological site productivity, when individuals may be less willing to impose costly sanctions upon their peers, yet at the same time face a greater risk of reducing available stocks to levels below critical thresholds.

We have found that peer punishment for violating quotas is used among all groups to which the treatment was applied in at least one round, except in one group under co-management in an abundance scenario, thus achieving lower extraction and transgression levels in comparison to formal enforcement.

Our results suggest that the willingness to punish peers in a group decreased in a scarcity scenario and increased in an abundance scenario. Moreover, the results suggest that, while formal (external) enforcement tends to complement the informal enforcement mechanism, it may also crowd out efforts by the group to control peers under conditions of low biological productivity.

Taken together, our results tend to confirm the recent findings of Lopez et al. (2013), who, using framed field experiments, found that formal government regulations may be complementary to informal community efforts, at least in the case of high biological productivity. These results have implications for the design of natural resource management based on decentralized efforts.

First, the fact that hybrid regulation can perform better in terms of compliance and resource conservation suggests that there may be limits to decentralization in natural resource management.

Second, the active use of punishment within groups suggests the relevance of control by peers for successful co-management of resources. Although the proper strategies to increase control by the local communities in managed areas is beyond the scope of this work, we can mention a few. For example, it seems that transforming informal enforcement into a more formal enforcement strategy could be useful if the formalized strategy is undertaken by the community. This may require communities to increase participation among members of organizations, design and agree on formal rules, increase leadership representation, and improve the coordination between organizations and the formal authority (i.e., government). Furthermore, these efforts could also be supported by the central authorities' provision of assistance to organizations in terms of strengthening and supporting enforcement capacities (e.g., subsidizing monitoring equipment, coordinating monitoring actions between fishers and the formal authority, etc.).

Finally, the fact that subjects reacted in different ways to resource availability indicates that the proper design of spatially-based regulation should give careful consideration to heterogeneity of sites' biological productivity. In the context of an increase in the use of TURFs-based regulation, there is more competition for access to fishing areas, and therefore areas with lower biological productivity are being allocated to user groups. In this situation, it may be critical for the government to participate through formal enforcement in order to avoid biological and economic tragedy at these sites.

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Appendix

Tables and Figures

Table 1: Values of the Parameters

Parameter	p	β	α	e	θ	m	S
Value	140	1600	20	8	1/5	200	40;80

Source: Authors, based on the experiments carried out in this work.

Table 2: Extraction Levels and Experimental Points Expected Per Round

	High productivity[a]			**Low productivity**[a]		
	Stage 1		**Stage 2**	**Stage 1**		**Stage 2**
Extraction level	x_i^{nash} 6	x_i^{social} 2	$x_i^{nash\_Externa}$ 4	x_i^{nash} 3	x_i^{social} 1	$x_i^{nash\_Externa}$ 2
Individual payment (esper. points)	680	840	800	740	820	800
Group profit	3400	4200	4000	3700	4100	4000

Source: Authors, based on the experiments carried out in this work.

[a]The minimum and maximum level of extraction for the players varies between 1 to 8 units.

Table 3: Description of the Application of Experiments

Experiment /Treatment	**Stage 1 (1-10 rounds)**	**Total Players**	**Total Observations**	**Stage 2 (11-20 rounds)**	**Total Players**	**Total Observations**
Experiment 1[a]	CPR baseline	60	600	Formal Enforcement [b]	60	600
Experiment 2[a]	CPR baseline	60	600	Informal Enforcement (peer monitoring and sanction)	60	600
Experiment 3[a]	CPR baseline	60	600	Formal Enforcement + Informal Enforcement	60	600

Source: Authors, based on the experiments carried out in this work.

[a] The totals include the abundance and scarcity scenarios.

[b] Low monitoring and public disclosure of formal enforcement.

Table 4: Descriptive Characteristics of Fishermen

Characteristics	Descriptive (Mean/percentage)	Standard Deviation
Number of participant fishermen	180	-
Age (years)	44	13.2
Years of schooling	7	2.9
% Male	83	-
% Female	17	-
Number of members of the Lafkenche community	10	-
% Fishermen	31	-
% Divers	45	-
% Coastal collectors	17	-
% Boat owners	6	-
% Performs no fishing activity (economic)	22	-
% Constitutes main household income	76	-
Number of members of the household	4	1.4
% Income range less than or equal to 100,000 pesos	35	-
% Income range between 100,001 and 200,000	39	-
% Income range between 200,001 and 300,000	16	-
% Income range between 300,001 and 400,000	3	-
% Income over 400,001	6	-

Source: Authors, based on the experiments and survey carried out in this work.

Table 5: Wilcoxon-Mann-Whitney Non-parametric Test, CPR Baseline (First Stage)

<table>
<tr><th colspan="2">Comparison</th><th>Extraction theory</th><th>Extraction average</th><th>p-value</th></tr>
<tr><td rowspan="4">High biological productivity</td><td rowspan="2">Exp. 3 v/s Exp. 1</td><td>6</td><td>4.8</td><td rowspan="2">0.6771</td></tr>
<tr><td>6</td><td>4.8</td></tr>
<tr><td rowspan="2">Exp. 3 v/s Exp. 2</td><td>6</td><td>4.8</td><td rowspan="2">0.4628</td></tr>
<tr><td>6</td><td>4.9</td></tr>
<tr><td rowspan="4">Low biological productivity</td><td rowspan="2">Exp. 3 v/s Exp. 1</td><td>3</td><td>3.8</td><td rowspan="2">0.2211</td></tr>
<tr><td>3</td><td>4.0</td></tr>
<tr><td rowspan="2">Exp. 3 v/s Exp. 2</td><td>3</td><td>3.8</td><td rowspan="2">0.6770</td></tr>
<tr><td>3</td><td>3.7</td></tr>
</table>

Source: Authors, based on the experiments carried out in this work.

Table 6: Wilcoxon-Mann-Whitney Non-parametric Tests, Second Stage

Comparison		Treatments	Extraction theory	Extraction average	*p-value*[a]
High biological productivity	Exp. 3 v/s Exp. 1	Formal+Informal	4	2.3	0.0000 [0.0126]
		Formal	4	3.0	
	Exp. 3 v/s Exp. 2	Formal+Informal	4	2.3	0.7022 [0.8530]
		Informal	4	2.4	
Low biological productivity	Exp. 3 v/s Exp. 1	Formal+Informal	2	2.5	0.0497 [0.5878]
		Formal	2	2.7	
	Exp. 3 v/s Exp. 2	Formal+Informal	2	2.5	0.0208 [0.1980]
		Informal	2	1.9	

Source: Authors, based on the experiments carried out in this work.

[a] Results of the tests in brackets when each observation is obtained as a mean extraction of each subject over the 10 rounds played under a given treatment.

Table 7: Description of the Variables Used in the Econometric Model

Name of the variable	Description
Dependent Variable model	
Harvest (x_{it})	Individual decision of Chilean abalone extraction. Values of 1 as lower limit and 8 as upper limit.
Independent variables	
FORMAL_HIGH	1 If it corresponds to a round between 11 and 20 in which the formal treatment with high level of biological activity has been applied; 0 if not
FORMAL_LOW	1 If it corresponds to a round between 11 and 20 in which the formal treatment with low level of biological activity has been applied; 0 if not
INF_HIGH	1 If it corresponds to a round between 11 and 20 in which the informal treatment with high level of biological activity has been applied; 0 if not
INF_LOW	1 If it corresponds to a round between 11 and 20 in which the informal treatment with low level of biological activity has been applied; 0 if not
FORMAL+INF HIGH	1 If it corresponds to a round between 11 and 20 in which the formal+informal treatment with high level of biological activity has been applied; 0 if not
FORMAL+INF LOW	1 If it corresponds to a round between 11 and 20 in which the formal+informal treatment with low level of biological activity has been applied; 0 if not
AGE	Fisherman's age in years
GENDER	Gender of the fishermen 1. Male 2. Female
LAFKENCHE	1 If the fisherman belongs to the Lafkenche community; 0 if not
YEARS-SCHOOLING	Years of formal education
NMEMBERS	Number of people who depend economically on the fisherman
MAIN_INCOME	His job is the main source of income for his household. 1. yes; 0. if not
OWN-BOAT	1 If the fisherman owns a boat; 0 if not
OWN_GEAR	1 If the fisherman owns the materials used in fishing (fishing nets, compressors, wet suits, etc.); 0 if not
ACTIVITY	Main activity category artisanal fishery record (RPA): 1. Diver; 2. Fisherman; 3. Owner; 4. Coastal collector
OTHER_ACTIVITY	1 If the fisherman performs non-fishing labor activities that contribute to his income; 0 if not
MAIN_ACT_FISH	1 If the main activity is fishing; 0 if not
INCOME	Income range: 1. Less than or equal to 100,000 pesos; 2. Income between 100,001 and 200,000; 3. Income between 200,001 and 300,000; 4. Income between 300,001 and 400,000; 5. Income higher than 400,001
AGREE_QUOTA	1 If agrees with extraction quota; 0 if not
SURVEILLANCE	1 If organization has a surveillance system; 0 if not

Table 8: Tobit Model Results Estimation

Dependent Variable HARVEST	TOBIT 1 (ABUNDANCE)	TOBIT 1B (ABUNDANCE)	TOBIT 2 (SCARCITY)	TOBIT 2B (SCARCITY)
	Coefficient	Coefficient	Coefficient	Coefficient
FORMAL_HIGH	.8919281*** (.14768)	.8061302*** (.17215)	-	-
INF_HIGH	.1134976 (.14882)	.1662951 (.18967)	-	-
FORMAL_LOW	-		2.535348*** (.37968)	2.451256*** (.39242)
INF-LOW	-		.9889811*** (.38422)	1.567193*** (.38999)
AGE	-	-.01106** (.00530)	-	-.0167702 (.01313)
GENDER	-	-.61649* (.36148)	-	-.9335353* (.5310902)
LAFKENCHE	-	-	5.009577*** (.48285)	3.441982*** (.64337)
YEARS-SCHOOLING	-	-.0126537 (.02891)	-	-.1067867** (.04870)
NMEMBERS	-	.1612222*** (.05817)	-	-.6295982*** (.11057)
MAIN_INCO	-	.2218289 (.19981)	-	2.332572*** (.36860)
OWN_BOAT	-	-.566455*** (.18914)	-	.6907423* (.40630)
OWN_GEAR	-	.4325838** (.17378)	-	-.7225252* (.41649)
ACTIVITY	-	.1826883* (.10463)	-	.2666522 (.18359)
OTHER_ACTIVITY	-	.4227586*** (.15836)	-	-1.017231** (.418717)
MAIN_ACT_FISH	-	-.33966106 (.28364)	-	-1.730794*** (.52641)
INCOME	-	-.1409092** (.06931)	-	-.0846758 (.11855)
AGREE_QUOTA	-	-.5606326*** (.2057287)	-	1.545643** (.63727)
SURVEILLANCE	-	-.0753396 (.16087)	-	-.3100923 (.30662)
CONSTANT	2.065126*** (.10516)	3.17612*** (.69093)	-1.004218*** (.32941)	2.672552 (1.66778)
Number of observations	900	900	900	900

Source: Authors, based on the experiments carried out in this work

*: $p \leq 0.10$; **: $p \leq 0.05$; ***: $p \leq 0.01$; standard errors in brackets.

Table 9: Use of Sanctions on Peers within Groups under Informal Enforcement and Co-management by Scenario of Biological Productivity

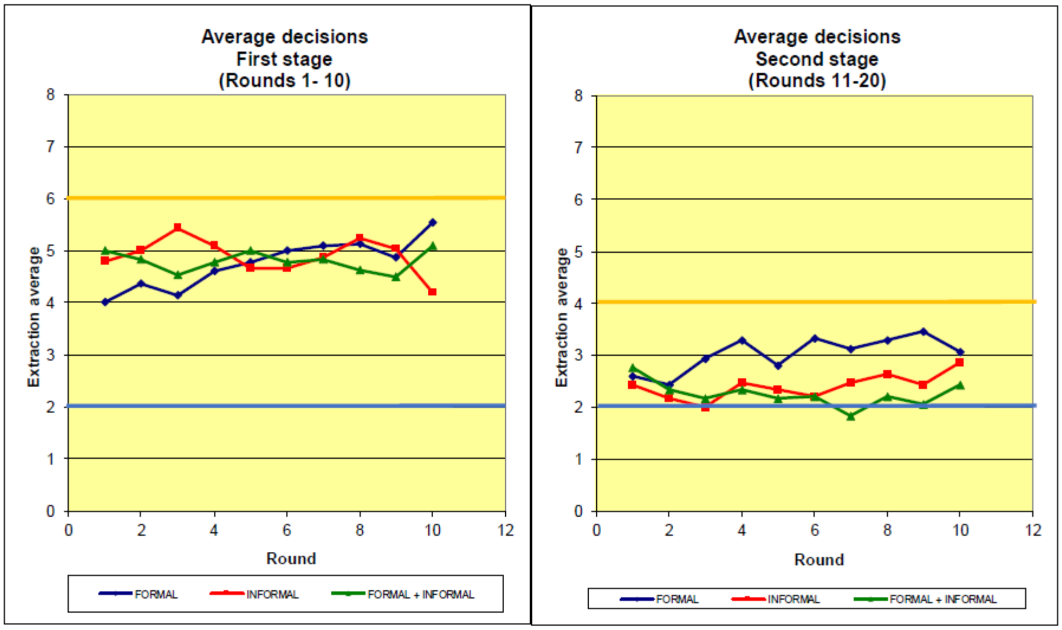
Treat/Scenario	Cost for the punisher[a]	Count[b]	%
Informal (local) Enforcement Abundance	0	228	73.8
	6	53	17.2
	12	12	3.9
	18	16	5.2
	Total	309	100
Formal + Informal Abundance	0	207	62.5
	6	63	19.0
	12	33	9.9
	18	28	8.5
	Total	331	100
Informal (local) Enforcement Scarcity	0	151	43.4
	6	72	20.7
	12	32	9.2
	18	93	26.7
	Total	348	100
Formal + Informal Scarcity	0	191	56.9
	6	59	17.6
	12	19	5.7
	18	67	19.9
	Total	336	100

Source: Authors, based on the experiments carried out in this work.

[a] The individual cost associated with each penalty option: 0, 18, 36, and 54.

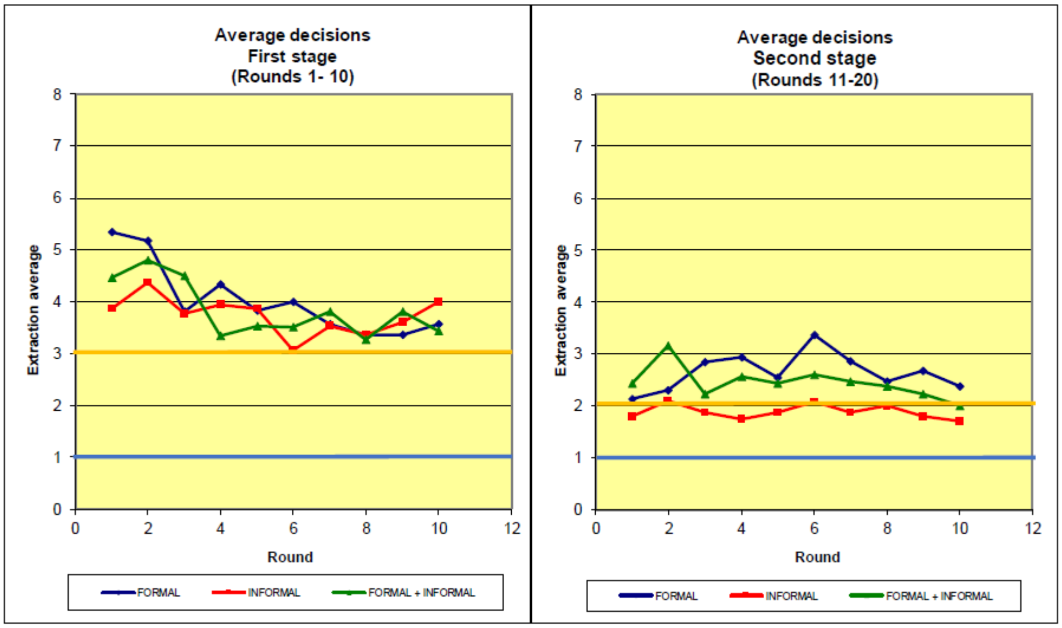
[b] Number of times that a sanction with this individual cost was imposed under this treatment (all rounds included). In the case of zero cost, the figure presents the number of fishers-rounds who did not use the sanctioning option.

Figure 1: Extractions for Treatment (First and Second Stage)-High Biological Productivity



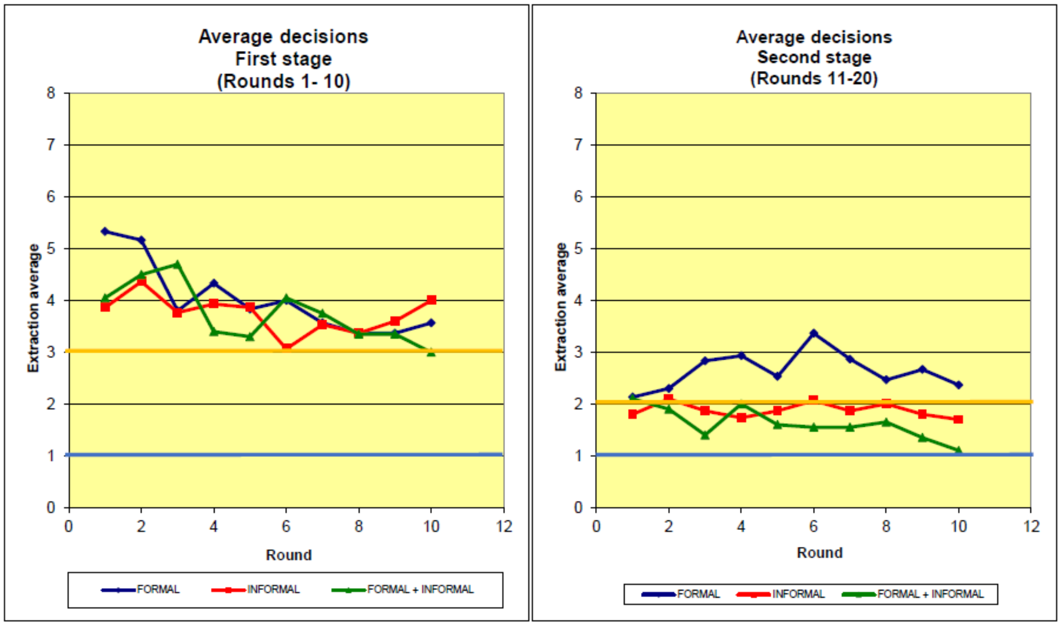
Source: Authors, based on the experiments carried out in this work.

Figure 2a: Extractions for Treatment (First and Second Stage)-Low Biological Productivity



Source: Authors, based on the experiments carried out in this work.

Figure 2b: Extractions for Treatment (First and Second Stage)-Low Biological Productivity



Source: Authors, based on the experiments carried out in this work.

Payoff Tables

Abundance: High Biological Productivity

LEVEL OF EXTRACTION OF THE OTHERS "LOCOS"	MY LEVEL OF EXTRACTION OF "LOCOS"							
Total	**1**(100)	**2**(200)	**3**(300)	**4**(400)	**5**(500)	**6**(600)	**7**(700)	**8**(800)
4(400)	830	920	990	1040	1070	1080	1070	1040
5(500)	810	900	970	1020	1050	1060	1050	1020
6(600)	790	880	950	1000	1030	1040	1030	1000
7(700)	770	860	930	980	1010	1020	1010	980
8(800)	750	840	910	960	990	1000	990	960
9(900)	730	820	890	940	970	980	970	940
10(1000)	710	800	870	920	950	960	950	920
11(1100)	690	780	850	900	930	940	930	900
12(1200)	670	760	830	880	910	920	910	880
13(1300)	650	740	810	860	890	900	890	860
14(1400)	630	720	790	840	870	880	870	840
15(1500)	610	700	770	820	850	860	850	820
16(1600)	590	680	750	800	830	840	830	800
17(1700)	570	660	730	780	810	820	810	780
18(1800)	550	640	710	760	790	800	790	760
19(1900)	530	620	690	740	770	780	770	740
20(2000)	510	600	670	720	750	760	750	720
21(2100)	490	580	650	700	730	740	730	700
22(2200)	470	560	630	680	710	720	710	680
23(2300)	450	540	610	660	690	700	690	660
24(2400)	430	520	590	640	670	680	670	640
25(2500)	410	500	570	620	650	660	650	620
26(2600)	390	480	550	600	630	640	630	600
27(2700)	370	460	530	580	610	620	610	580
28(2800)	350	440	510	560	590	600	590	560
29(2900)	330	420	490	540	570	580	570	540
30(3000)	310	400	470	520	550	560	550	520
31(3100)	290	380	450	500	530	540	530	500
32(3200)	270	360	430	480	510	520	510	480

Scarcity: Low Biological Productivity

	MY LEVEL OF EXTRACTION OF “LOCOS”								
LEVEL OF EXTRACTION OF THE OTHERS "LOCOS"	**Total**	**1**(100)	**2**(200)	**3**(300)	**4**(400)	**5**(500)	**6**(600)	**7**(700)	**8**(800)
	4(400)	820	880	900	880	820	720	580	400
	5(500)	800	860	880	860	800	700	560	380
	6(600)	780	840	860	840	780	680	540	360
	7(700)	760	820	840	820	760	660	520	340
	8(800)	740	800	820	800	740	640	500	320
	9(900)	720	780	800	780	720	620	480	300
	10(1000)	700	760	780	760	700	600	460	280
	11(1100)	680	740	760	740	680	580	440	260
	12(1200)	660	720	740	720	660	560	420	240
	13(1300)	640	700	720	700	640	540	400	220
	14(1400)	620	680	700	680	620	520	380	200
	15(1500)	600	660	680	660	600	500	360	180
	16(1600)	580	640	660	640	580	480	340	160
	17(1700)	560	620	640	620	560	460	320	140
	18(1800)	540	600	620	600	540	440	300	120
	19(1900)	520	580	600	580	520	420	280	100
	20(2000)	500	560	580	560	500	400	260	80
	21(2100)	480	540	560	540	480	380	240	60
	22(2200)	460	520	540	520	460	360	220	40
	23(2300)	440	500	520	500	440	340	200	20
	24(2400)	420	480	500	480	420	320	180	0
	25(2500)	400	460	480	460	400	300	160	-20
	26(2600)	380	440	460	440	380	280	140	-40
	27(2700)	360	420	440	420	360	260	120	-60
	28(2800)	340	400	420	400	340	240	100	-80
	29(2900)	320	380	400	380	320	220	80	-100
	30(3000)	300	360	380	360	300	200	60	-120
	31(3100)	280	340	360	340	280	180	40	-140
	32(3200)	260	320	340	320	260	160	20	-160