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Catch Uncertainty and Reward Schemes in a Commons Dilemma: An Experimental Study

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Abstract We design and conduct a laboratory experiment with students and a field experiment with fishermen to test how catch uncertainty and reward schemes affect extraction in an open access fishery. We find that uncertainty in the relationship between effort and catch increases extraction effort and accelerates resource depletion. Importantly, participants increase their extraction after a disadvantageous shock, but do not react to advantageous shocks. One possible explanation of this phenomenon is a self-serving bias. Price-responsive demand, relative to a fixed price setting, decreases extraction effort and increases efficiency. Price-responsive demand has a greater effect on students than on fishermen living inside a marine protected area, but fishermen outside this restricted area are very responsive to conditional pricing.

Keywords Framed field experiment · Artisanal fishery · Dynamic resource · Stochastic production function

Mathematics Subject Classification C72 · C92 · D03 · Q22 · Q57

The results […] were almost always less restrictive […] than those recommended. […], it was as if the council, when given a confidence limit around a recommended catch level, would always choose the higher end of that range rather than the average or an even more conservative level.

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– James Wilson on the regional fishing councils, which appoint representatives of the major industry stakeholders, in "The Drama of the Commons," 2002

1 Introduction

The economic analysis of environmental uncertainty in common pool resource (CPR) management often focuses on the risk-return tradeoff. Larger uncertainty can be socially desirable as a means to decrease risk exposure, lowering the pressure over the common resource (Bramoullé and Treich 2009; Sandler and Sterbenz 1990). When multiple sources of environmental uncertainty are considered, like stock size and catch per unit effort (CPUE), avoidance of the greatest source of uncertainty defines whether catch quotas or effort quotas are seen as the socially preferred control instrument (Danielsson 2002; Kompas et al. 2008).

The risk-return approach does however not capture a socially undesirable effect of uncertainty: environmental fluctuations triggered by uncertainty can distort social heuristics (e.g., fairness norms) and allow agents to exploit this variability in a self-serving manner (Kwaadsteniet et al. 2006; Roch and Samuelson 1997). The aim of this study is to examine the emergence of this self-serving bias in a controlled environment. We design and conduct a CPR experiment with monetary incentives to investigate whether a self-deceiving effect is triggered by uncertainty.

Previous experiments have explored sources of environmental uncertainty such as stock size (Budescu et al. 1995, 1990) and growth rate (Hine and Gifford 1996; Roch and Samuelson 1997). However, to the best of our knowledge, this is the first economic experiment to introduce CPUE uncertainty. The corresponding experimental manipulation is simple: subjects select a given fishing effort, and each effort unit grants a die roll dictating the catch. Unlike previous manipulations, uncertainty does not dwell within the environment, but rather lies in the effect of a subject's action (i.e., the exerted extraction effort) on observable outcomes (i.e., the caught units).

Our manipulation of uncertainty does not trigger a self-serving misperception of environmental fluctuations, but it rather transfers agency to a randomizing device. Hence, any self-serving bias found in our setting is associated to a loss of agency (i.e., subjects feeling less responsible for the consequences of their actions on others' welfare and on the environment), and not to the provision of imprecise information (e.g., estimates of stock size or growth). In the light of the debate for implementation of catch quotas or effort quotas (Danielsson 2002), a loss of agency effect could alter the conditions under which one control instrument is preferred to the other.

The CPUE, subject to our experimental manipulations, may be interpreted in two ways: as fishing power, which is defined as the product of the fishing gear during a time unit of operation (Sanders and Morgan 1976), or as a measure of stock abundance (Bannerot and Austin 1983). We will focus on the fishing power definition given that the CPUE will be orthogonal to the available stock in the game. Moreover, we will use the term *catch* when referring to CPUE, for the remainder of this paper.

To enhance the external validity of the experiment, as one of our subject pools we use a community of artisanal fishermen located in a marine protected area (MPA) in the Colombian Caribbean. Small-scale fisheries like the one in our study are subject to fishing power variability across diverse artisanal fishing gear, including hand line fishing, gill net fishing, and spear-fishing (Dalzell 1996).[1] There is also evidence of spatial variability in artisanal fishing power (Horta and Defeo 2012), and daily variation of fishing power driven by higher prices at the end of the week (Samy-Kamal et al. 2015).

We propose two payment schemes in our experiment: a fixed price per unit and a price-responsive demand. With a fixed price, the social dilemma is an intertemporal problem: units caught in the current period will not reproduce in the next one, thereby decreasing the stock value. However, in the absence of property rights, the characteristic rivalry of an open access resource minimizes the incentive to maintain the stock at sustainable levels. The demand function, which is inspired by a Cournot game, adds an intratemporal layer to the social dilemma: within each period, a lower total catch increases the price paid per unit, but reduced extraction efforts by other group members provide an incentive for the subject to increase their own extraction effort. Although the Nash equilibrium is the same across pricing schemes, the demand function increases the gains from cooperation.

The demand function emulates exchange platforms that aim to add value and shorten the fish supply chain. One example of such platforms is the model of community supported fisheries (CSFs), in which buyers pay an annual fee in advance for a share of the periodical yield from local fishermen. In exchange for this, commitments regarding more sustainable production are made (Brinson et al. 2011). A shorter fish supply chain is encouraged by cooperation agencies to improve the conditions of fisheries in Africa, Asia, and Latin America (FAO 2008).[2] A controlled experiment is an appropriate way to test such incentives in small-scale fisheries in developing countries.

The experiment was conducted in both the field and the laboratory. In June 2014, 72 fishermen living inside an MPA in the Colombian Caribbean took part in our study. In April 2015, we conducted additional sessions with 88 undergraduate students in a middle-sized Colombian city.

We found that catch uncertainty decreased efficiency by 15 percentage points and accelerated the collapse of the resource by 16 percent. We exploited the random deviations from the expected catch to distinguish between positive and negative shocks in terms of profits. It was found that negative shocks caused subjects to increase their extraction effort, and the probability of choosing the suboptimal maximum extraction effort increased from 13 to 23 percent, whereas positive shocks did not impact extraction effort.

Moreover, we found that conditional pricing had a cooperation-increasing effect for our student sample, but we did not observe the same effect for our initial sample of fishermen. We obtained additional evidence from another community of fishermen living on the same island but outside the MPA and showed that responsiveness to the payment scheme is directly correlated with the community's characteristics such as enforcement of social norms and access to markets. The efficiency gains derived from the demand function seem to be driven by the ability to respond to the previous choices made by other group members. For the students, the foregone opportunity to increase the price per catch kept the average extraction

[1] For instance, in Fiji, the fishing effort from handlining ranges from 0.14 to 12.12 kg/(line × hour), with an average of 2.27 kg/(line × hour); and the fishing effort from gill net fishing ranges from 15 to 26 kg/set (average of 18.9 kg/set) in Rabi Island, and from 10 to 60 kg/set (average of 31.8 kg/set) in Rotuma Island.

[2] The FAO report (2008) conveys this idea: "The challenge is not to produce more fish but to sell the same quantities of catches for better prices. The quality of the product supplied by artisanal fishermen is crucial for realizing higher prices. Improving quality requires good logistics for transporting, handling and preserving fish, as well as consciousness of the need to maintain the quality of fish along the fish distribution chain. Customers, who are willing to pay for quality, exist everywhere in Latin America. They are normally restaurants, specialized fish shops and some supermarkets."

effort at low to intermediate levels. For fishermen outside the MPA, the threat of falling in a negative reciprocity spiral kept the aggregate extraction effort at a low level.

2 Related Literature

The economic modelling of uncertainty in commons' dilemmas has focused on the risk-return tradeoff. Early contributions applied stochastic dynamic programming to bio-economic models of fisheries.[3] Under imperfect property rights, price uncertainty is found to be efficiency-enhancing because it decreases total extraction in the short run and the number of firms in the long run (Andersen 1982).

Subsequent game theoretical contributions shed light on the mechanism behind the efficiency-enhancing effect of uncertainty. Given an increase in the uncertainty associated with the common good, subjects move closer to the socially optimal behavior to reduce their individual risk exposure. This pattern is found for an open access fishery with catch uncertainty (Sandler and Sterbenz 1990), and for a pollution game in which higher emission levels increase the variance of the damage (Bramoullé and Treich 2009). The same outcome is obtained when uncertainty is modelled as ambiguity rather than as a measurable risk (Aflaki 2013). Due to ambiguity aversion, pessimistic beliefs cause the efficiency levels to increase in equilibrium.

Most of the experimental evidence in commons' dilemmas contradicts the efficiency-enhancing effect of environmental uncertainty (Kopelman et al. 2002). This is predicted for large uncertainty levels in coordination resource dilemmas (Rapoport and Suleiman 1992), but not in cooperation resource dilemmas.

In the coordination games, a group of n subjects make separate extraction requests from a resource of unknown size. Requests are granted if the total request does not exceed the realized stock size, otherwise the payoff is zero for all n subjects.[4] Greater uncertainty in the stock size is associated with larger requests, regardless of whether the requests are simultaneous (Budescu et al. 1990, 1992; Gustafsson et al. 1999; Kwaadsteniet et al. 2006) or sequential (Budescu et al. 1995, 1997). By contrast, group size uncertainty decreases the requested amounts (Au and Ngai 2003; Kwaadsteniet et al. 2008). Gustafsson et al. (1999) and Kwaadsteniet et al. (2006) discard that a perceptual bias, associated with issues relating to information processing, could explain that stock size uncertainty leads to larger requests. The two remaining explanations, supported by their experimental evidence, are an outcome desirability bias associated with overoptimistic expectations; and a self-serving bias triggered by the environmental fluctuations.

By cooperation games we refer to the traditional CPR dilemma with an inefficient dominant strategy representing overharvesting. Hine and Gifford (1996) find, for this game, an efficiency-diminishing effect of stock size and growth rate uncertainty. Roch and Samuelson (1997) report the same finding for an uncertain growth rate and, in addition, employs a measure of social value orientation to argue that non-cooperators extract more than cooperators because the former may interpret high resource fluctuations as a cue to abandon social heuristics (e.g., fairness). When the social dilemma is based on the provision rather than in the appropriation of a public good, uncertainty concerning returns of public good provi-

[3] Andersen and Sutinen (1984) provides a review of such models, grouping them into two categories: linear control problems with perfect property rights, and models with multiple firms exploiting a common resource. Firms are endowed with a utility function to account for the effects of risk preferences.

[4] Strictly speaking, this game is not a "dilemma" because sacrificing the appropriation of one unit less does not increase the social welfare, it only decreases the chances of a null payoff.

sion decreases cooperation. By contrast, uncertainty concerning the returns of the tokens not contributed to the public good increases contributions (Gangadharan and Nemes 2009).

Cárdenas et al. (2013) and Moreno-Sánchez and Maldonado (2010) introduced a deterministic, intertemporal, separation between catch and extraction effort. However, to the best of our knowledge, ours is the first study to introduce catch uncertainty. The difference with respect to previous manipulations is that uncertainty does not dwell in an environmental variable (e.g., stock size, group size, growth rate). Instead, it connects a decision variable, the exerted effort, with an environmental variable, the catch size. This manipulation allows testing a transfer of agency as a mechanism driving the socially undesirable effects of uncertainty. There is experimental evidence that delegation, a specific case in which agency is transferred to another subject, can lead to more self-interested actions (Fershtman and Gneezy 2001; Hamman et al. 2010).

Another consequence of a stochastic catch is that environmental fluctuations differ between subjects in a given round. The within-group differences in the realized catch can be interpreted as idiosyncratic (as opposed to correlated) shocks, and therefore transfers would play a role in these settings due to a higher demand for insurance (Friedl et al. 2014). Cherry et al. (2015) show that, in a public goods game, the presence of idiosyncratic negative shocks lead to transfers for risk pooling (although cooperation rates remained unaffected). Charness and Genicot (2009) report how positive income shocks in infinitely repeated games lead to transfers as a form of mutual insurance. However, ex ante inequality decreases these transfers.

Conditional reward schemes, such as our price-responsive demand, provide focal points that facilitate coordination. These schemes remain mostly unexplored in experimental resource dilemmas.[5] By contrast, conditional rewards have been shown to have positive effects in voluntary contribution mechanisms such as threshold public good games (Cadsby and Maynes 1999; Croson and Marks 2000) and in experimental labor market exchanges (Fehr et al. 1998; Gneezy and List 2006; Shearer 2004).

One methodological contribution from our experiment is how we introduce the resource dynamics. Previous experiments have introduced the dynamics of the resource in several ways including time-dependent externalities (Herr et al. 1997), intergenerational decision-making (Chermak and Krause 2002; Fischer et al. 2004), density-dependent renewal rates (Janssen et al. 2010), and a linear growth rate between decision periods (Cárdenas et al. 2013). Our implementation of a logistic growth function to emulate the fishery dynamics is biologically intuitive but also simple to grasp for participants.

3 The Model

The backbone of our model captures the rivalry and non-excludability of a CPR. It has three key elements: a stochastic production function, a pricing scheme for selling the resource, and the resource's logistic growth function.

3.1 The Decision Problem

There are n subjects, indexed by $i \in \{1, \ldots, n\}$, who have access to a resource of size X_t in period t. Subject i's decision consists of choosing an extraction effort level e_t^i in every

[5] The low payoffs resulting from larger harvest levels are associated to the concavity in the joint production function (Ostrom 2006). Anderson and Holt (2004) makes the analogy between this strategic setting and a Cournot model with individuals ignoring the negative externalities from their (harvested) quantity decisions.

period. Each unit of extraction effort is associated with an increase in subject i's catch, y_t^i, which we define below.

Each unit that is caught is sold at price $P_t(Y_t)$, which is a function of the aggregate catch in period t, $Y_t = y_t^i + Y_t^{-i}$. The term Y_t^{-i} represents the aggregate catch of the other group members, and is a function of their aggregate extraction effort, E_t^{-i}. Given the open access nature of the resource, e_t^i and E_t^{-i} are strategic substitutes. There is also a cost $c(X_t)$ associated with each extracted unit, which increases as the the stock size X_t decreases. The maximization problem for individual i can be written as:

$$\begin{aligned} &\underset{\{e_t^i\}}{\text{Max}} && \sum_{t=1}^{\infty} \delta^{t-1} \left[P_t(Y_t) - c(X_t)\right] y_t^i(e_t^i, E_t^{-i}) \\ &\text{subject to} && X_{t+1} - X_t = F(r, X_t) - Y_t. \end{aligned} \tag{1}$$

The intertemporal restriction in the maximization problem describes the resource dynamics. The difference in the stock level between two consecutive periods, $X_{t+1} - X_t$, equals the amount of renewed resource according to the growth function $F(r, X_t)$ minus the total amount extracted Y_t. The resource dynamics are described using a logistic functional form, as in the Gordon–Schaefer bio-economic model (Gordon 1954). That is, $F(r, X_t) = rX_t - rX_t^2/K$. The parameter r is the intrinsic growth rate and K represents the carrying capacity of the resource. In our experiment, r is set at $1/3$ and K is set at 100 units. The initial stock is set at the same level ($X_0 = K = 100$).

The catch has an additive uncertainty component. Hence, y_t^i is written as the sum of a deterministic and a stochastic component. The deterministic part captures the technological efficiency γ of each extraction effort unit. The stochastic part captures a random shock ω_t^i linked to each extraction effort unit, which is identically and independently distributed. The catch is expressed as follows:

$$y_t^i = \gamma e_t^i + \omega_t^i e_t^i. \tag{2}$$

We set $\gamma = 3$ and assume three equiprobable states of nature for the random component $\omega_t^i \in \{\omega^-, \omega^0, \omega^+\}$. The states of nature ω^-, ω^0, and ω^+ correspond to a negative, a null, and a positive shock, respectively, attached to each extraction effort unit. We set $\omega^- = -2$, $\omega^0 = 0$, and $\omega^+ = 2$.

We assume that extraction effort is costless ($c(X_t) = 0$). The main reason for this is to minimize the confounding effects of other-regarding preferences and risk preferences.[6] The costless extraction effort strengthens the intertemporal layer of the social dilemma. Subjects maximize their current catch given the difficulty of securing future property rights. However, by doing so, they decrease the value of the future stock. Another reason for a costless extraction effort is to keep the decision-making simple because the experiment is conducted in the field.

The game is finitely repeated. There are three termination rules that are common knowledge to the group: (a) players reach the terminal period of the game $T = 10$; (b) the stock level X_t falls below a threshold $\tilde{C} \equiv 12$ and the resource is closed; or (c) the total catch is at least as high as the current stock level ($Y_t \geq X_t$) and the resource collapses. If, in the last period of play, $Y_t < X_t$ (i.e., when rules (a) or (b) apply), subjects do not receive any

[6] With a costly extraction effort, a higher concavity in the subject's utility function will be associated with lower extraction levels. We acknowledge that extraction effort decisions under uncertainty are influenced by risk preferences (Bramoullé and Treich 2009). Nevertheless, the aim of this study is to explore other mechanisms triggered by uncertainty such as self-deception.

additional payoff for the remaining stock. If $Y_t > X_t$ (i.e., when rule (c) applies) the available units are divided proportionally according to the intended individual catches. Given the short duration of the experiment and the lack of individual-specific feedback fostering reputational incentives, we assume that there is no time discounting ($\delta = 1$).

In our experimental setting, we define groups of $n = 4$ subjects, each of whom can choose an extraction effort $e_t^i \in \{1, 2, 3\}$. Hence, by replacing y_t^i, Y_t, and $F(r, X_t)$, we can rewrite the maximization problem as:

$$\begin{aligned} &\underset{\{e_t^i\}}{\text{Max}} && \sum_{t=1}^{10} I_{X_t > \tilde{C}} \left[P_t \left(e_t^i, e_t^{-i} \right) \times \left(\gamma e_t^i + \omega_t^i e_t^i \right) \right] \\ &\text{subject to} && X_{t+1} - X_t = \left(r X_t - \frac{r X_t^2}{K} \right) - \sum_{i=1}^{n=4} \left(\gamma e_t^i + \omega_t^i e_t^i \right), \end{aligned} \tag{3}$$

where $I_{X_t > \tilde{C}}$ is an indicator function equal to 1 if the stock size exceeds the threshold $\tilde{C}$, or 0 otherwise.

Next, we discuss predictions based on this model for either a fixed price or a price-responsive demand.

3.2 Predictions with a Fixed Price

With a fixed price, the above maximization problem becomes trivial. The solution for a risk-neutral decision-maker is to exert extraction effort equal to $e_t^i = 3, \forall t$. This is also the subgame perfect Nash equilibrium for the game.[7] This is because each additional extraction effort unit will increase the catch by at least one unit at zero cost. If all group members follow this strategy, the expected aggregate catch per period will be $E(Y_t) = 36$, the resource will last for three periods before crossing the threshold $\tilde{C}$, and the total extraction $\boldsymbol{Y} = \sum_t Y_t$ will be 108 units.

This Nash equilibrium is suboptimal with respect to a social planner's solution. A social planner will also consider the tradeoff between the immediate benefits of extraction and the future value of the stock, i.e., the total aggregate catch $\sum Y_t^i$. In contrast, an individual will only internalize his own contribution to the resource's depletion, Y_t^i.

The social optimum will provide a total catch that is 50% larger than that under the Nash equilibrium, and the resource's duration is extended to its maximum length. The discreteness of the strategy set allows for multiple paths leading to this solution.[8] Nonetheless, these paths are similar: a medium to high extraction effort early in the game (periods 1 and 2), a low extraction effort in the intermediate periods, and a medium to high extraction effort at the end of the game (periods 9 and 10). The intuition for the extraction paths is as follows. It is optimal to initially move toward the stock level that maximizes the growth rate $X_t = (K/2)$. Once this stock level is reached, the extraction effort should be minimized to make the difference between the harvest and the reproduced stock as small as possible.[9]

7 Because of the repeated nature of the game, other Nash equilibria may appear if we withdraw the assumption that $\delta = 1$.

8 The feasible aggregate extraction effort level ranges from four units (when $e_t^i = 1 \,\forall\, i$) to 12 units (when $e_t^i = 3 \,\forall\, i$).

9 The same outcome would be the steady-state solution in an infinite horizon game. With a finite horizon, as in our situation, the incentive to deplete the resource before the end of the game increases the extraction effort levels in the final periods.

Table 1 Price offered as a function of the aggregate catch

Quantity	4–12	13–20	21–28	29–40	41–60
Price/unit	5	4	3	2	1

3.3 Predictions with a Price-Responsive Demand

In the case of a price-responsive demand, the price is a decreasing function of the group's aggregate catch. This demand function adds another intratemporal layer to the social dilemma. Specifically, this reflects the tension between the collective interest in increasing the price and the individual incentive to maximize the catch and free-ride on the others' contributions to raising the price.

The price-responsive demand function in our setting is shown in Table 1. The function was calibrated to assure that risk-neutral subjects cannot unilaterally increase the price by deviating from a symmetric extraction effort, e_t^i. It can easily be confirmed that an increase in the price requires at least two subjects to reduce their extraction effort. Hence, the Nash equilibrium $e_t^i = 3, \forall t$ remains unaltered under this demand function, and no other symmetric equilibria appear.

A social planner could maximize either aggregate income or aggregate catch. Income maximization gives an aggregate of \$672 and an expected aggregate catch of 159 units. Catch maximization gives an aggregate catch of 162 units and an aggregate income of \$666. In both cases, the resource lasts for its maximal length and the extraction path is the same as that described above.

We take catch maximization as a reference point to achieve the same maximum aggregate catch across pricing schemes. In the experiment, we set the fixed price at $P = \$2, \forall t$ to achieve the same total income of \$216 under the Nash equilibrium in both pricing schemes. This allows us to interpret any additional income obtained in the treatments with the demand function as the result of deviations from own-payoff-maximizing behavior.

4 Experimental Design

4.1 Experimental Conditions

We employ a 2×2 between-subjects experimental design. The first source of exogenous variation is whether the catch is *stochastic* or *deterministic*. The second source of variation is the pricing scheme. Groups were randomly assigned to either a fixed price per catch (*fixed*) or the price-responsive demand (*demand*).

In the *stochastic* condition, the catch has both a deterministic and a stochastic component, as shown in Eq. (2). The deterministic part is associated with an expected catch ($\gamma = 3$) per extraction effort unit. The stochastic part is represented by a random shock $\omega \in \{\omega^-, \omega^0, \omega^+\}$ per extraction effort unit. In the experiment, this random component was framed as follows. Each participant received three foldable paper boats (see panel B in Fig. 2). The folding direction of each paper boat indicate whether a fishing journey (i.e., an extraction effort unit) was taken or not. Each fishing journey gives the participant a numbered die to be rolled. The three equiprobable outcomes dictate the catch associated with that fish journey. The catch could be one (when $\omega = \omega^- = -2$), three (when $\omega = \omega^0 = 0$), or five units (when $\omega = \omega^+ = 2$).

Table 2 Experimental design. Each cell explains the treatment combinations and contains the number of participants from the fishermen (N^F) and student (N^S) samples

	Fixed	Demand
Stochastic	Fixed price and stochastic environment $N^F = 16$ $N^S = 24$	Price-responsive demand and stochastic environment $N^F = 16$ $N^S = 24$
Deterministic	Fixed price and deterministic environment $N^F = 20$ $N^S = 20$	Price-responsive demand and deterministic environment $N^F = 20$ $N^S = 20$

In the *deterministic* condition, the catch is given by γe_t^i, the first element in Eq. (2). Participants in this treatment also received the three paper boats to indicate how many fishing journeys (i.e., extraction effort units) they were willing to undertake in each period. Unlike the *stochastic* condition, no die rolling was involved. Instead, in the *deterministic* condition, each fishing journey granted an additional catch of three units.[10]

Regarding the pricing schemes, in the *demand* condition, the price is a function of aggregate extraction, $P_t(Y_t)$, as described in Table 1. In the *fixed* condition, the price is $P_t = \$2\,\forall t,\ Y_t$. Recall that $P = \$2$ is the predicted price in the *demand* condition when subjects play the Nash equilibrium.

We conduct the experiment with two subject pools: fishermen and students. Subjects were randomly assigned to one of the four treatment cells in each sample. Table 2 summarizes the number of participants per cell.

4.1.1 Participant Samples

In July 2014, we conducted eight sessions at Barú, an island of 60 km^2 located in the Caribbean Sea. All 72 participants in these sessions were artisanal fishermen living in the Barú *corregimiento*, a municipality subdivision of the city of Cartagena, located 40 km away. Barú is located inside an MPA with 820 households. Fishing is the main economic activity for around 140 individuals in the MPA, but most of the households are, directly or indirectly, related to the fishing activity (Villamil et al. 2015). The MPA imposes fishing gear restrictions subject to strong social norms. Fishermen use low extractive techniques (e.g., handlines, harpoons, and fish traps), and enforce the prohibition of more extractive gear (e.g., gill nets and drag nets) by communicating any breach of the rules to the environmental authorities (see "Appendix B" for more details).

Fishermen earned an average of 22,900 Colombian pesos (COP) from the CPR game, plus 6600 COP from an incentivized risk-elicitation task (see footnote 14). Average total earnings

[10] The use of a dice roll in the *stochastic* condition, but not in the *deterministic* condition, might raise an heterogeneous experimenter demand effect (Zizzo 2010). The "fun" from rolling dice might induce a greater extraction effort. Our design attempts to mitigate this problem by using a fixed number of dice, regardless of the extraction effort choice.

were roughly equivalent to 1.4 times the daily minimum wage.[11] Sessions lasted for between 80 and 100 min.

In April 2015, we conducted 10 sessions at the Universidad Autónoma de Bucaramanga with a total of 88 students, mostly from the undergraduate programs in economics and law. The students were invited to participate via a general mailing list one week before the study took place. They did not have any previous experience participating in economic experiments.

All of the sessions were conducted in a large classroom on the university campus. We conducted eight sessions with eight participants and two sessions with 12 participants. On average, the students earned 22,800 COP from the CPR game. Each session lasted for between 60 and 80 min.

4.2 Experimental Procedures

After the participants' arrival, the game instructions were read aloud to the whole group (see "Appendix D" for the transcripts of the instructions). Instructions were not provided in written form because of the moderate literacy rates among the sample of fishermen. Once the procedure was understood, the participants signed the consent form.

All of the groups in each session were assigned to a specific treatment: *stochastic + fixed*, *stochastic + demand*, *deterministic + fixed*, or *deterministic + demand*. Balance across treatments is reported in Tables 7 and 8 for fishermen, and in Table 9 for students.[12] Groups were spatially isolated from each other to avoid contamination during the disclosure of group-specific information. Subjects could identify their fellow group members, but not their choices. Any form of communication was forbidden throughout the entire activity.

Throughout the experiment, there were two posters in front of each group of four participants, one to keep track of the current stock (see panel A in Fig. 2) and the other with the price list from Table 1 (only in the *demand* condition).

In every period, the timing of the game was as follows: (i) subjects decided on the number of extraction effort units (fishing trips). (ii) Subjects received a numbered die for each extraction effort unit. To ensure anonymity of decisions, participants also received a number of null dice in case of non-maximal extraction effort. Thus each participant was rolling the same number of dice, and the resulting noise could not be used by other group members to infer decisions. On each six-sided die, the values 1, 3, and 5 each appeared twice (see panel C in Fig. 2). The sum of the outcomes indicated the participant's catch in that period. (iii) The monitor privately took note of each participant's catch. Then, he publicly announced the aggregate extraction effort and the aggregate catch, and computed the stock level for the next period. (iv) The price was computed according to the pricing scheme. It was common knowledge that this process would be repeated until one of the three termination rules (as discussed in Sect. 3.1) applied.

[11] Average total earnings (29,500 COP) corresponded to approximately \$15.7 US dollars (based on an exchange rate of 1 USD = 1880 COP in August 2014). Colombia's daily minimum wage in 2014 was 20,533 COP.

[12] In the fishermen community, groups of four subjects were formed using a quasi-random procedure. Quasi-randomness allowed us to balance participants from different fishermen's associations and to allocate family members (e.g., siblings from different households) to different groups. In the student sample, assignment to groups was entirely random.

5 Results

In the following section, we compare efficiency and individual extraction effort choices across the two dimensions in our experimental design, namely, the catch uncertainty and the pricing scheme. Each dimension is then analyzed in more detail in Sects. 6 and 7.

5.1 Group-Level Outcomes

Table 3 shows the comparison across experimental conditions in terms of efficiency, resource duration, and aggregate catch. Our unit of observation is the group of four fishermen. We perform a Mann–Whitney U test comparing groups across conditions. Column (3) shows the differences across catch conditions (*stochastic* vs *deterministic*), while column (6) shows the comparison across pricing schemes (*fixed* vs *demand*). Efficiency is defined as the ratio between the realized and the maximum group earnings. Therefore, efficiency is equal to zero for the Nash equilibrium prediction and equal to one for the social planner's solution.

We find that catch uncertainty decreases efficiency, resource duration, and total catch. This result is similar to previous findings with uncertain stock size and growth rate (Hine and Gifford 1996; Roch and Samuelson 1997). However, this effect is only statistically significant in the student sample. The decrease in efficiency of 14.8 percentage points represents a drop of 26% with respect to the socially optimal solution. In absolute terms, groups in the *stochastic* and *deterministic* conditions are, on average, far from the Nash equilibrium outcome represented by a zero efficiency level. This is also reflected in the game duration, which is at least twice that expected under the Nash equilibrium predictions. The difference between treatments is significant, and the effect is also driven by the students. A survival analysis yields the same results for the comparison across treatments in terms of resource duration (see "Appendix C"). The difference in total catch shows that a longer resource duration does not necessarily imply a lower aggregate harvest. Instead, it means that subjects postpone their share of the total extraction effort in favor of future interactions.

The comparison between the *fixed* and the *demand* pricing schemes yields similar results. The *demand* pricing scheme increases efficiency, resource duration, and total catch. The differences are significant in the pooled sample, but the effect is again driven by the student sample. The efficiency gap between the *fixed* and the *demand* pricing schemes is 14.6 percentage points, or 26%.[13] Similar to the comparison across catch conditions, this efficiency gap is the result of a longer duration of the game combined with a higher total catch under the *demand* condition compared with the *fixed* condition.

[13] The result is robust to an alternative measure of efficiency, namely, the ratio between the hypothetical and the maximum group earnings, *as if* everyone would have been paid according to Table 1. The intuition underlying this alternative measure is that if the efficiency gap between payment schemes is small, the more complex payment scheme is not salient. The most relevant comparison with the alternative efficiency measure is across payment schemes. Table 11 shows that for students, the efficiency gap reaches 19 percentage points, or 33%. By contrast, for fishermen, the efficiency gap only reaches 0.7 percentage points. Looking at the comparison between the *stochastic* and the *deterministic* conditions on the left side of the table, the efficiency gap reaches 29%. This gap in favor of the *demand* condition is slightly larger than that under the original efficiency measure.

Table 3 Comparisons between payment schemes using Mann–Whitney tests: efficiency, resource duration, and total catch

	Catch			Pricing scheme		
	Stochastic	*Deterministic*	Diff.	*Fixed*	*Demand*	Diff.
Efficiency						
Pooled ($N_g = 40$)	0.413	0.561	– 0.148**	0.414	0.559	– 0.146**
	(0.189)	(0.192)	[0.024]	(0.205)	(0.175)	[0.044]
Fishermen ($N_g = 18$)	0.443	0.547	-0.103	0.455	0.547	– 0.093
	(0.186)	(0.207)	[0.398]	(0.214)	(0.184)	[0.426]
Students ($N_g = 22$)	0.392	0.574	– 0.182**	0.380	0.569	– 0.189*
	(0.196)	(0.186)	[0.037]	(0.201)	(0.176)	[0.053]
Duration [*periods*]						
Pooled	6.20	7.40	– 1.20**	6.35	7.25	– 0.90*
	(1.32)	(1.50)	[0.021]	(1.59)	(1.33)	[0.065]
Fishermen	6.63	7.50	– 0.875	7.00	7.22	– 0.22
	(1.30)	(1.72)	[0.341]	(1.73)	(1.48)	[0.787]
Students	5.92	7.30	– 1.38**	5.82	7.27	– 1.45**
	(1.31)	(1.34)	[0.032]	(1.33)	(1.27)	[0.023]
Total catch						
Pooled	129.35	137.55	– 8.2***	130.35	136.55	– 6.2*
	(10.37)	(7.49)	[0.007]	(11.07)	(7.51)	[0.089]
Fishermen	130.13	137.7	– 7.58	132.56	136.11	– 3.55
	(9.97)	(8.06)	[0.138]	(11.54)	(7.18)	[0.654]
Students	128.83	137.4	– 8.57**	128.55	136.91	– 8.36*
	(11.04)	(7.32)	[0.034]	(10.88)	(8.10)	[0.070]

The unit of observation, N_g, is a group of four participants
Standard deviations are in parentheses
p-values are in square brackets, $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

5.2 Individual Extraction Effort

We adopt a regression analysis to explore the differences in extraction effort decisions across treatments and evaluate the effect of catch uncertainty, as well as the differences across payment schemes, on the subjects' choices.[14]

In each period, subjects choose whether to exert 1, 2, or 3 units of extraction effort. Hence, we employ an ordered logistic regression with the extraction effort decision as the dependent variable. Random effects are added to control for multiple observations per subject. Given the dynamic nature of our CPR game, we control for the current stock level using a quadratic polynomial and cluster the standard errors at the group level. We limit our sample to periods

[14] We also tested the effect of risk preferences, but did not find any correlation between risk preference and extraction behavior (results available upon request). The risk-elicitation task, which was part of the post-experimental survey, consists of choosing one of five lotteries that increase simultaneously in terms of expected value and payoff variance (see Table 10). This task was inspired by Binswanger (1980), and has previously been implemented in populations with low literacy levels (Barr and Genicot 2008; Cárdenas and Carpenter 2013; Eckel and Grossman 2008). The task was incentivized in the sample of fishermen and non-incentivized in the student sample.

Table 4 Odds ratios from the ordered logistic model explaining the extraction effort

Dependent variable: e_t^i	Pooled Periods 2–4		Students Periods 2–4		Fishermen Periods 2–4	
	(1)	(2)	(3)	(4)	(5)	(6)
Stochastic	2.228***	2.155***	3.032***	2.958***	1.714	1.714*
	(0.554)	(0.509)	(1.116)	(1.153)	(0.576)	(0.556)
Demand	0.616*	0.639*	0.380***	0.386**	1.001	0.992
	(0.153)	(0.157)	(0.129)	(0.159)	(0.342)	(0.323)
Fishermen	0.852	0.874				
	(0.220)	(0.210)				
Others' lagged catch	0.986		0.983		0.970	
	(0.0228)		(0.0384)		(0.0342)	
Others' lagged extraction effort		1.058		0.987		0.993
		(0.0843)		(0.158)		(0.115)
σ_u^2	3.885***	4.144***	4.493*	4.635*	2.713**	2.907***
	(1.658)	(1.783)	(3.527)	(3.695)	(1.057)	(1.156)
Observations	480	480	264	264	216	216
Number of ID	160	160	88	88	72	72

Additional controls: Second-order polynomial for current stock level (S_t). Standard errors clustered at the group level are shown in parentheses
$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

one to four. In the first four periods, none of the groups collapsed or faced closure of the resource. We do this to avoid overweighting the decisions from groups that manage to exploit the resource for a longer period of time.

The estimation was performed using the maximum likelihood method. Table 4 shows the odds ratios for the ordered logistic regressions.[15] The use of a nonlinear probability model limits the interpretation of the coefficients in their linear form. The odds ratio, representing the coefficient in an exponential form, can be interpreted as the multiplicative effect that an additional unit in the covariate x_k has on the probability of increasing the extraction effort by one unit. We observe that the *stochastic* condition increases the likelihood of exerting one additional unit of extraction effort by approximately 2.2 times with respect to the *deterministic* condition. The effect is larger and statistically significant for students but not for fishermen. In addition, we find that the *demand* pricing scheme decreases the probability of exerting an additional extraction effort unit by approximately $0.36 (= 1 - 0.64)$ times with respect to the *fixed* pricing scheme. This effect is driven by the student sample.

We test the validity of the random effects assumption using the Mundlak correction (Mundlak 1978).[16] The random effects assumption holds when we control for the others' lagged catch or the others' lagged effort (see Table 12 in the "Appendix"). Note that the assumption in the case of others' lagged effort does not hold for the sample of fishermen. However, for this sample we also did not observe any significant effect of the stochastic catch in the first

[15] Results are similar if the ordered logistic regression is replaced by a Poisson model with random effects. The results using the Poisson model are available upon request.

[16] The Mundlak correction consists in adding the individual average for each one of the time-variant covariates into the random effects regression. The test evaluates the joint significance of all the individual averaged time-variant regressors.

place. As an additional check we run the regression removing the random effects, keeping the errors clustered at the group level, and the results do not differ from those reported in Table 4.

6 Explaining the Effect of Stochasticity

Uncertainty increases the malleability of the decision environment (Bénabou and Tirole 2011). As a consequence, self-serving interpretations of catch fluctuations may lead to more self-interested outcomes (Kwaadsteniet et al. 2006; Roch and Samuelson 1997). That is, responses to profitable and unprofitable shocks to the catch-to-effort ratio do not compensate each other. To test this hypothesis, we run an additional ordered logistic regression with the subsample of subjects that faced the *stochastic* condition. As in the previous section, we limit our sample to periods one to four, add random effects to the model, and cluster the standard errors at the group level.

Table 5 shows the odds ratios for this logistic model. The regressors of interest in columns (1) and (2) are the catch-to-effort ratio from each subject, $(y/e)^i_{t-1}$, and from the subject's fellow group members, $(Y/E)^{-i}_{t-1}$. The coefficients for these variables should be equal to one (as odds ratios are multiplicative effects) only if a previous fluctuation in the catch does not affect the current decision. Instead, we find a coefficient that is significantly less than one. This can be interpreted in two ways: either an increase in $(y/e)^i_{t-1}$ is associated with a decrease in extraction effort, as if subjects compensate for their "good luck" by decreasing the future extraction effort, or a decrease in $(y/e)^i_{t-1}$ entitles the subjects to increase their future extraction effort to compensate for their "bad luck."

We test whether the responses to positive and negative deviations with respect to the expected $(y/e)^i_{t-1}$ are symmetric. We substitute $(y/e)^i_{t-1}$ for two categorical variables indicating a positive shock ($y/e > 3$) and a negative shock ($y/e < 3$). The results of testing this behavior are shown in columns (3) and (4). While we do not find responses to positive shocks, a negative and disadvantageous shock increases the likelihood of exerting an additional extraction effort unit by 2.4 times. In absolute probabilities, this is equivalent to an increase of 10 percentage points in the probability of choosing $e = 3$ (from 13 to 23%), which is compensated for by a reduction of 15 percentage points in the probability of choosing $e = 1$ (from 39 to 24%). This effect is not statistically different among fishermen and students (regression results not shown but available upon request).

The asymmetric responses to advantageous and disadvantageous shocks appears to be the mechanism behind the efficiency-decreasing effect of catch uncertainty. We argue that catch fluctuations allow self-deceiving or self-serving interpretations of the decision environment (Kwaadsteniet et al. 2006). This reasoning is aligned with theoretical models in which uncertainty increases self-deception through an increase in the malleability of beliefs (Bénabou and Tirole 2011). Thus, we argue that in this particular case, the self-serving bias acts as a transfer of agency from the subject to the randomizing device, the die. This result is in line with previous experiments indicating that a transfer of agency to a third party leads to more self-interested actions (Fershtman and Gneezy 2001; Hamman et al. 2010).

While we think that the asymmetric responses to catch fluctuations are driven by a self-serving interpretation of the environment, it is worth discussing two alternative explanations: income targeting (Camerer et al. 1997), and inequity aversion in an unpredictable environment (Fehr and Schmidt 1999; Friedl et al. 2014).

The idea behind income targeting is that subjects set an earnings goal. Disadvantageous shocks make them less willing to cooperate in the future in order to catch up with their

Table 5 Odds ratios for the catch-to-effort ratio (y/e) explaining effort exerted

Dependent variable: e_t^i	(1)	(2)	(3)	(4)
Lagged catch-to-effort ratio $(y/e)_{t-1}^i$	0.799**	0.795**		
	(0.0783)	(0.0777)		
Others' lagged catch-to-effort ratio $(Y/E)_{t-1}^{-i}$	0.635**	0.560**		
	(0.128)	(0.137)		
Positive shock			1.411	1.396
			(0.439)	(0.436)
Negative shock			2.487***	2.430***
			(0.835)	(0.838)
Others' positive shock			1.014	0.903
			(0.486)	(0.387)
Others' negative shock			2.606**	3.045**
			(1.219)	(1.644)
Demand	0.393***	0.410***	0.356***	0.378***
	(0.109)	(0.126)	(0.110)	(0.124)
Fishermen	0.654	0.677	0.632	0.665
	(0.232)	(0.236)	(0.243)	(0.252)
Others' lagged catch		1.022		1.032
		(0.0400)		(0.0374)
σ_u^2	3.408***	3.629***	4.069***	4.614***
	(1.566)	(1.535)	(2.018)	(2.109)
Observations	240	240	240	240
Number of ID	80	80	80	80

Additional controls: second-order polynomial for current stock level (S_t). Standard errors clustered at the group level are shown in parentheses
$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

goal. However this theory fails to explain the asymmetric responses to positive and negative shocks. Assuming the earnings goal is already set, one would expect advantageous shocks to be followed by reductions in extraction effort.

The second alternative explanation is based on a greater dislike of disadvantageous inequality compared to the dislike of advantageous inequality (Fehr and Schmidt 1999). Friedl et al. (2014) show that this behavior holds in an insurance context, and is much stronger for idiosyncratic compared to correlated risks. The idea that a disadvantageous shock decreases your utility from social comparison more than the equivalent increase in utility from an advantageous shock cannot be disentangled from the self-serving explanation by looking only to the responses to the shocks. However, the responses to the aggregate deviation from the other group members shed some light to disentangle the competing theories.

Dislike of disadvantageous inequality would imply that a positive shock in the others' catch should trigger the same response as a negative shock in one's own catch, since in both cases one is getting behind in the average earnings. However, Table 5 shows that the deviation in the lagged catch-to-effort ratio from other subjects, $(Y/E)_{t-1}^{-i}$, has very similar coefficients to the variable $(y/e)_{t-1}^i$.

The first explanation involves limited capacity in information processing. After the die roll, subjects know their own catch and extraction effort. At the end of the period, after the monitor announces the period's aggregate catch and extraction effort, subjects can compute the catch-to-effort ratio from the other group members. However, this is not a simple calculation. Hence, the reported coefficients for $(Y/E)^{-i}_{t-1}$ may actually be capturing the individual responses to the aggregate catch-to-effort ratio $(Y/E)_{t-1}$. If this is the case, our hypothesis regarding the self-serving bias also applies to unexpected fluctuations at the aggregate level. That is, negative shocks faced by the whole group also entitle subjects to increase their extraction effort.

An alternative explanation involves highly sophisticated subjects who are able to anticipate that fellow group members experiencing a negative shock to their catch will increase their extraction effort. Due to the strategic substitutability, the best response to an expected increase in extraction effort by others is a symmetric response, as observed in the data.

7 Explaining the Effect of the Pricing Scheme

In this section, we explore the gains from the *demand* pricing condition in more detail. First, we provide evidence from a neighboring sample of fishermen located outside the MPA boundaries, where subjects are highly responsive to the demand function. Second, we study how the price-responsive demand drives subjects to respond to the history of the game.

7.1 Additional Evidence from Another Sample of Fishermen

In Sect. 5, we saw that fishermen are less sensitive to the manipulations of uncertainty (*stochastic* vs *deterministic*) and pricing schemes (*fixed* vs *demand*) than students. This finding raises the question of whether the fishermen are truly less responsive to these variations or whether our sample of fishermen was biased.

In this section, we report the results of an experiment conducted with another group of fishermen from the same island. The most striking difference between the groups of fishermen is that this second sample is located outside the limits of the MPA. Thus, we refer to our initial sample as the fishermen inside the MPA and to the new sample as the fishermen outside the MPA. The consequences of this geographic difference are lower access to markets and tighter fishing gear constraints for fishermen inside the MPA. A detailed description of the differences between the samples of fishermen is provided in "Appendix B".

In the second sample, we only manipulated one of the variables in our experimental design, given the smaller sample size. All sessions used the *stochastic* environment. We randomly assigned twenty-four subjects to the *fixed*, and another twenty-four subjects to the *demand* pricing scheme. Balance across treatments is reported in Table 13.

Table 6 shows the different responses of the two samples of fishermen to the *fixed* and *demand* pricing conditions. We present results concerning efficiency, but find similar results concerning resource duration and total catch. For the pooled sample of fishermen, the *demand* pricing condition increases efficiency compared with the *fixed* pricing condition. In Sect. 5, we saw that fishermen were not very sensitive to the pricing scheme. By contrast, for fishermen outside the MPA, the differences are larger and statistically significant.

The efficiency under the *fixed* pricing condition was much lower for the fishermen outside the MPA (17%) compared with both the fishermen inside the MPA (26%) and the students (28%). The *demand* pricing condition not only increases efficiency, but also closes the gap between the samples. In fact, efficiency under the *demand* pricing condition is slightly higher,

Table 6 Comparisons between pricing schemes for efficiency (using Mann–Whitney tests). All the subjects reported in this table face a stochastic catch (*stochastic* condition)

	Pricing scheme		
	Fixed	*Demand*	Diff.
Efficiency			
Pooled Fishermen ($N_g = 20$)	0.259	0.518	− 0.259**
	(0.213)	(0.172)	[0.0155]
MPA ($N_g = 8$)	0.398	0.496	− 0.098
	(0.274)	(0.018)	[1.000]
Out-MPA ($N_g = 12$)	0.166	0.533	− 0.366**
	(0.106)	(0.229)	[0.0103]
Students ($N_g = 12$)	0.281	0.503	− 0.222*
	(0.181)	(0.149)	[0.0782]

The unit of observation, N_g, is a group of four participants. The label "MPA" refers to the initial sample of fishermen. The label "Out-MPA" refers to the fishermen introduced in this section. The sample of students is introduced for comparability purposes Standard deviations are shown in parentheses
p-values are shown in square brackets, ***p <0.01; **p <0.05; *p <0.1

albeit statistically insignificant, for the fishermen outside the MPA (53%) than for the fishermen inside the MPA (50%) and the students (50%).[17]

To get a better idea about the relative low efficiency (under the *fixed* pricing condition) for fishermen outside the MPA we might compare them to students. Table 6 reveals that the average efficiency level in the student sample is equidistant to the average efficiency levels reached by fishermen inside and outside the MPA. A descriptive analysis hints that the difference in efficiency levels between fishermen from outside the MPA and students could be tied to the initial extraction effort. A larger aggregate extraction effort at the beginning of the game brings the group closer, and more rapidly, to the stock level yielding the maximum growth rate.

We ruled out the alternative explanation that differences in gender composition (40% women in the student sample) influences cooperation and efficiency levels. Although some experimental evidence suggests that women are more altruistic than men (Eckel and Grossman 1998; List 2004), we did not find any difference in extraction effort between women and men assigned to the *fixed* pricing condition (χ^2 test, p-value = 0.746[18]).

7.2 Interaction Between *Demand* Pricing and History

The *demand* pricing scheme does not alter the unilateral incentives to maximize the extraction effort with respect to the *fixed* pricing condition. Nonetheless, the *demand* pricing scheme raises efficiency by increasing the gains attainable through cooperation, especially among

[17] The responsiveness to a payment scheme with additional price incentives to not overharvest is community-dependent. The community of fishermen added in this section differs from the initial sample in several respects. Therefore, we cannot entirely isolate the factors associated with a higher responsiveness to the *demand* pricing condition. Nevertheless, we can reject the hypothesis that fishermen were not responding to the experimental manipulations as a result of their low level of educational attainment. Fishermen inside the MPA completed 2.8 additional years of education compared with those outside the MPA (see Table 15).

[18] This is a lower bound of the p-value because multiple observations from the same subject are assumed to be independent.

the groups that were behaving more selfishly under the *fixed* pricing condition. The aim of this subsection is to compare how fishermen from inside and outside the MPA, as well as students, react to the increasing gains from cooperation. The key feature of the *demand* pricing condition is that price variation acts as a signal of the collective outcome. Out-of-equilibrium cooperative outcomes are, in principle, sustained by reciprocal behavior. Thus, we analyze the responses to the extraction effort exerted by other group members.

We run an ordered logistic regression for each sample and focus on the first four periods of play. For comparability, and to benefit from a greater variance in choices, we only consider subjects in the *stochastic* condition. Given our interest in reciprocal responses, the variable of interest is the lagged extraction effort of the other group members (E^{-i}_{t-1}) in each pricing scheme.

Regression coefficients are reported in Table 14. Fishermen inside the MPA exhibit anti-reciprocal behavior. The more cooperative the fellow group members' choices, the lower the probability of choosing the minimum extraction effort. This behavior fits what Ostrom (1999) defines as an "unpredicted and strong pulsing pattern" in CPR dilemmas: low aggregate extraction efforts from others trigger individual deviations toward more inefficient extraction levels, and vice versa. This behavior is observed for both the *fixed* and the *demand* pricing conditions, and is consistent with the findings reported in Tables 3 and 6: fishermen inside the MPA are not responsive to the pricing scheme.

Fishermen outside the MPA behave reciprocally in the *demand* pricing condition. The probability of choosing the minimum extraction effort increases when fellow group members also reduce their extraction effort. Falk et al. (2002) show that the presence of conditional cooperators transforms the commons dilemma into a coordination game. Thus, we argue that the *demand* pricing condition amplifies this effect by providing multiple focal points, with cooperative outcomes being more rewarding.

Students also exhibit the anti-reciprocal pattern displayed by fishermen inside the MPA, but only in the *demand* pricing condition. Within the *fixed* pricing condition, neither fishermen outside the MPA nor students respond to the others' extraction effort, partly because the probability of choosing the minimum extraction effort is very low.

Subjects that benefit from the *demand* pricing condition with respect to the *fixed* condition take into account their group's aggregate extraction effort in the past. Surprisingly, attempts to coordinate a low aggregate extraction effort (based on a credible threat of extraction effort maximization otherwise) seem to be as effective as the pulsing pattern that "corrects" temporary increases in the aggregate extraction effort. The realized (or foregone) opportunity to increase the price tends to drive extraction effort levels downwards, increasing efficiency in the *demand* pricing condition.

8 Concluding Remarks

We designed and conducted an experiment in both the laboratory and the field to test how environmental uncertainty affects behavior in a CPR dilemma. Catch uncertainty proved to be efficiency decreasing. We exploited exogenous variations in the catch-to-effort ratio to show that negative shocks entice subjects to increase their extraction effort, whereas positive shocks were not compensated for by a reduction in the extraction effort. This self-serving bias was larger in the student sample compared with the sample of fishermen. Previous experimental evidence showed that uncertainty in the stock size and in the growth rate was efficiency decreasing (Budescu et al. 1995; Hine and Gifford 1996; Kopelman et al. 2002).

We show a similar effect of uncertainty, but unlike previous studies, our manipulation of catch uncertainty introduces a form of environmental variability connecting the subject's action and its consequences. Therefore, the self-deceiving effect of uncertainty cannot be attributed only to a perceptual or an outcome desirability bias since it also involves a loss of agency.

Danielsson (2002) show that the choice between catch quotas or effort quotas depends on the relative magnitude of uncertainty in the stock size and the CPUE. Since the mechanism behind this result is risk-aversion, it would be interesting to study its theoretical and experimental robustness in the presence of a perceptual self-serving bias for stock size variability, and the perceptual bias plus the loss of agency for CPUE variability.

An additional difference with respect to previous manipulations of environmental uncertainty is the idiosyncratic rather than correlated nature of catch fluctuations. Even if the information regarding stock levels and catch becomes very precise, fishermen attributing a low harvest to bad luck may exacerbate the commons problem. It may be technically difficult to decrease the catch variability among artisanal fishermen without raising their extractive capacity. Hence, risk-pooling mechanisms might be a more sustainable solution to minimize the catch variations among groups of fishermen across fishing trips. The potential benefits of these mechanisms remains as an open question for experimental and empirical research.

We also find that a price-responsive demand increases the gains from cooperation, compared with a fixed price per catch, by providing multiple focal points for coordination. Students are responsive to the pricing scheme, but fishermen inside the MPA are not. We present evidence of a neighboring community of fishermen located outside the MPA whose members experienced a large efficiency increase when the demand pricing function was introduced.

We argue that responsiveness to the immediate gains from this pricing scheme is linked to the different value placed by communities to the future stock. Fishermen inside the MPA hold a positive valuation of the future stock, regardless of the pricing scheme. This is the result of a healthier stock level and the commoners' compliance with social norms dictating acceptable harvest levels. Fishermen profit from immediate rewards in the *demand* pricing condition, but this does not change their behavior because the future rewards from the stock were already present in their choice. By contrast, for fishermen outside the MPA, the future stock has a lower (or even null) valuation. There are no institutional arrangements or social norms preventing overharvesting of the resource. Under the *fixed* pricing condition, the best response to the low valuation of the future stock is to overharvest. The *demand* pricing scheme introduces an immediate reward that shifts the expected gains from not overharvesting upwards.

Reward schemes focusing on current benefits are promising, but they need to be pursued with caution. The existing local norms regarding socially acceptable extraction levels may decrease the responsiveness to such incentives, making the implementation of such policies less cost-effective. Subjects who profited from the demand pricing function incorporated their fellow group members' aggregate extraction effort into their choices. Fishermen outside the MPA are able to maintain a low aggregate extraction effort by inducing reciprocal behavior. Although students deviate more often from the minimum extraction effort, the foregone gains from a higher price drive them back to exerting a lower extraction effort.

As a methodological contribution, this study offers a simpler field experimental protocol for resource dilemmas. The randomizing device we introduced is useful for maintaining the participants' focus on the experiment. Moreover, it may also increase the proportion of selfish choices, thereby decreasing the sample-size requirements in the power analysis. It also provides exogenous variations in the experimental outcomes that could be useful in statistical analysis.

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Appendix A: Additional Tables

See Tables (7, 8, 9, 10, 11, 12, 13, 14).

Table 7 Balancing across uncertainty conditions in the sample of fishermen: *deterministic* [n = 40] and *stochastic* [n = 32]

	Deterministic Mean	*Stochastic* Mean	Diff.	*p* value
(a) Fishing inputs and market access				
Sells to local monopsonist	0.775	0.719	0.056	0.590
Boat ownership	0.600	0.563	0.038	0.753
Handlining	0.750	0.594	0.156	0.162
Harpoon	0.550	0.438	0.113	0.350
Fish traps	0.075	0.125	1 0.050	0.484
Gill nets	0.125	0.250	1 0.125	0.175
Drag nets	0.025	0.125	1 0.100	0.100
(b) Socioeconomic characteristics				
Age	41.300	37.719	3.581	0.275
Education (years)	4.000	5.125	1 1.125	0.152
Other economic activity	0.650	0.656	1 0.006	0.957
Weekly earnings (1000 × COP)	151.531	139.375	12.156	0.549
Perceived relative wealth (1–10)	3.525	4.125	1 0.600	0.283
No. adults in household	3.575	3.281	0.294	0.424
No. children in household	1.900	1.875	0.025	0.947
Perceived luck fishing (1–10)	6.000	6.594	1 0.594	0.331
Gambling in dominoes	0.525	0.500	0.025	0.836

***p <0.01; **p < 0.05; *p < 0.1

Table 8 Balancing across pricing schemes in the sample of fishermen: fixed price *(fixed)* [n = 36] and price-responsive demand *(demand)* [n = 36]

	Fixed Mean	*Demand* Mean	Diff.	*p* value
(a) Fishing inputs and market access				
Sells to local monopsonist	0.750	0.750	0.000	1.000
Boat ownership	0.667	0.500	0.167	0.156
Handlining	0.639	0.722	– 0.083	0.455
Harpoon	0.583	0.417	0.167	0.162
Fish traps	0.083	0.111	– 0.028	0.696
Gill nets	0.139	0.222	– 0.083	0.365
Drag nets	0.083	0.056	0.028	0.649
(b) Socioeconomic characteristics				
Age	42.111	37.306	4.806	0.139
Education (years)	4.417	4.583	– 0.167	0.832
Other economic activity	0.639	0.667	– 0.028	0.808
Weekly earnings (1000 × COP)	142.396	149.861	– 7.465	0.711
Perceived relative wealth (1–10)	3.583	4.000	– 0.417	0.455
No. adults in household	3.083	3.806	– 0.722**	0.045
No. children in household	2.167	1.611	0.556	0.134
Perceived luck fishing (1–10)	6.667	5.861	0.806	0.183
Gambling in dominoes	0.500	0.528	– 0.028	0.817

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Table 9 Balancing across catch conditions (*deterministic* [N = 40] and *stochastic* [n = 48]) and pricing schemes (*fixed* [n = 44] and *demand* [n = 44]) for the sample of students [n = 88]

	Mean	Mean	Diff.	*p* value
(a) Balance: catch	*Deterministic*	*Stochastic*		
Age	20.375	20.438	– 0.063	0.9384
Education (years)	13.355	13.448	– 0.093	0.7818
Weekly earnings (1000 × COP)	118.400	126.996	– 8.596	0.7576
No. adults in household	3.375	2.891	0.484	0.1388
No. children in household	1.444	1.259	0.185	0.6442
Perceived luck (1–10)	6.903	6.479	0.424	0.2458
Gender (1 if male)	0.531	0.563	– 0.031	0.7864
(b) Balance: pricing scheme	*Fixed*	*Demand*		
Age	20.400	20.425	– 0.025	0.9748
Education (years)	13.423	13.400	0.023	0.9440
Weekly earnings (1000 × COP)	131.953	116.324	15.628	0.5619
No. adults in household	3.053	3.125	– 0.072	0.8232
No. children in household	1.375	1.286	0.089	0.8208
Perceived luck fishing (1–10)	6.692	6.600	0.092	0.7967
Gender (1 if male)	0.600	0.500	0.100	0.3751

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Table 10 Lotteries proposed to elicit risk-aversion preferences. The r parameter corresponds to the coefficient of relative risk aversion in the utility function $U(x) = (x^{1-r})/(1-r)$. The reported payoffs were offered in Colombian pesos

Lottery	Outcomes	Expected value	Variance in payoffs	Risk aversion range (CRAA)
A	5000–5000	5000	0×10^6	$r > 3.26$
B	4000–8000	6000	4×10^6	$3.26 \geq r > 1.11$
C	3000–11,000	7000	16×10^6	$1.11 \geq r > 0.68$
D	2000–14,000	8000	36×10^6	$0.68 \geq r > 0.47$
E	1000–17,000	9000	64×10^6	$0.47 \geq r > 0$

Table 11 Between-treatment comparisons for an alternative definition of efficiency: the ratio between hypothetical earnings and maximum earnings in the *demand* pricing condition. Hypothetical earnings refer to the earnings that would have been obtained if the *demand* function had also been applied in the *fixed* pricing condition. Efficiency is set at zero for the Nash equilibrium prediction

	Catch			Pricing scheme		
	Stochastic	*Deterministic*	Diff.	*Fixed*	*Demand*	Diff.
Efficiency						
Pooled (N = 40)	0.43	0.603	−0.173**	0.466	0.567	−0.101
	(0.188)	(0.183)	[0.015]	(0.219)	(0.178)	[0.113]
Fishermen (N = 18)	0.493	0.61	−0.117	0.561	0.554	0.007
	(0.175)	(0.212)	[0.374]	(0.225)	(0.186)	[0.895]
Students (N = 22)	0.388	0.596	−0.208**	0.388	0.577	−0.189**
	(0.192)	(0.159)	[0.023]	(0.188)	(0.179)	[0.028]

Standard deviations are in parentheses. p-values are in square brackets, ***$p < 0.01$; **$p < 0.05$; *$p < 0.1$

Table 12 Mundlak correction for the regression reporting odds ratios from the ordered logistic model in Table 4

Dependent variable: e_t^i	Pooled Periods 2–4		Students Periods 2–4		Fishermen Periods 2–4	
	(1)	(2)	(3)	(4)	(5)	(6)
Stochastic	2.379***	2.390***	3.971***	4.033**	1.642	1.651
	(0.681)	(0.700)	(2.080)	(2.315)	(0.587)	(0.591)
Demand	0.572**	0.560*	0.298**	0.268**	0.982	0.997
	(0.162)	(0.170)	(0.148)	(0.170)	(0.350)	(0.356)
Fishermen	0.801	0.806				
	(0.218)	(0.222)				
Others' lagged catch	0.999		1.001		0.992	
	(0.0226)		(0.0314)		(0.0361)	
E_t (others' lagged catch)	0.933		0.885		0.895	
	(0.0506)		(0.0852)		(0.0714)	
Others' lagged extraction effort		1.163		1.125		1.126
		(0.111)		(0.153)		(0.158)
E_t (others' lagged extraction effort)		0.708*		0.608		0.555*

Table 12 continued

Dependent variable: e_t^i	Pooled Periods 2–4		Students Periods 2–4		Fishermen Periods 2–4	
	(1)	(2)	(3)	(4)	(5)	(6)
		(0.143)		(0.230)		(0.168)
α_1	0.0959	0.105	0.0652	0.0711	0.00129	0.000518*
	(0.194)	(0.229)	(0.177)	(0.214)	(0.00542)	(0.00237)
α_2	0.755	0.838	0.567	0.623	0.00912	0.00370
	(1.551)	(1.849)	(1.562)	(1.892)	(0.0387)	(0.0170)
σ_u^2	3.673***	3.855***	4.040**	4.204**	2.381	2.381
	(1.675)	(1.776)	(2.877)	(3.045)	(1.285)	(1.273)
Mundlak test (p value $E_t(.) = 0$)	0.2040	0.0860	0.2050	0.1882	0.1659	0.0515
Observations	480	480	264	264	216	216
Number of ID	160	160	88	88	72	72

Additional controls: second-order polynomial for current stock level (S_t)
Standard errors clustered at the group level are shown in parentheses
$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 13 Balancing across pricing schemes in the sample of fishermen outside the MPA: fixed price (*fixed*) [n = 24] and price-responsive demand (*demand*) [n = 24]

	Fixed Mean	*Demand* Mean	Diff.	p value
(a) Fishing inputs and market access				
Sells to local monopsonist	0.625	0.500	0.125	0.394
Boat ownership	0.625	0.667	− 0.042	0.769
Handlining	0.542	0.917	− 0.375**	0.003
Harpoon	0.042	0.000	0.042	0.323
Gill nets	0.208	0.083	0.125	0.229
Drag nets	0.542	0.375	0.167	0.256
(b) Socioeconomic characteristics				
Age	47.208	49.542	− 2.333	0.564
Education (years)	2.917	1.708	1.208	0.141
Other economic activity	0.458	0.500	− 0.042	0.778
Weekly earnings (1000 × COP)	158.261	170.208	− 11.947	0.775
Perceived relative wealth (1–10)	2.542	3.125	− 0.583	0.244
No. adults in household	3.208	4.167	− 0.958*	0.063
No. children in household	1.875	1.417	0.458	0.242
Perceived luck fishing (1–10)	7.083	6.250	0.833	0.363
Gambling in dominoes	0.542	0.458	0.083	0.573

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Table 14 Random-effects ordered logistic model explaining the exerted extraction effort. Standard errors are clustered at the group level. The estimations are based on the first four periods, the latest point in time at which subjects from all the groups are still allowed to make an extraction effort decision

Dependent variable: Exerted extraction effort e_t^i	Fishermen Inside MPA (1)	Fishermen Outside MPA (2)	Students (3)
Demand	− 1.912*	− 5.443**	1.016
	(1.080)	(2.146)	(1.633)
Others' lagged effort ($\sum_{-i} e_{t-1}^j$)	− 0.439***	− 0.125	0.0651
	(0.152)	(0.250)	(0.230)
Demand × $\sum_{-i} e_{t-1}^j$	0.352*	0.720**	− 0.572**
	(0.186)	(0.330)	(0.253)
α_1	− 10.44*	− 3.140	0.0987
	(5.662)	(2.851)	(1.808)
α_2	− 8.362	− 0.579	2.791*
	(5.704)	(2.689)	(1.688)
σ_u^2	0.854**	2.462	0.304
	(0.378)	(1.823)	(0.447)
Observations	96	144	144
Number of ID	32	48	48

Additional controls: second-order polynomial for the current stock level (S_t)
Clustered standard errors are in parentheses
$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Appendix B: Methodology: Samples of Fishermen and Recruitment in the Field

The two samples of fishermen, inside and outside the MPA, are situated in distant locations on Barú Island. They also differ in terms of their distance from the city of Cartagena, the closest urban agglomeration. Fishermen inside the MPA are further from the city. This translates into transportation costs that are three times greater than those of fishermen outside the MPA.[19]

Fishermen inside the MPA are more constrained in terms of market access and allowable fishing gear than those outside the MPA. Table 15 shows the differences between the two samples of fishermen in terms of fishing inputs, market access, and socioeconomic variables. This information was collected in a post-experiment survey. Regarding market access, it can be seen that the percentage of fishermen selling their catch to a monopsonist is 72% inside the MPA and 56% outside the MPA. The fishermen reported that these buyers were also their source of informal insurance.[20] Harpoons and fish traps are widely employed by fishermen

[19] Land transportation is highly constrained from the south side of the island in vehicles other than motorbikes. Therefore, the best available form of transport for fishermen inside the MPA is a speedboat.

[20] Ice and gas are obtained on credit by the fishermen prior to setting out on their journeys, and paid for with a share of their catch. If the catch is insufficient to repay the debt, the outstanding amount accumulates.

Table 15 Mean tests by sample location. The number of subjects from inside and outside the MPA is 32 and 48, respectively. For categorical variables, we report the p-value for the Chi-squared test (instead of the t-test).

	MPA Mean	Out-MPA Mean	Difference	p value
(a) Fishing inputs and market access				
Sells to local monopsonist	0.719	0.563	0.156^{++}	0.161
Boat ownership	0.563	0.646	– 0.083	0.460
Handlining	0.594	0.729	– 0.135	0.210
Harpoon	0.438	0.021	0.417***	0.000
Cast net	0.250	0.146	0.104	0.248
Fish traps	0.125	0.000	0.125*	0.012
Gill net / trammel	0.125	0.458	– 0.333***	0.001
Drag net / *boliche*	0.000	0.229	– 0.229***	0.003
(b) Socioeconomic characteristics				
Age	48.4	37.7	10.7***	0.001
Education (years)	5.13	2.31	2.81***	0.000
Other economic activities	0.656	0.479	0.177^{+}	0.122
Weekly earnings (1000 × COP)	139.375	164.362	– 24.987	0.397
Perceived relative wealth (1–10)	4.125	2.83	1.292***	0.008
No. adults in household	3.28	3.69	– 0.41	0.275
No. children in household	1.88	1.65	0.23	0.472
Perceived luck when fishing (1–10)	6.26	6.67	– 0.403	0.442
Gambling in dominoes[a]	0.514	0.500	0.014	0.883

The abbreviation COP refers to Colombian pesos

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$; $^{++}p < 0.05$; $^{+}p < 0.10$ considering the full sample of fishermen inside the MPA

[a] Sixty percent of the subjects play dominoes. Of these, 80 percent bet on the outcome of the game

inside the MPA. By contrast, technologies with high extractive capacity such as gill nets and drag nets are widely employed by fishermen outside the MPA. It can also be seen that fishermen inside the MPA are older and more educated, and their perception of relative wealth is greater than that of fishermen outside the MPA, even though the reported earnings are not statistically different.

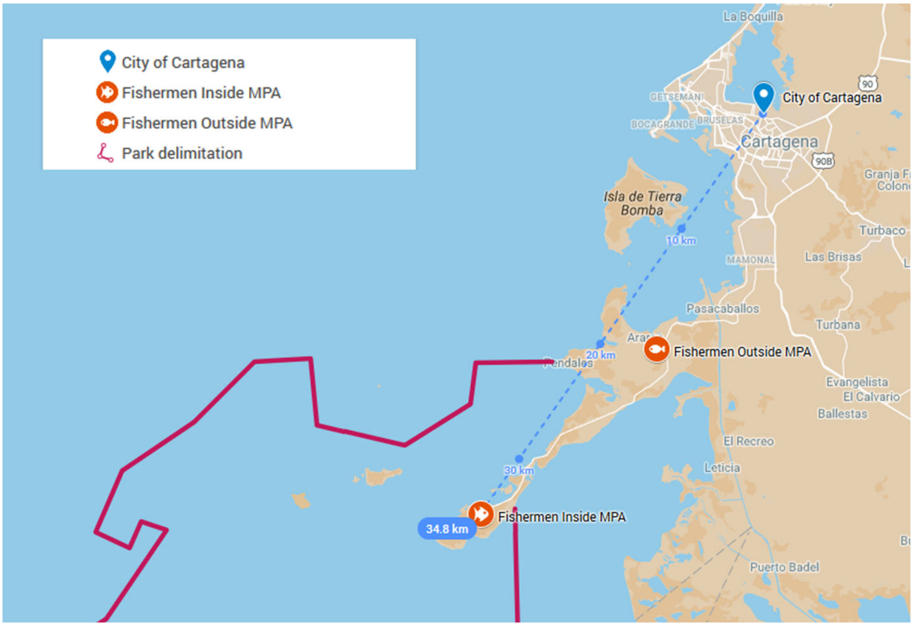

Fig. 1 Map of the National Natural Park "Corales del Rosario y San Bernardo," the marine protected area defining our site location. Park delimitation drawn based on the original map from the: "Plan Básico de Manejo Ambiental (Parques Nacionales)." The purple line defines the limits of the park. Map data ©2018 Google. (Color figure online)

B.1 Recruitment

The participants located in the MPA were recruited with the help of a local member of the research team who is a part-time fisherman and the head of a fishermen's association.[21] He had previous experience in a scientific project involving survey-data collection. We agreed on a recruitment target of 60 to 75 participants, or about half of the fishermen in the community. The fishermen were invited to participate in the activity two weeks in advance. For each session, we invited a roughly equal number of participants from each of the four fishermen's associations, which are geographically distant from each other within the community, although the fishermen from the different associations generally know each other. All of the sessions were conducted in a communal room. To minimize selection issues, the sessions were conducted in the afternoons because the fishermen work from 5:00 to 13:00. We conducted four sessions with eight participants, three sessions with 12 participants, and one session with four participants. These numbers were predetermined, and the variance was the result of our sampling requirement of including fishermen from different associations in each group of four participants.

The experiment outside the MPA was conducted a week after the sessions with the fishermen inside the MPA. The recruitment procedure was similar. We contacted the head of each fishermen's association three weeks in advance, and they extended the invitation to the members of their respective associations. We had a meeting a week before the experiment commenced to explain the details of the sampling procedure (Fig. 1).

[21] Fishermen's associations facilitate the collective ownership of assets such as boats and storage equipment. They also serve as a source of informal insurance (Villamil et al. 2015).

Appendix C: Survival Analysis

We use survival analysis to consider a larger set of covariates in the between-treatments comparison of resource duration. Survival analysis directly exploits the variation in the final period in which group k is observed. The final period is denoted as T^F. When $T^F < 10$, we say that the "failure event," or the last period in which the stock level exceeds the threshold $\tilde{C} = 12$, occurred in T^F. When $T^F = 10$, we do not observe this "failure event," and the data for this group are censored.

The Cox proportional hazards model yields the effect that a covariate x_j has on the probability of the failure event occurring. The estimation is defined in terms of the hazard function $h(t_j)$, which is the instantaneous failure rate. The model's underlying assumption is that the effect of the vector of covariates $\boldsymbol{X_j}$ is time-invariant. Hence, the hazard function is written as:

$$h(t_j) = exp(\boldsymbol{X_j \beta}).$$

We estimate $\boldsymbol{\beta}$ via the maximum likelihood method. The exponential form of each element β_j is interpreted as the hazard ratio of the variable x_j, that is, the relative probability of failure given two different levels of x_j. When $exp(\beta_j) > 1$, an additional unit of x_j increases the probability of failure by $100 \times (exp(\beta_j) - 1)$ percent. When $exp(\beta_j) < 1$, a unit increase in x_j is associated with a decrease in the probability of the failure event of $100 \times (1 - exp(\beta_j))$ percent.

Table 16 reports the hazard ratios for different model specifications. The *STO* treatment is associated with an increase of between 229 and 291 percent in the probability of failure. That is, in every period of the game, the probability of depleting or closing the resource is at least twice as large with the stochastic catch as it is with the deterministic catch. The result is robust to controlling for a categorical variable for fishermen. Indeed, the hazard ratios in columns 3 and 4 indicate that the probability of failure for the sample of fishermen is about 40 percent lower than that for students. The results are also robust to multiple interactions between covariates (see columns 4 to 6).

The *demand* pricing condition decreases the probability of failure by about $100 \times (1 - 0.6) = 40$ percent with respect to the *fixed* pricing condition. The coefficient becomes statistically significant once we control for whether the participant is a fisherman.

We check the proportional hazards assumption using the Schoenfeld residuals test. The χ^2 value is statistically insignificant in every specification. Therefore, we cannot reject the possibility that the residuals follow a random pattern over time and the Cox model's assumption is valid.

Table 16 Hazard ratios using the Cox proportional hazards model

	Hazard ratios (1)	(2)	(3)	(4)	(5)	(6)
Stochastic	2.287***	2.315*	2.379***	2.480**	2.648***	2.905**
	(0.647)	(1.012)	(0.673)	(1.004)	(0.883)	(1.315)
Demand	0.643	0.652	0.563**	0.591	0.556**	0.605
	(0.187)	(0.307)	(0.160)	(0.269)	(0.164)	(0.274)
Stochastic × demand		0.974		0.912		0.847
		(0.591)		(0.537)		(0.502)
Fishermen			0.603**	0.601*	0.683	0.693
			(0.155)	(0.156)	(0.241)	(0.239)
Stochastic × Fishermen					0.777	0.747
					(0.405)	(0.391)
Schoenfeld residuals PH test						
χ^2 global test	1.76	2.82	1.23	2.21	2.1	3.02
	[0.416]	[0.420]	[0.746]	[0.698]	[0.718]	[0.697]
Observations	313	313	313	313	313	313

Standard errors clustered at the group level are shown in parentheses
p values from the χ^2 test are shown in square brackets, $^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

Appendix D: Experimental Protocol

The following instructions will be given in Spanish to the participants. The participants could interrupt and ask questions at any time. Whenever the following type of text e.g. [MONITOR: Complete the example removing 20 magnets and inserting again 5 magnets.] is found below, it refers to specific instructions to the monitor at that specific point that will not be read out loud.

Instructions

Greetings. We want to thank everyone here for attending the call, and specially thank to (the local organization that helped in the logistics) who made this possible. We will spend about two hours and a half between explaining the exercise, playing it and finishing with a short survey at the exit. So, let us get started.

The following exercise is a different and entertaining way of participating actively in a project about the economic decisions of individuals. Besides participating in the exercise, and being able to earn some cash, you will participate in a community workshop next (date and time of the meeting) to discuss the exercise and other matters about natural resources.

Once the game finishes, we will ask you some information about you and your community, and then we will give you what you earn during the game. All the collected information will be treated anonymously, the other participants will not know during or after the experiment, about your individual decisions and earnings. The funds to cover these expenditures have been donated by the Latin American and Caribbean Environmental Economics Program.

1. Introduction

It is very important that while we explain the rules of the game you do not engage in conversations with other people in your group. This exercise attempts to recreate a situation where

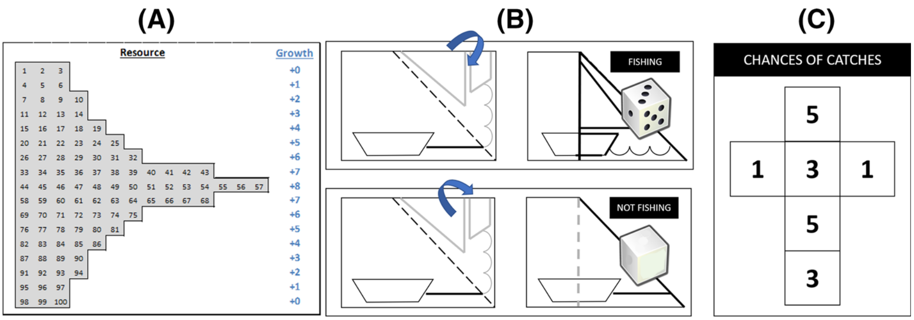

Fig. 2 Panel A. Resource Board. The cells on the left represent the current stock level. The cerulean cells on the right represent the resource's growth. Panel B. Fishing form. According to the side in which it is folded it represents one additional effort unit [FISHING] or not [NOT FISHING]. Panel C. Unfolded dice. The three possible yield levels, 1, 3 and 5, were equally likely to be draw

a group of families must make decisions about how to use the resources of a fishery. In the case of this community, an example would be the extraction of (name of a fish usually caught in the community) in the (name of an actual local commons area in that village) zone.

You have been invited to participate in a group of four people. The game in which you will participate now is different from the ones others have already played in this community, thus, the comments that you may have heard from others do not apply necessarily to this game. This experience is also different from other games in which you could have been invited to participate years before.

In this game you will play for several periods that are equivalent, for instance, to weeks of work in which you can complete between one and three fishing trips.

At the end of the game you will receive your earnings in cash according to the amount of money you accumulate during the exercise. Your earnings will be approximated to the closest multiple of $1,000 [MONITOR: Give a couple of examples of how to approximate the game earnings.].

2. The Resource Board

Let us begin by presenting the RESOURCE BOARD (See panel A in Figure 2). We will suppose that there are initially 100 units of fish, corresponding to each one of the magnets in the board. Suppose now that in a given period, or a week in our game, the total amount of resource caught among the four players was 20 units. This means that we will remove the last 20 magnets of the board.

Before moving to the next week or period, the remaining fish in the RESOURCE BOARD will reproduce. The number of newborn fish will depend on the actual number of fish. At the end of each period, we will count the remaining fish and read the blue number on the right side of the board indicating the resource's GROWTH for that specific stock level. We will add this number of magnets into the RESOURCE BOARD [MONITOR: Complete the example removing 20 magnets and inserting again 5 magnets.].

As you may have noticed, when there is a lot of fish the resource does not grow rapidly. This is because there is not enough food for all the fish to reproduce. Similarly, when there is few fish the resource neither grows rapidly. This is because there are not enough fish that can reproduce themselves. Now that we know how the resource is reproduced let's move to understand how we can extract it.

3. The Fishing Trips

Every week, or period, you can make up to three FISHING TRIPS. Each period you will receive three FISHING FORMS (See panel B in Figure 2). You will use them to indicate how many fishing trips you are planning to make in that specific round. You must fold each FISHING FORM to indicate if you want to fish or not. If you fold it in one direction the boat will stay in ground (as in the NOT FISHING drawing), and if you fold it in the opposite direction the boat will go to the sea (as in the FISHING drawing).

It is very important to keep in mind that the number of FISHING TRIPS you decide in each period are absolutely individual. You don't have to show your decision to the rest of group members if you don't want to. The monitor will pass collecting your private decisions to guarantee its privacy.

4. A. Catching Fish (Deterministic Treatment)

You will receive 3 FISH UNITS per each FISHING TRIP you make.

Once we know the total number of FISHING TRIPS in the week, the MONITOR will calculate and announce publicly the total amount of fish FISH UNITS caught by the group, will remove the same amount of magnets from the RESOURCE BOARD and will annotate the weekly earnings (period earnings) for each one of the participants.

4.B. Catching Fish (Stochasctic Treatment)

To determine your catch the monitor will give you one numbered dice for each FISHING TRIP you decided to make (see panel C in Figure 2). You will have equal probabilities of having a GOOD, REGULAR or BAD day as you have two faces of the dice marked with the numbers 5, 3 and 1. A GOOD day gives you 5 FISH UNITS, a REGULAR day gives you 3 FISH UNITS and a BAD day gives you 1 FISH UNIT [MONITOR: Show the poster with the unfolded dice.]. The monitor will give you a total of three dices, the quantity of numbered dices will match your number of FISHING TRIPS and the remaining dices will be blank on all their sides. In this way we can guarantee the privacy of your decisions.

Once we know the result of all the FISHING TRIPS in the week, the MONITOR will calculate and announce publicly the total amount of fish FISH UNITS caught by the group, will remove the same amount of magnets from the RESOURCE BOARD and will annotate the weekly earnings (round earnings) for each one of the participants.

5.A. Paying the Fish (Fixed Price Treatment)

The monitor will annotate the FISH UNITS you caught each week. Each FISH UNIT will be paid at 2 tokens. The monitor will pay, at the end of the game the amount earned by the fish sold.

5.B. Paying the Fish (Conditional Contract Treatment)

The monitor will give annotate the FISH UNITS you caught each week. Each unit caught will be paid according to the total number of units extracted in the week. After the monitor announces the total amount of fish caught he will announce the price paid for each unit of fish according to the following table (See Table 1). [MONITOR: Show the table with the conditional contract.]. The monitor will pay, at the end of the game the amount earned by the fish sold.

6.A. Finishing the Game (Fixed Price Treatment)

The game will finish once we reach the 10th week, or equivalently period 10. However, if the resource reaches a level below 13 units (only twelve magnets in the RESOURCE BOARD) the game will finish in advance. If, at some point of the game, the FISH UNITS caught by the group exceed the remaining FISH UNITS in the board, you will receive a proportion of the remaining units equal to the proportion of your FISH UNITS with respect to the group's FISH UNITS caught in that week. For example, suppose that you caught 6 FISH UNITS and the total group caught 24 FISH UNITS but there were only 20 FISH UNITS remaining in the board. According to our rule, you will receive the fourth part of the remaining units, this is 5 FISH UNITS.

6.B. Finishing the Game (Conditional Contract Treatment)

The game will finish once we reach the 10th week, or equivalently period 10. However, if the resource reaches a level below 13 units (only twelve magnets in the RESOURCE BOARD) the game will finish in advance. If, at some point of the game, the FISH UNITS caught by the group exceed the remaining FISH UNITS in the board, you will receive a proportion of the remaining units equal to the proportion of your FISH UNITS with respect to the group's FISH UNITS caught in that week, and they will be paid according to the total FISH UNITS the group was expecting to catch. For example, suppose that you caught 6 FISH UNITS and the total group caught 24 FISH UNITS but there were only 20 FISH UNITS remaining in the board. According to our rule, you will receive the fourth part of the remaining units, this is 5 FISH UNITS and will be paid at $3 each.

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