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Influence of human capital on the trial and error learning process in a common pool resource (CPR) game

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ABSTRACT: This paper presents a study regarding the behavior of Pacific-Colombian fishers in a Common Pool Resource game. Results show that decision-making depends on human capital accumulation and the learning process. Specifically, through trial and error, those players with more human capital adjust their decisions on the basis of a cooperative-collusive solution by following the feedback of their own most successful strategies in past rounds. Notably, fishers with the higher levels of formal schooling tend to harvest less because they have a better understanding of dilemma-type games and the higher benefits involved when they cooperate.

Influencia del capital humano en el proceso de aprendizaje de prueba y error en un juego de recursos de uso común (CPR)

RESUMEN: Este estudio presenta resultados sobre el comportamiento de los pescadores del Pacífico colombiano en un juego de recursos de uso común. Los resultados muestran que la toma de decisiones depende del capital humano y del proceso de aprendizaje. A través de prueba y error, aquellos jugadores con más capital humano ajustan sus decisiones hacia una solución cooperativa-colusoria siguiendo la retroalimentación de sus propias estrategias más exitosas en rondas pasadas. Particularmente, los pescadores con niveles mayores de educación formal tienden a extraer menos unidades debido a mejor comprensión de los juegos tipo dilema social y los mayores beneficios obtenidos al cooperar.

KEYWORDS / *PALABRAS CLAVE*: Colombian Pacific coast, Common-Pool Resources, Non-cooperative games, Trial and Error Learning Process / Costa Pacífico colombiana, Recursos de uso común, Juegos no cooperativos, Aprendizaje de prueba y error.

JEL classification / *Clasificación JEL*: I12, C72, D83.

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1. Introduction

The ZEPA (acronym in Spanish for Exclusive Areas for Artisanal Fishing) and the DRMI (acronym in Spanish for and Regional Districts for Integrated Management) are successful cases of territorial organization on the Northern Pacific coast of Colombia and examples to guide the management of fisheries resources towards sustainability (Vieira *et al.,* 2016). The ZEPA declared 2.5 nautical miles permanently on July 2013 (MinAgricultura, 2013) and the DRMI established 55,974 marine hectares in October 2017 (MinAgricultura, 2017). These two areas that connect to each other, form a conjoint territory for exclusive use of artisanal fishers.

These designations have provided benefits to the fisher communities by mitigating the conflicts between artisanal and industrial fisheries, engaging at least 700 small scale fishers and reducing the pressure from industrial boats (Ramírez-Luna, 2013). Their derived benefits range from the increase in capture per unit of effort (López-Angarita *et al.,* 2018); extra premiums paid by consumers for responsibly caught fish and directly bought from the territory (Sáenz-Pacheco, 2014). Consequently, higher revenues are derived from a moralistic supply chain based on selective and diversified fishing and non-destructive gears (Cobos *et al.,* 2016; Satizábal, 2018; Satizábal & Batterbury, 2018); food security (Ramírez-Luna, 2013); and biological services due to the nursing of several species (Navia *et al.,* 2010).

Notwithstanding, these designations have brought struggles among fishers, jeopardizing the effectiveness of their implementation (Hernández & Díaz, 2012; Ramirez-Luna, 2013). These struggles arise from the distortion of the social interactions and place-based social control mechanisms (Satizábal, 2018), and the unawareness of fishers in regard to the depletion and obligations of the resources and their environmental balance (Diaz & Caro, 2016).

In order to propose solutions to these struggles under the experimental economics approach, several experiments have been run in Colombia following the framework proposed by Ostrom *et al*. (1994). These studies have provided findings regarding how the perceived inequality in the group constrains the effectiveness of communication (Cardenas, 2000); how the modest enforcement of the cooperative equilibrium outperform face-to-face communications (Cardenas, 2003); and how the combination of internal communication and external non-coercive intervention leads to better results in terms of community organization (Moreno-Sánchez & Maldonado, 2010).

However, the direct effect of human capital and education in solving Common Pool Resources (CPR) dilemmas has not been conclusive and it is still not clear whether education promotes competitive or cooperative behavior. Particularly, some studies indicate that the education, both formal and informal, turns out to be an effective management tool in marine protected areas. It increases community awareness, attitudes, behaviors, and perceptions (Adler, 1996); and despite total education costs that continually increases, it remains, in terms of money and effort, lower than the costs of enforcement (Alcock, 1991). Essentially, high school graduates should understand the significance of the ocean in the earth system and how the ocean and humans are interconnected (Plankis & Marrero, 2010) and be able to make informed and responsible decisions concerning marine resources (Shoedinger *et al.,* 2006); nevertheless, field experiments show diverging results.

On the one hand, some field-lab studies show that more schooled players are open to accepting external interventions and rules aimed at promoting sustainable use of resources (Moreno-Sánchez & Maldonado, 2010). Additionally, players with higher levels of human capital and cognitive skills are willing to contribute more to collective actions (Arroyo-Mina *et al.,* 2016; Cardenas *et al.,* 2009; Brañas *et al.,* 2009), and are less inclined to free-ride (Brañas *et al.,* 2009).

On the other hand, education can also promote competitive behavior when the more schooled players take advantage of less schooled ones. In this case, when the latter ones are unsure about their own decisions, they use the others as a reference leading to a competitive equilibrium (Velez *et al.,* 2009).

Results from filed experiments often indicate that, under some circumstances, external motivations drive the strategic behavior of those more educated players towards cooperative outcomes; however, we notice that none of them explain how this behavior is internally driven by the available information those players have, and how they use it as feedback to look for better outcomes. Due to this gap in the behavioral and experimental economics literature, we attempt to explain how higher levels of schooling drive the individual behavior to a cooperative-collusive solution through a Trial and Error Learning Process (Huck *et al.,* 2000; 2004a). Our purpose is to contribute to this discussion by explaining how education, human capital and cognitive skill formation are influential in driving strategic behavior. By applying CPR games over 10 rounds to a set of villagers in the Pacific coast of Colombia, we find that players with higher schooling levels lead their actions towards higher payoffs. These games were carried out with Pacific-Colombian fishers inhabiting a remote territory where there is low schooling and a illiteracy rate of 15.2 % of the population (DANE, 2005).

The remaining part of the paper is structured as follows: Section 2 presents a brief discussion on the influence of human capital on strategic behavior. Section 3 presents the theoretical model for analyzing the behavior of fishers. Section 4 presents the game design, the procedures during the experiments and reports on the results obtained. Section 5 provides final comments and a conclusion.

2. Human capital and strategic behavior [1]

Despite the lack of evidence on how human capital drives decisions in CPR games, the role of cognitive skills in decision making has been studied intensively under the context of repeated Prisoner's Dilemma (PD) games. In this context players with higher human capital are better at understanding repeated PD games (Brosig,

[1] As a global consensus, years of formal education and schooling are considered a measure of human capital, although this may not necessarily translate into marketable skills (Becker, 1964); besides, formal education enhances the human capital stock by improving the cognitive skills for problem solving (Bowen, 1977; Pallas, 2000).

2002; Burks *et al.,* 2003; Schramm, 1998; Tan & Zizzo, 2008) and better able to adapt their behavior, even when they do not know each other and have played only once (Boone *et al.,* 2002; De Jong, 2015).

Additionally, the evidence from experiments using university students as subjects present interesting findings. These studies argue that players with higher cognitive skills are more patient, therefore have higher savings rates (Jones, 2008) in both the short and long-run. In addition, these skills are associated with higher social awareness, better prediction of consequences of their actions, and performance of calculations for reducing the number of errors[2]. These skills seem to elicit a greater tendency to be cooperative in a strategic setting, and players with these skills appear to cooperate more often when playing repeated PD games (Burks *et al.,* 2009).

Aside from this, human capital drives strategies to cooperative-collusive solution behavior in contradiction to the rationality proposed in game theory (De Jong, 2015). Interestingly, these findings make clear that the more educated players are not necessarily more altruistic; instead, they behave strategically in order to control their context and to obtain higher outcomes. In other words, in a PD game, players with more schooling play more cooperatively on average because it is in their self-interest, and in the long run, cooperation provides higher payoffs (Boone *et al.,* 2002).

Now, considering that previous experiences in Colombia are not conclusive on how education drives strategic behavior in a CPR game, we analyze how villagers with different levels of schooling make decisions. In order to do this, we designed a CPR game in which the payoff structure simulated a dilemma between the cooperative-collusive and competitive solutions. In this game, we analyzed how players adjusted their decisions according to their levels of schooling and *learning processes*.

3. Theoretical Framework: Learning Process

A *learning process* is defined as a searching among strategies and payoffs (Huck *et al.,* 2000; 2004a). This search is initiated by an aspiration-induced mechanism which motivates a player to search for a new decision if current payoff is below an initial aspiration level; then changing their strategy to another with relatively higher payoffs (Karandikar *et al.,* 1998; Vainstein *et al.,* 2007). After several repetitions, players learn how to direct their actions towards an overall higher payoff (Huck *et al.,* 1999; 2004b; Selten & Buchta, 1998).

3.1. Learning process based on the experience of others

Although learning process has not received much attention under a CPR game context, Huck *et al*. (1999) define two types of learning process under a Cournot's Oligopoly game context, which provides repeated dilemmas in decision-making similar to CPR's framework. These learning processes are based on the experience of

[2] Kosmidis (2018) indicates that formal schooling trains cognitive skills and strategies; thereby, there are some procedures that unschooled individuals are not able to manage.

others. The first one is defined as *Best Reply*, where players choose in every period a best reply from their rivals' total output in the last period. To play best replies requires knowing the rivals' profits; and in an infinite-period game, *Best Reply* converges to a static Nash equilibrium. The second one is defined as *Imitate the Best*, where every player chooses the strategy that received the highest payoff in the last period; mostly, when players behave according to this dynamic they attain the Walrasian equilibrium in the long run. Imitating the best requires knowing and listing each period's quantities and the profits of each player. Accordingly, players learn from rivals if their beliefs and rewards are available (Offerman & Sonnemans, 1998). As long as players have more information about their rivals' outcomes, they become more competitive (Huck *et al.,* 1999).

For analyzing these processes based on others' experiences, we assume that the benefit of a fisher is defined by a constant and symmetric benefit from external activities to fishing w. A fishing harvest function $g(x_i)=ax_i-bx_i^2$. The strict concavity of $g(x_i)$ indicates diminishing marginal private returns to harvesting. This harvesting is sold at price p=1. For simplicity we assume zero costs at first stage. Finally, we have the externality cost of the aggregate harvest $\varphi\sum x_j$ caused by n fishers. The total private benefit is expressed in Equation 1[3]:

$$\pi_i = w + ax_i - bx_i^2 - \varphi \sum_{j=1}^{n} x_j \qquad [1]$$

Now, when optimizing the former expression, we obtain:

$$\partial\pi_i/\partial x_i = a - 2bx_i - \varphi = 0$$

and the resulting competitive harvest:

$$x_{com} = (a - \varphi)/2b \qquad [2]$$

This expression indicates that the individual optimal harvest does not depend on the rivals' harvest, and the individual decision is driven only by their own benefit maximization. Now, if we assume all fishers harvest the same amount by imitating each other's harvest, we replace the expression of the aggregate harvest $\varphi\sum x_j$ for φnx. Then, obtaining an identical benefit function for every fisher:

$$\pi = w + ax - bx^2 - \varphi nx$$

when optimizing it we obtain:

$$\partial\pi_i/\partial x_i = a - 2bx - \varphi n = 0$$

and the resulting solution for imitation:

$$x_{imi} = (a - \varphi n)/2b \qquad [3]$$

[3] The theoretical model implemented is adapted from Cardenas (2000).

Note that the former expression requires that all fishers have the same benefit structure, i.e. they are symmetrical. Thus, to behave under a learning process based on others' experiences it requires symmetrical benefit functions. Additionally, we can observe that the more fishers, the less they can harvest. Now, by introducing a cost $c_i > c_j$ we obtain the following expression:

$$\pi_i = w_i + ax_i - bx_i^2 - c_i x_i - \varphi \sum_{j=1}^{n} x_j$$

for x_i:

$$x_i = (a - c_i - \varphi)/2b$$

and for x_j:

$$x_j = (a - c_j - \varphi)/2\mathrm{b}$$

Under these circumstances we obtain $x_i < x_j$; thus, imitation is not suitable nor is further cooperation-collusion a feasible solution.

According to the literature, human behavior has evolved to consider a neighbors' experience as good as a player's own and players tend to imitate the behavior of those they can observe (Eshel *et al.,* 1998); although conditioned to homogeneity in the structure of the neighborhood and the local interaction of players in it. Only then, it is more likely for a player to learn from each other's experience (Kirchkamp & Nagel, 2007). This argument allows us to understand that, although players may interact in a framework of incomplete information about the types of rivals, they can be consistent with rational behavior (Kreps *et al.,* 1982);

Now, we know the imitation process is not always suitable; because of this, Huck *et al*. (1999) indicates that there are other possible learning processes when there is a lack of coordination during a game. This process, defined as Trial and Error, does not require players to know the information about their rivals' actions and payoffs and it is based on their own experiences during the game. In the next section we explain what is a Trial and Error learning process and the implication of following it during a game.

3.2. Trial and error and learning based on own experience

The basic argument of this learning process is that players would not repeat a mistake. If players experience a decrease in payoffs in the last round due to say an increase in quantity, then they would not increase the quantity again, and vice versa. Thereof, players' strategies can oscillate between two extreme values led by their own feedback; then, it is feasible that players' decisions are led to a cooperative-collusive outcome (Huck *et al.,* 2000; 2004a). Moreover, players can exhibit this behavior even in an environment dominated by defectors (Eshel *et al.,* 1998; Helbing & Yu, 2009).

This learning is mostly an intuitive process performed by the player. Here, in the absence of information about their rivals' costs or benefits, players can conclude where to find the best decisions to make.

The expression (4) formalizes the idea that if a direction was successful in the past round, it is repeated in the current round; when a direction fails, a reverse action is taken in the current round; if the change in payoffs or the change in quantities were zero in the previous round, the current quantity remains the same (Huck *et al.,* 2000). Mainly, players who behave according to trial and error learning are aware of feedback from past rounds.

The discrete-time version supposes that players behave according to the following rule:

$$x_{it} = x_{it-1} + \delta sign(x_{t-1} - x_{t-2}) * sign(\pi_{t-1} - \pi_{t-2}) \qquad [4]$$

where $\delta > 0$ is some arbitrarily small size step and *sign* (Δ) is defined as:

$$sign\ (\Delta) = \begin{cases} -1\ if\ \Delta < 0 \\ \ \ 0\ if\ \Delta = 0 \\ \ \ 1\ if\ \Delta > 0 \end{cases} \qquad [5]$$

It is plausible that during the learning process players make mistakes at executing their strategies and systematically try out different actions. Then, they do not always coordinate decisions to attain cooperation-collusion.

Furthermore, yielding cooperative-collusive solution requires that all subjects play according to the rule of *Trial and Error*. If the case any subject fails to comply, there is not convergence to the theoretical prediction. Hence, aggregate quantities can fall far from the cooperative-collusive solution (Huck *et al.,* 2000).

We propose that during these games, players behave according to the *Trial and Error* learning process thus, due to this dynamic, it does not require any cognitive effort from players, nor information about rivals' actions, nor the payoff function of the game. Therefore, it is applicable to repeat dilemma-type games like CPR because strategy sets can be ordered, players cannot observe the individual actions and outcomes of their rivals, and they have no coordination or punitive menace (Huck *et al.,* 2000; 2004a).

4. Game design and performance

The design of this game follows the one proposed by Cardenas (2000). We modified it slightly to allow the possibility to apply it to groups of 4 and 5 players. The objective of this modification is to permit all arriving participants to play the game once it is being performed in the field lab. Thus, we avoid the exclusion of any fisher in the communities and minimize any ethical problems in future activities.

In this game, a group of players perform a 10-round game simulating a social dilemma. Here, each player individually and secretly decides how much to harvest from a fishing bank, simultaneously interacting with the aggregate harvest of co-players or rivals. Moreover, the player only knows the rivals' harvest at the end of the round, when the assistant researcher discloses the aggregation. In the end, each player's payoff depends on a combination between their individual and rivals' aggregate decisions. This procedure is repeated during the 10 rounds. To summarize: The aggregate harvest of the group is public information while individual harvest, payoff and rivals' harvest is private information.

To calculate the payoff structure, we follow expression (1) and replace $w = 1530$, $a = 130$, $b = 5$ and $\varphi = 50$. We use these parameters to ensure a strictly positive harvest and to calibrate the payoffs to local daily earnings (see Appendix A). Then, we substitute the parameters in expression (3), individual harvest ranges $1 \leq x_i \leq 8$. Aggregate harvest for 4-player groups ranges $4 \leq \sum x_j \leq 32$; for 5-player groups ranges $5 \leq \sum x_j \leq 40$.

The social equilibrium, i.e. cooperative-collusive solution for 4-players group is obtained when $(x_i, \sum x_j - x_i) = (1,3)$; for 5-players groups when $(x_i, \sum x_j - x_i) = (1,4)$. The Nash equilibrium, i.e. the competitive solution for 4-player group is obtained when $(x_i, \sum x_j - x_i) = (8, 24)$; for 5-player groups when $(x_i, \sum x_j - x_i) = (8, 32)$.

The payoffs range between a minimum of 50 points (corresponding to a harvest $x_i = 1$, when rivals' harvest is $\sum x_j - x_i = 32$; i.e. a private social harvest against a competitive harvest from rivals) and a maximum of 1730 points (corresponding to a harvest of $x_i = 8$, when the rivals' harvest is $\sum x_j - x_i = 3$ or $\sum x_j - x_i = 4$; i.e. a free-riders' outcome). In order to avoid ethical problems with payoffs of different-participant groups, we ensure that both types of group had the same range of payoff (see appendix A). With this function, we generate a social dilemma regarding the payoffs structure; thus creating a conflict between individual and rival's payoffs.

4.1. Sampling

These games were performed in 8 communities located on the Northern Pacific coast of Colombia: *Nuqui*, *Pangui*, *Coqui*, *Jovi*, *Termales*, *Arusi*, *Tribuga* and *Jurubira*. For obtaining the sample, we applied two methods. The first one was to publish on local billboards located in community councils. The second one was word-of-mouth, to reach isolated communities. The latter is very effective for disclosing information among the Colombian villages because this method is a traditional form of communication medium.

According to DANE (2005), 29.8 % of population live in Nuqui, the head of the municipality. The remaining 70.2 % are distributed in the rural villages. In the sample, we obtained 154 participants. The largest attendance was in Nuqui, with 40 participants. This implies that we obtained 26 % participants from Nuqui, and 74 % from rural villages. We conducted only one daily session per community and due to a weekend in the middle, the entire fieldwork lasted 10 days. The average number of participants per session was 19.87 and the session lasted around 2 hours, accounting also for the time devoted to the final payments and a semi-structured survey conducted at the end of each game.

In this survey we obtained information from 79 players who attended up to any level of high schooling. We defined these as HS players[4]. We also obtained information from 75 who had only attended up to any level of elementary school (Table 1). We defined these as ES players. Additionally, we collected information on age, gender, experience in fishing and civil status (proportion of married fishers as a proxy of head of the household). Participants have received earnings from the fishing activity at least once in their lives.

TABLE 1

Socioeconomic information

Schooling	Variable	Average	Std. Dev.	Min	Max
HS	Age	38.68	(14.07)	15	74
	Gender (male)	89 % [1]	(0.32)	-	-
	Years of experience	21.47	(14.75)	1	65
	Civil status (married)	65 % [3]	(0.48)	-	-
ES	Age	47.39	(14.47)	15	79
	Gender (male)	91 % [2]	(0.29)	-	-
	Years of experience	28.75	(16.27)	1	69
	Civil Status (married)	75 % [4]	(0.44)	-	-

[1 2] Proportion of male fisher are generally higher in these communities.
[3 4] Proportion of fishers who are married.
Source: Own elaboration.

In each session, groups of 4 and 5 players with different levels of schooling were formed in circles turning their back to each other, assisted by a researcher who forbade communication among them. We obtained 34 groups in total, 16 with 4 participants and 18 with 5 participants. The players were distributed randomly in the groups. We obtained 17 groups (50 %) dominated by HS players; i.e. at least 3 of them were HS players.

Before starting the game, the context and the rules to follow were presented to players. For ensuring understanding of the game, three previous rounds were performed before the real game started; thereof, any feedback and extra explanations for better understanding were provided. Additionally, we informed players how many periods the game lasts for ensuring common knowledge of duration. During these games, anonymity was enforced and every player was assigned a code, with which they were identified for final payment at the end of the game.

[4] In Colombia, elementary school comprises 5 years of schooling; high school takes 6 more years of schooling; and a technician degree is an undergraduate program that takes up to three years of schooling; a bachelor degree takes five years to obtain.

4.2. Descriptive analysis

For understanding the behavior of players, we analyze independently the group of HS players from the ES[5] one (Table 2). The overall average harvest is 4.55 units. Discriminating by level of schooling, the ES average harvest is higher than HS. This difference of 0.27 units is significant at the 5 % level (Mann-Whitney test: $z = 2.44$; *p-value* = 0.015).

TABLE 2

Harvest behavior during the game

Variable [1]	Average	St. Dev.	Min	Max
x_i Overall	4.55	(2.19)	1	8
x_i HS	4.42	(2.19)	1	8
x_i ES	4.69	(2.18)	1	8
$\sum x_j$	21.06	(5.06)	8	36
$\sum x_j - x_i$	16.51	(4.55)	4	31
π_i HS [2]	1,018.54	(243.09)	\$100	\$1,700
π_i ES [3]	1,020.08	(239.16)	\$200	\$1,730

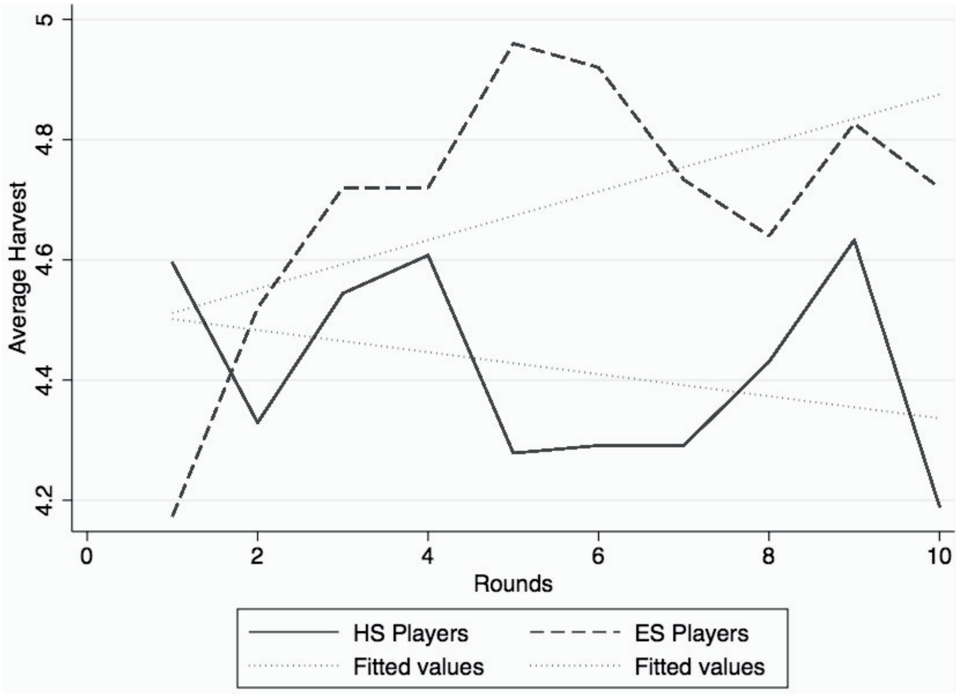
[1] Average calculated by round.
[2 3] Exchange rate USD\$ 1 = COP\$3,123.
Source: Own elaboration.

Now, by analyzing players' behavior by round, we observe that ES players harvest 4.2 units on average in first round and exhibit a tendency to increase their harvest as long the game is carried out. Their average harvest in the last round is 4.72. On the other hand, HS players harvest 4.6 units on average in the first round and exhibit a slight tendency to decrease their harvest during the experiment. Moreover, they finish with 4.2 units of harvest on average in round 10 (Figure 1).

5 We analyzed the levels of schooling for each group in order to identify if there were a real difference in human capital accumulation. For ES players, the average schooling was 2.82 years; for HS was 9.42 years. Mann-Whitney test: $z = -34.31$; *p-value* = 0.00.

FIGURE 1

The average harvest of ES and HS players

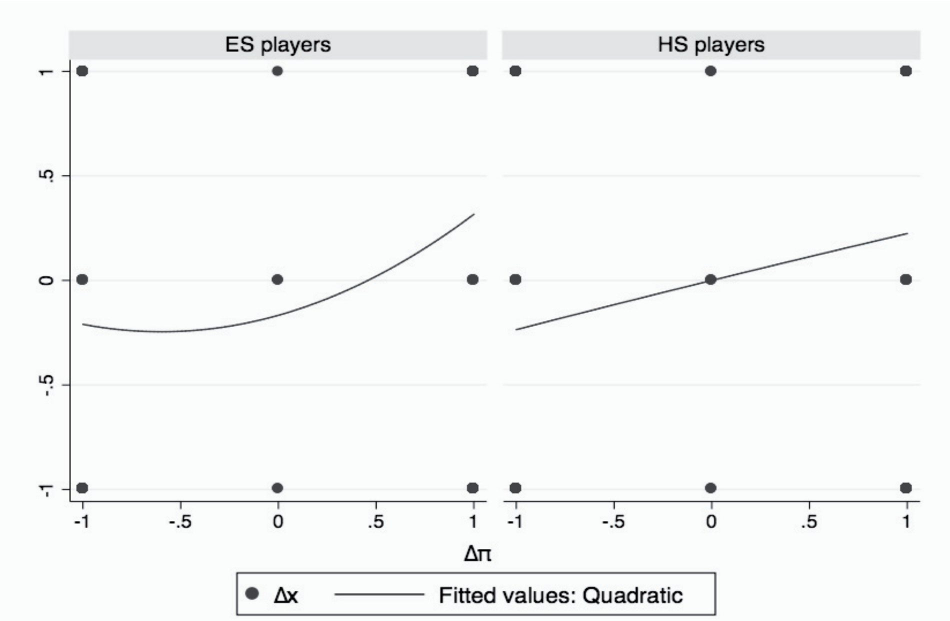


Source: Own elaboration.

By analyzing the feedback processing, we can address some differences between behaviors of the two types of players. ES players tend to increase their harvest despite payoffs feedback and move either the same or contrary directions. Additionally, HS players tend to increase their harvest when feedback is positive, whereas they decrease their harvest when feedback is negative, creating a monotonic path between quantities and payoffs; this means that HS players seem to reverse their decision when being competitive does not generate rewards (Figure 2).

FIGURE 2

Feedback processing



Source: Own elaboration.

4.3. Statistical analysis

Firstly, for understanding the behavior and learning process of players during the game, we analyze how players harvest x_i according different demographic variables. Following expression (4) from the theoretical model, we estimate *ordinary least squares* (OLS), panel regression controlling for *random effects* (RE)[6], and *panel-corrected standard errors* (PCSE) models. It is necessary to specify that PCSE, estimated according to serial correlation, is explicitly addressed in the theoretical and experimental analysis. This estimation allows for fitting correlation and unequal-variance error. Then, we enhance the efficiency of the parameter in the presence of autocorrelation AR(1) within panels, cross-sectional correlation, and heteroskedasticity across panels. By estimating this model with asymptotic standard errors corrected for correlation between panels, allows for relaxing the restriction that requires at least as many period observations as there are panels (Beck & Katz 1995).

The individual harvest x_{it} is estimated as the dependent variable; the first lag of individual harvest x_{it-1} and the function quantities-payoffs fxp_i that measure feedback

[6] Since the fixed effects model only accounts for within-subject variation and does not contemplate time-invariant variables, we propose random effects and panel-corrected standard error models. This latter model is more suitable for this case study, since the variable *dHS,* which is the main object of analysis, is time-invariant and we want to know its effect on the individual decision of players.

are estimated as independent variables; additionally, we use a function of the lag of rivals' harvest fz_j in order to identify whether players follow some sort of imitation from rivals' former strategies. This function takes value 1 if the harvest increased in the previous round, -1 if it decreased and 0 it remained constant. We propose using this function instead of the aggregate amount because for a player it is easier to identify if the harvest increases, decreases or is stable rather than 28 possible strategies the rivals could choose. Additionally, we introduce a control variable *domHS*, which takes the value of 1 if the group where a player performs is dominated by HS players; 0 otherwise. These variables are estimated interacting with a dummy variable *dHS* that takes value 1 if player is HS and 0 otherwise. These interactions are performed for discriminating behavior according to levels of schooling. Finally, we estimate the effect of control variables such as gender *s*, which is a dummy variable that takes value 1 when the player is a man and 0 when player is a woman[7]; the age of player *a*; years of experience in fishing *exp*; civil status *cs* as a proxy for head of household, which is a dummy variable taking the value of 1 when a player is married or in consensual union and 0 when is single or divorced; and the variable *g* is given to control the size of the group. This variable takes value of 1 if group is 5-player and 0 when it is 4-player (Table 4)[8].

TABLE 4

ES vs. HS. Learning processes

Variable [1]	Schooling	OLS	OLS (n.c.)[2]	RE	RE (n.c.)[3]	PCSE	PCSE (n.c.)[4]
x_{it-1}	ES	0.13***	0.13***	0.13**	0.13**	0.1***	0.11***
		(0.03)	(0.03)	(0.05)	(0.05)	(0.04)	(0.04)
	HS	0.14***	0.14***	0.14**	0.14**	0.08**	0.08**
		(0.03)	(0.03)	(0.05)	(0.05)	(0.03)	(0.03)
fxp_i	ES	0.14	0.14	0.14	0.14	0.08	0.07
		(0.09)	(0.09)	(0.10)	(0.10)	(0.08)	(0.08)
	HS	0.17*	0.17*	0.17*	0.17*	0.18**	0.18**
		(0.09)	(0.09)	(0.10)	(0.10)	(0.09)	(0.09)
fz_j	ES	0.13	0.13	0.13	0.13	0.13	0.13
		(0.09)	(0.09)	(0.10)	(0.10)	(0.09)	(0.09)
	HS	-0.15*	-0.15*	-0.15*	-0.15*	-0.15*	-0.15*
		(0.09)	(0.09)	(0.08)	(0.08)	(0.09)	(0.09)
domHS	ES	0.22	0.20	0.22	0.20	0.21	0.19
		(0.20)	(0.20)	(0.23)	(0.22)	(0.19)	(0.19)

7 Interactions between *s* and *dHS* are not estimated because we obtained information for only 7 ES and 9 HS women players. Gender discussions of the activity are beyond the scope of this research.

8 We also estimated a Heckman's Model (see Appendix B) to correct the possible selection bias. Since the Inverse Mills Ratio is not significant, we assume that models presented in Table 4 represent the behavior of players during the experiment.

Variable [1]	Schooling	OLS	OLS (n.c.)[2]	RE	RE (n.c.)[3]	PCSE	PCSE (n.c.)[4]
	HS	-0.32*	-0.35*	-0.32	-0.35	-0.31*	-0.34*
		(0.19)	(0.19)	(0.27)	(0.26)	(0.19)	(0.18)
s		0.47**	0.45**	0.47	0.45	0.46**	0.44**
		(0.22)	(0.21)	(0.32)	(0.29)	(0.22)	(0.20)
a		0.00	-	0.00	-	0.00	-
		(0.01)	-	(0.01)	-	(0.01)	-
ex		0.00	-	0.00	-	0.00	-
		(0.019)	-	(0.01)	-	(0.01)	-
cs		-0.12	-	-0.12	-	-0.12	-
		(0.14)	-	(0.19)	-	(0.13)	-
g		-0.33**	-0.32**	-0.33**	-0.32**	-0.32**	-0.31**
		(0.14)	(0.14)	(0.18)	(0.18)	(0.14)	(0.14)
Constant		3.77**	3.83***	3.77***	3.83***	3.67***	3.73***
		(0.34)	(0.25)	(0.49)	(0.39)	(0.34)	(0.26)

[1] Dependent variable x_{it}.
[2 3 4] These models are estimated without non-significant controls to verified robustness.
Significance: *10 %; **5 %; *** 1 %.
Source: Own elaboration.

Results show that harvest decisions in round *t* depend on decisions made in the past round *t–1* for both levels of schooling in every model estimated. By including AR(1) correlation in PCSE, the current harvest decision exhibits a slight decrease in dependence on lagged decisions.

Estimations on feedback present interesting results. On the one hand for ES players, fxp_i exhibit no statistical relation to harvest decision x_{it} in any model estimated, and coefficients vary slightly. On the other hand for HS players, fxp_i exhibit a statistically significant relation indicating that their successful decisions made in the past round are repeated in the current round. These estimations also indicate that HS players identify and rely on feedback from past rounds (Archibald & Elliot, 1989). Accordingly, HS players move forwards on a monotonic path, evidencing that players conclude in which direction better decisions can be made. Then, in the absence of information about rivals' feedback, the best decision to make is in the direction that was successful in the last period. Thereby, all moving players who adopt this behavior improve their profit building in a monotone-payoff path, even though others may experience losses. This evidence provides arguments to accept the hypothesis that HS players behave strategically following a trial and error learning process.

Analyzing the function of the lag of rivals' harvest fz_j we can conclude that ES players seem not to follow their rivals' experiences; nevertheless, HS players tend to decrease their harvest when their rivals increased in past rounds and vice versa. However, oligopolistic and CPR games are not ideal to assess imitation learning because its large strategy space. The main reason is because players can choose many different strategies among a large number of possible quantities. Often, players will choose new quantities that have not been tried before (Kirchkamp & Nagel, 2007).

Regarding variable *domHS*, we find a slight negative and significant relation of HS harvest when interacting in groups dominated by HS. Thereby, the context-based imitation learning process that prompts other agents to become cooperative-collusive can be observed over HS players. This conclusion aligns with similar arguments proposed by Eshel *et al*. (1998) and Kirchkamp & Nagel (2007). Then, a neighborhood dominated by HS players tends to reach cooperation-collusion during these games. Nevertheless, ES players show no context-based imitation.

Accordingly, variable *s* indicates that women are less competitive than men (Croson & Gneezy, 2009). However, remaining control variables like age, experience and civil status seem not to have statistical significance in relation to harvest during the performances of the game.

Estimation regarding the size of the group *g* aligns with the theoretical prediction of expression (3). This expression indicates that when groups are smaller, they can optimally harvest more. This estimation is significant in every model and indicates that groups of 4 participants harvest more compared to groups of 5 participants. This is a rational behavior motivated by the maximization of the benefits function.

The *Constant* in these models provides a broad estimation of the players' harvest starting point. This estimation is not too intuitive and requires an extra explanation. Assuming that in some rounds player's feedback is equal to zero, meaning that player did not find a way to improve their profit, the player is motivated to alternate between moving up or down (Huck *et al.,* 2004a), starting again looking for the strategies which provide profit improvement. This starting point ranges from 3.73 to 3.83 depending on the estimation.

4.4. Decision-making and payoffs

In order to analyze the incentives of players during the game, we run a regression over of payoffs π_{it} obtained during the game[9]. The independent variables are the individual harvest x_{it}; rivals' aggregate harvest z_{jt}, i.e. the total amount of rivals' harvest instead of the function. Here we use the total amount because the payoffs are defined by the ordered pair made between the individual and aggregate harvest, and not by the simple function. Finally, we estimate the influence of the environment *domHS*. These variables are estimated interacting with level of schooling *dHS*. Finally, we control for gender *s* and group size *g* (Table 5).

[9] Since the fixed effects model only accounts for within-subject variation and does not contemplate time-invariant variables, we propose random effects and panel-corrected standard error models. This latter model is more suitable for this case study, since the variable *dHS,* which is the main object of analysis, is time-invariant and we want to know its effect on the individual decision of players.

TABLE 5

Payoffs

Variable[1]	Schooling	OLS	OLS (n.c.)[2]	RE	RE (n.c.)[3]	PCSE	PCSE (n.c.)[4]
x_{it}	ES	36.51***	36.42***	36.95***	36.94***	36.51***	36.42***
		(1.60)	(1.60)	(1.44)	(1.43)	(1.66)	(1.65)
	HS	35.87***	35.74***	35.22***	35.21***	35.87***	35.74***
		(1.58)	(1.57)	(1.54)	(1.53)	(1.52)	(1.51)
z_{jt}	ES	–42.36***	–42.36***	–46.20***	–46.19***	–42.36***	–42.36***
		(0.78)	(0.78)	(0.91)	(0.91)	(0.78)	(0.78)
	HS	–43.72***	–43.77***	–47.13***	–47.14***	–43.72***	–43.77***
		(0.76)	(0.76)	(0.64)	(0.64)	(0.73)	(0.72)
domHS[e]	ES~*domHS*	1.124	–0.256	–6.370	–7.498	1.124	–0.256
		(7.94)	(7.87)	(14.57)	(14.11)	(7.12)	(7.03)
	HS~*domES*	37.19*	38.84*	32.47*	33.08*	37.19*	38.84*
		(22.38)	(22.35)	(19.71)	(19.91)	(20.81)	(20.75)
	HS~*domHS*	10.04	10.42	2.256	1.892	10.04	10.42
		(21.49)	(21.49)	(18.02)	(18.16)	(20.44)	(20.43)
s		–10.59	-	-8.639	-	-10.59	-
		(8.172)	-	(17.64)	-	(8.860)	-
g		–71.76***	–70.53***	–64.34***	–63.34***	–71.76***	–70.53***
		(5.67)	(5.59)	(11.75)	(11.39)	(5.19)	(5.14)
Constant		1,608***	1,598***	1,667***	1,659***	1,608***	1,598***
		(17.35)	(15.75)	(19.10)	(12.45)	(16.51)	(14.57)

[1] Dependent variable: Payoff by round π_{it}.
[2 3 4] These models are estimated without non-significant controls to verified robustness.
[e] Baseline: ES dominated by ES players, ES~*domES.*
Significance: *10 %; **5 %; *** 1 %.
Source: Own elaboration.

Estimations show that harvests of both levels of schooling are positively related to payoffs; i.e. payoffs increase when players increase harvests despite their level of schooling. These coefficients are statistically equal ($\chi^2(1) = 0.36$; *p-value* = 0.547); thereof marginally, ES and HS players receive the same payoffs. These estimations also indicate that when rivals' aggregate harvests increase, individual payoffs decrease for both ES and HS players. This effect is statistically the same for both levels of schooling ($\chi^2(1) = 0.01$; *p-value* = 0.918).

From estimations on *domHS*, we observe that the environment yields differences in payoffs during the game. Having ES interacting in an environment dominated by ES as baseline, we observe that when HS players interact in an environment dominated by ES players (HS~*domES*), they receive higher payoffs than ES players despite the environment in which they interact (HS~*domES* = ES~*domHS*: $\chi^2(1) = 14.58$; *p-value* = 0.00). When HS players interact in an environment dominated by HS players, their payoffs tend to be also higher; however, none of these latter coefficients are statistically significant in any model estimated. These results indicate that by harvesting closer to cooperative-collusive solution, HS players can obtain higher payoffs and revenues, even if they face defection from rivals.

Smaller groups, that harvest higher amounts (see Table 4) can obtain higher payoff. This is because the payoff structure allows smaller groups to reach the optimum at a higher level of harvest with higher revenues (see expressions (1) and (3)). From this situation, we can conclude that despite the benefits range is the same for either 4-player or 5-player groups, smaller groups obtain higher revenues when playing this dilemma-type game. However, this particular case should be explored more deeply in further studies.

Finally, *Constants* in these models provide insights into average payoffs per round of a female fisher with elemental schooling, who interacts in an environment dominated by ES players and plays against 3 rivals. These values range from $\$1,598 \leq \pi \leq \$1,667$ depending on the estimation.

4.5. Discussions

4.5.1. ES players' behavior

It is necessary to emphasize that the human brain has not evolved specifically for developing core skills like reading, writing or making calculations; these are very complex skills created by contemporary human culture. Therefore, our brains have to make an extra effort using abilities that have evolved for different purposes. Thus, to use cognitive skills has become a great accomplishment, which requires polishing many functions including basic visual searching, phonological awareness and working memory (Huettig *et al.,* 2018). These advantages lead literates, frequently correlated with schooled individuals, to outperform illiterates, even in simple visual searching tasks (Malik-Moraleda *et al.,* 2018).

For these reasons, ES players are not presumed to be bad learners or to commit errors; besides, statistical evidence raises the hypothesis that the chosen action is the best possible considering their ability to process feedback. Thus, first changing expectations would make it difficult to have accurate perceptions of their alternatives. Hence, we presume that ES players act looking for some payoff aspiration level, behaving as competitors instead of as colluders. This behavior incentivizes players to harvest, subject to small random perturbations; these influence players to switch strategies despite the fact that payoffs obtained were lower than before (Karandikar *et al.,* 1998; Young, 2009).

4.5.2. HS players' behavior

According to Huck *et al*. (2000, 2004a), it is feasible that individual harvesting tends towards cooperation-collusion despite the aggregate harvest in the group that was not even close to the collusive outcome, i.e. interacting in a group dominated by defectors (Helbing & Yu, 2009). Furthermore, a unique competitive solution will not be stable under the trial and error approach because there are movements away from the equilibrium that are profitable for all players, and somehow in repeated dilemma-type games, players reduce their probability of defection. This will increase players' expected payoff.

Unfortunately evidence fails to determine when cooperative-collusive behavior appears. Nevertheless, findings indicate that infinite rounds are not required to make cooperation possible, and often, a few rounds seem sufficient (Andreoni & Miller, 1993; Kreps *et al.,* 1982). However, it is important to note that these findings state that cooperative-collusive behavior occurs when players interact in fixed groups during the entire experiment (Huck *et al.,* 2001; Huck *et al.,* 2004b). Also, they are required to understand what is a joint-profit maximizing solution and how to interpret their rivals' decisions (Rassenti *et al.,* 2000). Besides, since players were not constrained to adjust their harvest by one unit, it is possible that cooperative-collusive individual harvest appears suddenly during the early rounds.

4.5.3. Human Capital and Cognitive Skills

Even when human capital and cognitive skills are important characteristics for understanding the behavior of agents and their ability to learn when facing different economic situations, they are generally treated as endowments and approximations of the individual's welfare. Notwithstanding, learning is optimal only if feedback is optimal, though this condition is strict and infrequently satisfied (Archibald & Elliot, 1989). This situation leads behavior to a non-unique equilibrium set sensitive to variations in initial expectations.

Feedback is indisputably incomplete because players are unable to discover the consequences of non-chosen strategies. Hereby, it is important to consider that players with higher cognitive skills and human capital make these decisions because of a better understanding of the information provided, and better processing of the feedback from their own game interactions. This behavior proceeds from the advantage that schooling brings to more educated players at information processing, allowing maximization of their well-being through problem solving and better adaptation to new situations with different expectations (Bowen, 1977; Pallas, 2000; Pallas & Jennings, 2009).

However, confidence in judgment due to cognitive skills is not a regular economistic attribute in *homo economicus* (Archibald & Elliot, 1989). Therefore, it raises the need for correlating trial and error of well-informed rational agents with human capital, cognitive skills, and different preferences. This also raises the need for creating a new theoretical approach for explaining economic behavior, containing explanations on the implications of the aforementioned characteristics in successful decision-making, risk aversion, and inter-temporal allocation of resources; as well as entrepreneurship, longevity, health and better judgment in their actions and consequences.

4.5.4. What about the territorial context?

The need for complying with FAO's Code of Conduct for Responsible Fisheries (FAO, 1995) led to the creation of the Law 13 in Colombia, in 1990. Based on this law, ZEPA and DRMI were established to ensure the management of fishery resources towards sustainability (Vieira *et al.,* 2016).

These designations, formally defined as Territorial Use Rights for Fisheries (TURF's), are site-specific management arrangements attached to territorial culture. TURF-based management systems provide relative controls, preventing rent dissipation from economic waste due to excess of effort caused by applying higher levels of capital and labor (Christy, 1982). Accordingly, some studies have found that TURF-based management coordinates fishing effort for avoiding inefficient allocation of fishing effort (Cancino *et al.,* 2007; Gaspart & Seki, 2003); although the sustainability of fisheries is subject to on-going debate (Nguyen ThiQuynh *et al.,* 2017).

Notwithstanding, it is necessary that the government complies not only by declaring territories destined for exclusive sustainable exploitation in this region, but by ensuring a broader form of welfare for local communities. Accounting for a 15.2 % rate of illiteracy and the 41.4 % who only attended basic school, it is necessary that a more active presence of the government be felt; especially in those communities that require more investment in education and human development. In this way, it will be possible to encourage fishers to be more aware of the resources they exploit (Adler, 1996), and help them to understand how the ocean and humans are interconnected (Plankis & Marrero, 2010). Only by so doing, would coastal communities be able to make informed and responsible decisions concerning the ocean resources.

5. Conclusions and final remarks

Results show that players with higher human capital exhibit a trial and error learning process moving towards higher payoffs under the context of a CPR game. According to Huck *et al*. (2000; 2004a) this behavior leads to cooperative-collusive solutions. These findings confirm the existence of individual learning based on feedback from past rounds (Huck *et al.,* 2000; 2004a; Selten & Buchta, 1998). Particularly, we can observe that players with higher levels of schooling, therefor with higher human capital, exhibit this learning process.

Previous findings indicate that subjects with higher human capital are willing to contribute more to collective actions (Arroyo-Mina *et al.,* 2016; Brañas *et al.,* 2009; Cardenas *et al.,* 2009), and are less inclined to free-ride (Brañas *et al.,* 2009). Furthermore, players with higher human capital are better at understanding and adapting their behavior in a repeated PD game (Boone *et al.,* 2002; Brosig, 2002; Burks *et al.,* 2003; De Jong, 2015; Schramm, 1998; Tan & Zizzo, 2008), and on average they play more cooperatively considering that in the long run cooperation provides higher payoffs (Boone *et al.,* 2002).

During this experiment, both ES and HS current harvests depend on decisions made in past rounds. However, those HS players with the higher human capital consider that the best decision to make is in the direction that was successful last time, relying on feedback and building a monotone-payoff path to cooperative-collusive solutions; this happens in the absence of coordination or information about their rivals' decisions.

HS players tend to harvest towards cooperative-collusive solutions and, when surrounded by homogenous players, they tend to yield cooperation. This behavior can be sustained even though they interact in a group dominated by defectors (Helbing & Yu, 2009). However, evidence fails to determine when cooperative-collusive behavior appears. Nevertheless, during the game players are allowed to adjust their harvest at their convenience, thus cooperative-collusive solution decisions can be made suddenly during the first rounds.

Estimations indicate that marginal payoffs are the same for both levels of schooling. However, the environment in which they interact yields differences in their payoffs. A HS player obtains higher payoffs when interacting in an environment dominated by ES players. Moreover, a HS player tends to obtain higher payoffs when interacting in an environment dominated by HS players; however, these latter estimations are not significant. Therefore, overall higher payoffs motivate HS players harvesting closer to cooperative-collusive solution where higher payoffs can be obtained, even when defection from rivals produces losses.

The territorial context can help to explain the behavior of fishers regarding the coordination when approaching cooperative-collusive solutions. The institutional efforts in the region have promoted sustainable fishing for over 20 years and they could bring this experience to the field game. Particularly, players with higher human capital are the ones that exhibited evidence for using this as an advantage during the experiment. Considering this, it is necessary that the government takes an active role by investing more in education in the region.

Finally, we are aware that the standard for any empirical study in the social sciences is random sampling and experimentation (Angrist & Pischke, 2008); a non-appropriate randomization could lead to truncated samples in which the values of the independent variable are unknown because the dependent variable is unobserved for part of the relevant population. However, after testing the possibility of selection bias, our results indicate that the proposed models are unbiased and efficient estimations on players' behaviour.

References

Adler, J. (1996). "Costs and Effectiveness of Education and Enforcement, Cairns Section of the Great Barrier Reef Marine Park". *Environmental Management,* 20, 541-551. https://dx.doi.org/10.1007/BF01474654.

Alcock, D. (1991). "Education and extension: Management's best strategy". *Australian Parks and Recreation,* 27(1), 15-17.

Andreoni, J. & Miller J.H. (1993). "Rational cooperation in the finitely repeated Prisoner's Dilemma: Experimental Evidence". *The Economic Journal,* 103(418), 570-585. https://dx.doi.org/10.2307/2234532.

Angrist, J.D. & Pischke, J.S. (2008). *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton: Princeton University Press.

Arroyo-Mina, J.S., Revollo-Fernández, D.A., Aguilar-Ibarra, A. & Georgantzis, N. (2016). "Economic behavior of fishers under climate-related uncertainty: Results from field experiments in Mexico and Colombia". *Fisheries Research,* 183, 304-317. https://dx.doi.org/10.1016/j.fishres.2016.05.020.

Archibald, R.B. & Elliot, C.S. (1989). "Trial and Error Learning and Economic Models". *Kyklos,* 42*,* 39-59.

Beck, N.L. & Katz, J.N. (1995). "What to do (and not to do) with time-series cross-section data". *American Political Science Review,* 89(3), 634-647. https://dx.doi.org/10.2307/2082979.

Becker, G. (1964). *Human Capital*. Chicago: The University of Chicago Press.

Brañas P., Cardenas, J.C. & Rossi, M. (2009). *Gender, Education, and Reciprocal Generosity: Evidence from 1,500 Experiment Subjects*. ECINEQ Working Paper 2009, 128.

Boone, C., De Brabander, B., Carree, M., De Jong, G., Van Olffen, W. & Van Witteloostuijn, A. (2002). "Locus of control and learning to cooperate in a prisoner's dilemma game". *Personality and Individual Differences,* 32(5), 929-946. https://dx.doi.org/10.1016/S0191-8869(01)00100-3.

Bowen, H.R. (1977). *Investment in Learning: The Individual and Social Value of American Higher Education*. San Francisco: Routledge.

Brosig, J. (2002). "Identifying cooperative behavior: some experimental results in a prisoner's dilemma game". *Journal of Economic Behavior and Organization,* 47(3), 275-290. https://dx.doi.org/10.1016/S0167-2681(01)00211-6.

Burks, S.V., Carpenter, J.P., Goette, L. & Rustichini, A. (2009). "Cognitive skills affect economic preferences, strategic behavior, and job attachment". *Proceedings of the National Academy of Sciences,* 106(19), 7745-7750. https://dx.doi.org/10.1073/pnas.0812360106.

Burks, S.V., Carpenter, J.P. & Verhoogen, E. (2003). "Playing both roles in the trust game". *Journal of Economic Behavior and Organization,* 51(2), 195-216. https://dx.doi.org/10.1016/S0167-2681(02)00093-8.

Cancino, J.P., Uchida, H. & Wilen, J.D. (2007). "TURF's and ITQs: Collective vs. Individual Decision Making". *Marine Resource Economics,* 22(4) 391-406. https://dx.doi.org/10.1086/mre.22.4.42629569.

Cárdenas, J.C. (2000). "How do groups solve local commons dilemmas? Lessons from experimental economics in the field". *Environment, Development and Sustainability,* 2, 305-322. https://dx.doi.org/10.1023/A:1011422313042.

Cárdenas, J.C. (2003). "Real wealth and experimental cooperation: experiments in the field lab". *Journal of Development Economics,* 70(2), 263-289. https://dx.doi.org/10.1016/S0304-3878(02)00098-6.

Cárdenas, J.C., Chong, A. & Ñopo, H. (2009). "To what extent do Latin Americans trust, reciprocate, and cooperate? Comments evidence from experiments in six Latin American countries". *Economia,* 9(2), 45-94.

Certo, S.T., Busenbark, J.R., Woo, H.S., Semadeni, M. (2016). Sample selection bias and Heckman models in strategic management research. Strategic Management Journal, 37, 2639-2657. https://doi.org/10.1002/smj.2475.

Christy, F. (1982). *Territorial use rights in marine fisheries: definitions and conditions*. FAO Fisheries Technical Paper No. 227. Rome: Food and Agriculture Organization of the United Nations.

Cobos, A.J., Due-as, J.D. & Velandia, M.C. (2016). "Aspectos economicos de la pesca artesanal". In Diaz, J.M. Guillot, L. & Velandia, C.M. (Eds.): *La pesca Artesanal en el Norte del Pacífico Colombiano: Un Horizonte Ambivalente* (pp. 91-103). Bogota: Fundación MarViva.

Croson, R. & Gneezy, U. (2009). "Gender differences in preferences". *Journal of Economic Literature,* 47(2), 448-474. https://dx.doi.org/10.1257/jel.47.2.448.

Deb, P. & Seck, P. (2009). *Internal migration, selection bias and human development: Evidence from Indonesia and Mexico.* Human Development Research Paper (HDRP) Series no. 31.

De Jong, G. (2015). "The impact of social and human capital on individual cooperative behaviour. Implications for international strategic alliances". *Critical Perspectives on International Business,* 11(1), 4-29. https://dx.doi.org/10.1108/cpoib-12-2012-0063.

Departamento Administrativo Nacional de Estadística (DANE). (2005). *Censo General*. Bogotá.

Díaz, J.M. & Caro, N. (2016). "El mar como territorio y la pesca como actividad tradicional en el territorio Chocoano". In Díaz, J.M., Guillot, L. & Velandia, M.E. (Eds.): *La Pesca Artesanal en el Norte del Pacífico Colombiano: Un Horizonte Ambivalente* (pp. 29-43). Bogota: Fundación MarViva.

Eshel, I., Samuelson, L. & Shaked, A. (1998). "Altruists, egoists, and hooligans in a local interaction model". *American Economic Review,* 88(1), 157-179.

FAO. (1995). *Code of Conduct for Responsible Fisheries*. Rome: Food and Agricultural Organization of the United Nations.

Gaspart, F. & Seki, E. (2003). “Cooperation, status seeking and competitive behavior: Theory and evidence”. *Journal of Economic Behavior and Organization,* 51(1), 51-77. https://dx.doi.org/10.1016/S0167-2681(02)00139-7.

Helbing, D. & Yu, W. (2009). “The outbreak of cooperation among success-driven individuals under noisy conditions”. *Proceedings of National Academy of Sciences,* 106(10), 3680-3865. https://dx.doi.org/10.1073/pnas.0811503106.

Hernández, A. & Diaz, J.M. (2012). “La Zona Exclusiva de Pesca Artesanal en la costa norte del Pacífico colombiano: Escenario de conflictos socio-ambientales”. *La Timonera,* 17, 49-51.

Huck, S., Müller, W. & Normann, H. (2001). “Stackelberg beats Cournot: On collusion and efficiency in experimental markets”. *The Economic Journal,* 111(474), 749-765.

Huck, S., Normann, H.T. & Oechssler, J. (1999). “Learning in Cournot Oligopoly. An experiment”. *The Economic Journal,* 109 (454), 80-95.

Huck, S., Normann, H.T. & Oechssler, J. (2000). *Trial and error to collusion, the discrete case*. Bonn Econ Discussion Papers, 6. Bonn: Graduate School of Economics (BGSE), Universität Bonn.

Huck, S., Normann, H.T. & Oechssler, J. (2004a). “Through trial and error to collusion”. *International Economic Review,* 45(1), 205-224.

Huck, S., Normann, H.T. & Oechssler, J. (2004b). “Two are few and four are many: Number effects in experimental oligopolies”. *Journal of Economic Behavior and Organization,* 53(4), 435-446. https://dx.doi.org/10.1016/j.jebo.2002.10.002.

Huettig, F., Kolinsky, R. & Lachmann, T. (2018). “The culturally co-opted brain: How literacy affects the human mind”. *Language, Cognition and Neuroscience,* 33(3), 275-277. https://dx.doi.org/10.1080/23273798.2018.1425803.

Jones, G. (2008). “Are smarter groups more cooperative? Evidence from prisoner’s dilemma experiments, 1959-2003”. *Journal of Economic Behavior and Organization,* 68(3-4) 489-497. https://dx.doi.org/10.1016/j.jebo.2008.06.010.

Karandikar, R., Mookherjee, D., Ray, D. & Vega-Redondo, F. (1998). “Evolving Aspirations and Cooperation”. *Journal of Economic Theory,* 80(2), 292-331. https://dx.doi.org/10.1006/jeth.1997.2379.

Kreps, D.M., Milgrom, P., Roberts, J. & Wilson, R. (1982). “Rational cooperation in the finitely repeated prisoners’ dilemma”. *Journal of Economic Theory,* 27(2), 245-52. https://dx.doi.org/10.1016/0022-0531(82)90029-1.

Kirchkamp, O. & Nagel, R. (2007). “Naive learning and cooperation in network experiments”. *Games and Economic Behavior,* 58(2), 269-292. https://dx.doi.org/10.1016/j.geb.2006.04.002.

Kosmidis, M.H. (2018). “Challenges in the neuropsychological assessment of illiterate older adults”. *Language, Cognition and Neuroscience,* 33(3), 373-386. https://dx.doi.org/10.1080/23273798.2017.1379605.

López-Angarita, J., Tilley, A., Díaz, J.M., Hawkins, J.P, Cagua, E.F & Roberts, C.M. (2018). "Winners and losers in area-based management of a small-scale fishery in the Colombian Pacific". *Frontiers in Marine Science,* 53, 1-12. https://dx.doi.org/10.3389/fmars.2018.00023.

Malik-Moraleda, S., Orihuela, K., Carreiras, M. & Duñabeita, J.A. (2018). "The consequences of literacy and schooling for parsing strings". *Language, Cognition and Neuroscience,* 33(3), 293-299. https://dx.doi.org/10.1080/23273798.2017.1313436.

Moreno-Sanchez, R.P. & Maldonado, J.H. (2010). "Evaluating the role of co-management in improving governance of marine protected areas: An experimental approach in the Colombian Caribbean". *Ecological Economics,* 69(15), 2557-2567. https://dx.doi.org/10.1016/j.ecolecon.2010.07.032.

Ministerio de Agricultura y Desarrollo Rural, Colombia (MinAgricultura). (2013). *Resolución 0899.* Bogotá: Autoridad Nacional de Acuicultura y Pesca.

Ministerio de Agricultura y Desarrollo Rural, Colombia (MinAgricultura). (2017). *Resolución 2111.* Bogotá, Colombia: Autoridad Nacional de Acuicultura y Pesca.

Navia, A.F., Mejía-Falla, P.A., López-García, J., Mufioz, L.A. & Ramírez-Luna, V. (2010). *Pesquería artesanal de la zona norte del Pacifico colombiano: Aportando herramientas para su administración. Fase 2*. Technical Report. Colombia: Fundación SQUALUS.

Nguyen ThiQuynh, C., Schilizzi, S., Hailu, A. & Iftekhar, S. (2017). "Territorial Use Rights for Fisheries (TURFs): State of the art and the road ahead". *Marine Policy,* 75, 41-52. https://dx.doi.org/10.1016/j.marpol.2016.10.004.

Offerman, T. & Sonnemans, J. (1998). "Learning by experience and learning by imitating successful others". *Journal of Economic Behavior and Organizations,* 34(4), 559-575. https://dx.doi.org/10.1016/S0167-2681(97)00109-1.

Ostrom, E., Gardner, R. & Walker, J.M. (1994). *Rules, Games, and Common-Pool Resources*. Michigan: Ann Arbor.

Pallas, A.M. (2000). "The effects of schooling on individual lives". In Hallinan, M.T. (Ed.): *Handbook of the Sociology of Education* (pp. 499-526). New York: Kluwer Academic/Plenum Publishers.

Pallas, A.M. & Jennings, J.L. (2009). "Cumulative knowledge about cumulative advantage". *Swiss Journal of Sociology,* 35(2), 211-229.

Plankis, B.J. & Marrero, M.E. (2010). "Recent ocean literacy research in United States public schools: Results and implications". *International Electronic Journal of Environmental Education,* 1, 21-50.

Ramírez-Luna, A.V. (2013). *The Exclusive Fishing Zone for the Artisanal Fishery in Choco Colombia: Origins, Development, and Consequences for Artisanal Fisheries and Food Security*. Master Dissertation. Environmental Science Program. Memorial University of Newfoundland and Labrador.

Rassenti, S., Reynolds, S., Smith, V.L. & Szidarovszky, F. (2000). "Adaption and convergence of behavior in repeated experimental Cournot games". *Journal of Economic Behavior and Organization,* 41(2), 117-146. https://dx.doi.org/10.1016/S0167-2681(99)00090-6.

Sáenz-Pacheco, G. (2014). *Marviva, Pesca Responsable y Comunicación Para la Gobernanza en Bahía Solano y Nuquí (Pacífico Norte Colombiano*). Barranquilla, Colombia: Editorial Universidad del Norte.

Satizábal, P. (2018). "The unintended consequences of 'responsible fishing' for small-scale fisheries: Lessons from the Pacific coast of Colombia". *Marine Policy,* 89, 50-57. https://dx.doi.org/10.1016/j.marpol.2017.12.005.

Satizábal, P. & Batterbury, S.P. (2018). "Fluid geographies: Marine territorialisation and the scaling up of local aquatic epistemologies on the Pacific coast of Colombia". *Transactions of the Institute of British Geographers,* 43(1), 61-78.https://dx.doi.org/10.1111/tran.12199.

Schramm, A.J.H.C. (1998). *What Have We Learned From Experiments?* Gothenburg, Sweeden: Presidential Address, European Public Choice Society.

Selten, R. & Buchta, J. (1998). "Experimental sealed bid first price auctions with directly observed bid functions". In Budescu, D., Erev, I. & Zwick, R. (Eds.): *Games and Human Behavior: Essays in Honor of Amnon Rapoport.* Mahwak, USA: Lawrenz Erlaaum Association.

Schoedinger, S., Cava, F. & Jewell, B. (2006). "The need for ocean literacy in the classroom: Part I". *The Science Teacher,* 73(6), 44-47.

Vainstein, M.H., Silva, A. & Arenzon, J. (2007). "Does mobility decrease cooperation?" *Journal of Theoretical Biology,* 244(4), 722-728. https://dx.doi.org/10.1016/j.jtbi.2006.09.012.

Velez, M.A., Stranlund, J.K. & Murphy, J.J. (2009). "What motivates common pool resource users? Experimental evidence from the field". *Journal of Economic Behavior and Organization,* 70(3), 485-497. https://dx.doi.org/10.1016/j.jebo.2008.02.008.

Vieira, C.A., Díaz, M.C. & Díaz, J.M. (2016) "Ordenamiento y manejo pesquero en la costa norte del Pacífico colombiano". In Diaz, J.M., Guillot, L. & Velandia, M.C. (Eds.): *La pesca Artesanal en la Costa Norte del Pacífico Colombiano: Un Horizonte Ambivalente* (pp. 45–57). Bogota: Fundación MarViva.

Tan, J.H.W. & Zizzo, D.J. (2008). "Groups, cooperation and conflict in games". *The Journal of Socio-Economics,* 37(1), 1-17. https://dx.doi.org/10.1016/j.socec.2006.12.023.

Young, H.P. (2009)." Learning by trial and error". *Games and Economic Behavior,* 65(2), 626-643. https://dx.doi.org/10.1016/j.geb.2008.02.011.

Wooldridge, J.M. (2010). *Econometric Analysis of Cross Section and Panel Data*. Cambridge: MIT Press.

Appendix A. Payoffs calculations

Considering Equation (1), we assigned the following values w = 1525, a = 130, b = 5 and φ = 50. These parameters were chosen to obtain roughly equivalent outcomes to local daily earnings, as well as to ensure that these parameters are strictly positive. After optimizing and replacing parameters, we obtain the individual competitive harvest:

$$x_{com} = (a - \varphi)/2\,b = (130 - 50)/2\,(5) = 8$$

Now, accounting for the social equilibrium solution, we replaced the parameters for a group of 5 players:

$$x_{soc} = (a - \varphi n)/2\,b = \big(130 - 50(5)\big)/2\,(5) = -12$$

For a group of 4 players, the parameters can be replaced as such:

$$x_{soc} = (a - \varphi n)/2\,b = \big(130 - 50(4)\big)/2\,(5) = -7$$

Because we cannot account for a socially optimal negative harvest during the experiment, we constrained x_{soc} =1. Therefore, the individual harvest ranges from $1 \leq x_i \leq 8$. Now, to calculate the payoffs, we replaced the parameters w = 1530, a = 130, b = 5 and φ = 50. We considered w as independent from the harvest and made an arithmetic series with a marginal benefit function. In the case of 1 unit of private harvest, and 1 unit of harvest for each rival, the individual payoff is:

$$\pi = 1530 + \sum_{xi=1}^{8} \partial\,\pi/\partial\,x_i - \varphi x_j = 1530 + \sum_{xi=1}^{8} (a - 2bx_i) - \varphi x_j$$

$$\pi = 1530 + 130(130)(1) - 2(5)(1) - 50(4) = 1450$$

When the rivals' harvest x_j increases in 1 unit, the private benefit decreases in 50 points, which is the marginal cost of the externality φ. We used 4 rivals as a benchmark and kept the same payoff structure for 3 rivals. We decided to use this approach to facilitate the sums and avoid quadratic calculations in the field due to the lack of access to calculators or any computational device.

A3. Payoff structure

According to the expression:

$$\pi = 1530 + \sum_{xi=1}^{8} (130 - 10bx_i) - 50x_j$$

when a player increased their harvest x_i by one unit (keeping the harvest of rivals x_j constant), the payment increased; however, marginally decreasing. Now, when the rivals' harvest x_j increased by one unit (keeping the private harvest x_i constant), the individual payment decreased by 50 units, which was the cost of the externality. This decrease was constant.

A.4. Payoffs Sheet for 4-player groups

AGGREGATE HARVEST OF RIVALS	MY HARVEST							
	1	2	3	4	5	6	7	8
3	1,450	1,520	1,580	1,630	1,670	1,700	1,720	1,730
4	1,400	1,470	1,530	1,580	1,620	1,650	1,670	1,680
5	1,350	1,420	1,480	1,530	1,570	1,600	1,620	1,630
6	1,300	1,370	1,430	1,480	1,520	1,550	1,570	1,580
7	1,250	1,320	1,380	1,430	1,470	1,500	1,520	1,530
8	1,200	1,270	1,330	1,380	1,420	1,450	1,470	1,480
9	1,150	1,220	1,280	1,330	1,370	1,400	1,420	1,430
10	1,100	1,170	1,230	1,280	1,320	1,350	1,370	1,380
11	1,050	1,120	1,180	1,230	1,270	1,300	1,320	1,330
12	1,000	1,070	1,130	1,180	1,220	1,250	1,270	1,280
13	950	1,020	1,080	1,130	1,170	1,200	1,220	1,230
14	900	970	1,030	1,080	1,120	1,150	1,170	1,180
15	850	920	980	1,030	1,070	1,100	1,120	1,130
16	800	870	930	980	1,020	1,050	1,070	1,080
17	750	820	880	930	970	1,000	1,020	1,030
18	700	770	830	880	920	950	970	980
19	650	720	780	830	870	900	920	930
20	600	670	730	780	820	850	870	880
21	550	620	680	730	770	800	820	830
22	500	570	630	680	720	750	770	780
23	450	520	580	630	670	700	720	730
24	400	470	530	580	620	650	670	680

A.4 Payoff Sheet for 5-player groups

	MY HARVEST							
AGGREGATE HARVEST OF RIVALS	1	2	3	4	5	6	7	8
4	1,450	1,520	1,580	1,630	1,670	1,700	1,720	1,730
5	1,400	1,470	1,530	1,580	1,620	1,650	1,670	1,680
6	1,350	1,420	1,480	1,530	1,570	1,600	1,620	1,630
7	1,300	1,370	1,430	1,480	1,520	1,550	1,570	1,580
8	1,250	1,320	1,380	1,430	1,470	1,500	1,520	1,530
9	1,200	1,270	1,330	1,380	1,420	1,450	1,470	1,480
10	1,150	1,220	1,280	1,330	1,370	1,400	1,420	1,430
11	1,100	1,170	1,230	1,280	1,320	1,350	1,370	1,380
12	1,050	1,120	1,180	1,230	1,270	1,300	1,320	1,330
13	1,000	1,070	1,130	1,180	1,220	1,250	1,270	1,280
14	950	1,020	1,080	1,130	1,170	1,200	1,220	1,230
15	900	970	1,030	1,080	1,120	1,150	1,170	1,180
16	850	920	980	1,030	1,070	1,100	1,120	1,130
17	800	870	930	980	1,020	1,050	1,070	1,080
18	750	820	880	930	970	1,000	1,020	1,030
19	700	770	830	880	920	950	970	980
20	650	720	780	830	870	900	920	930
21	600	670	730	780	820	850	870	880
22	550	620	680	730	770	800	820	830
23	500	570	630	680	720	750	770	780
24	450	520	580	630	670	700	720	730
25	400	470	530	580	620	650	670	680
26	350	420	480	530	570	600	620	630
27	300	370	430	480	520	550	570	580
28	250	320	380	430	470	500	520	530
29	200	270	330	380	420	450	470	480
30	150	220	280	330	370	400	420	430
31	100	170	230	280	320	350	370	380
32	50	120	180	230	270	300	320	330

Appendix B. Estimation of selection bias

We made a quota sampling to try to ensure a rigorous procedure. Communities for the sample are *Nuqui*, which is the head of the municipality; *Pangui*, *Coqui*, *Jovi*, *Termales*, *Arusi*, *Tribuga* and *Jurubira*, which are *corregimientos* or rural villages that belong to the municipality. According to DANE (2005), 29.8 % of population live in Nuqui. The remaining 70.2 % are distributed in the rural villages. Among all of the communities, we obtained 159 participants. The largest attendance was in Nuqui, with 40 participants. This implies that we obtained 26.62 % participants from Nuqui, and 73.38 % from rural villages.

A Heckman Model is estimated to correct the possible selection bias. We used the probability of inhabiting the head of municipality of Nuqui dN as the censored variable. As instrumental variables we selected age a, age squared a^2. These variables were selected based on Deb & Seck (2009), who argue that age is a factor that determines human migration from rural villages to urban centers in search of opportunities and better income. In our case study, we can tell that Nuqui offers full school coverage, health centers and other sources of work than fishing. Finally, given the exclusion restrictions that require that variables of the first stage do not appear in the second stage (Certo *et al.,* 2016), age is omitted (Table B1).

TABLE B1

Players' behavior: Heckman's correction

Variable [1]	Schooling	Heckman [2]
x_{it-1}	ES	0.231***
		(0.0615)
	HS	0.0939
		(0.0646)
fxp_i	ES	0.151
		(0.193)
	HS	–0.103
		(0.173)
fz_j	ES	0.182
		(0.187)
	HS	–0.112
		(0.166)
domHS	ES	–0.0700
		(0.390)
	HS	0.170
		(0.349)
s		0.400
		(0.516)
g		–0.721*
		(0.407)
Constant		2.828***
		(1.011)

Variable [1]	Schooling	Heckman [2]
First stage [3]		
a		0.0759***
		(0.0154)
a^2		–0.000554***
		(0.000162)
Constant		–2.935***
		(0.350)
λ		0.624
		(0.597)

[1] Second stage dependent variable: Individual harvest x_{it}.
[2] Models estimated with two-stage least squares.
[3] First stage dependent variable: Nuqui inhabitant *dN*.
Significance: *10 %; **5 %; *** 1 %.

The first stage exhibits that age and age squared are significant indicating that as players age increases, the probability to live in the head of the municipality increases; later this probability decreases after a turning point. The second stage shows some similarities with results presented in Table 4. These estimations share signs with variables such as x_{it-1}, fz_j, s and g. However, there are differences in the magnitudes and significance of their coefficients. For variables such as fxp_i and *domHS,* we find significant differences in sign, magnitude and significance of coefficients. Due to this, we state 2 remarks:

1. The relation between players' age and the probability of inhabiting Nuqui is quadratic. This means that players age is a predictor to explain players' mobility. This is largely due to the fact that these rural villages have school coverage only up to 5 years of elementary school. Therefore, young people tend to travel to the head of the municipality to complete their high school studies. In general, these results show consistency with those shown by Deb & Seck (2009).
2. The coefficient that accompanies the inverse Mills ratio (IMR) λ is not significant. This indicates that this model does not contain an endogeneity problem due to selection bias (Certo *et al.,* 2016; Wooldridge, 2010). We assume that models presented in Table 4 represent the behavior of the participants in the experiment more efficiently than a *two-least square* model.

Appendix C. Individual decision sheet

Player No. ____________________

Age ____________________

Sex ____________________

Years of schooling ____________________

Rounds	A: Individual Harvest	B: Aggregate Harvest of Group	C (B–A): Aggregate Harvest from Rivals	D: Payoff
Practice 1				
Practice 2				
Practice 3				
1				
2				
3				
...				
10				
Total				