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Essays on the influence of schooling on artisanal fishing in Colombia

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Essays on the influence of schooling on artisanal fishing in Colombia

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Introduction

The evidence generally agrees that low-skilled people involved in agricultural activities fail at improving their earnings due to the fact they simply become overconfident and underestimate their need to develop alternative sources of revenue and the risk of relying entirely on natural exploitation of resources (Gylfason, 2001); aside from this, some researchers argue that resource-based economies tend to undervalue the importance of investing in education and skill formation due to their dependence on these resources (Gylfason, 2001; Papyrakis and Gerlagh, 2004; Sachs and Warner, 2001). Thereof, this lack of interest for finding direct incomes from alternative activities has been considered the principal cause of degradation of natural resources (Anderson 1980; Cunningham, 1993; Smith, 1979; 1981; Panayatou, 1988).

This problem especially affects the small-scale fisheries, both marine and inland. Usually, communities that depend on this activity are located in remote rural areas, with very few employment opportunities (Smith, 1979; Panayotou, 1988), tending to include non-skilled, poor, and landless people who rely their livelihoods only on fishing (Bailey, 1988; Cunningham, 1993; Mackenzie, 1979; Payne, 2000). Due to this, open access fisheries are considered as a last resort for fishing households when a failure to obtain a different source of income exists (Bailey and Jentouf, 1990; Panayotou, 1988; Townsley, 1998).

Accordingly, Smith (1979) argues that the lack of alternative income opportunities in the rural sector intensifies the fishing effort, and solutions to this problem might be found outside the activity. This can be achieved by enhancing the set of capabilities such as education and diversified livelihood activities strengthening the income of small-scale fishers; thus, ensuring the community development and the reduction of their vulnerability (Bailey and Jentoft, 1990; Bene and Friend 2009; Kraan, 2009).

In particular, investing in education helps to avoid depletion of resource-based economies by promoting efficient management (Hu and Xiao, 2007), eliminating the negative effect caused by a resource boom (Bravo-Ortega and De-Gregorio, 2007), encouraging technological improvement (Kurtz and Brooks, 2011), and increasing the possibility of substitution between production factors and economic activities (Shao and Yang, 2014).

Considering this problem, this research presents findings from three case studies from small-scale fishing communities from Colombia. The objective of this research is to contribute to the discussion by arguing that solutions for the problem regarding the pressure on fisheries can also be found by enhancing human capital and providing different economic opportunities of fishing communities.

To conduct this research, this document presents three chapters where three approaches are applied over three different fishing communities.

Chapter 1 presents findings on fishing communities inhabiting Inirida's Fluvial Confluence, located in the Colombian Amazon. According to DANE (2005), 17% of this population is illiterate, and only 42% have attended to elementary school.

In this case, a Sustainable Livelihoods Approach is applied. The results indicate that fishermen are not necessarily linked to alternative employment opportunities; although, the level of education of a fisherman is important to determine his opportunity cost and opportunities outside the fishing sector (Ikiara and Odink, 2000), and for obtaining better selling prices (Smith, 1979). Also, it is observed that those more-schooled fishermen have more probability of diversifying their livelihoods (Ellis, 1998; 2000). This document is published on vol. 17(2), December 2017 by the journal *Agricultural and Resource Economics* (EARN in Spanish).

Chapter 2 presents findings on communities inhabiting at Gulf of Tribuga, located at the Northern Pacific Coast of Colombia. According DANE (2005) 15,2% of this population is illiterate, and only 41.4% have attended to elementary school.

In this case, a Behavioral Approach is applied. The results indicate that fishermen with higher human capital exhibit a trial and error learning process moving towards higher payoffs under the context of a Common Pool Resource game. These results confirm the existence of individual learning based on feedback from past rounds (Huck et al., 2000; 2004; Selten and Buchta, 1998). This behavior indicates that the best decision to make is in the direction that was successful last time, relying on feedback and building a monotonic-payoff path to cooperative-collusive solutions.

Chapter 3 presents findings on communities inhabiting in the municipality of Tumaco, located at the Southern Pacific Coast of Colombia. According DANE (2005) 17,8% of population is illiterate, and only 43.5% have attended to elementary school.

In this case a Bioeconomics Approach is applied. Results indicate the presence of cross-section depreciation of human capital among shellfishermen. As long as human capital depreciates, this gives the fishermen motivation to increase their efforts. These results are consistent with the theoretical analysis of Bravo-Ortega and de-Gregorio (2007), indicating that as long as human capital increases, the total output obtained from natural resource sector decreases. This document is published on vol. 10(3), May 2019 by the *Mediterranean Journal of Social Sciences.*

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Chapter 1:

The lack of alternative income sources: the case of ornamental fishing in the Inirida Fluvial Confluence, Colombian Amazon[1]

Abstract

In this paper we present a case study of the impoverished ornamental fishing situation in the Inirida Fluvial Confluence (IFC) in Colombia. For this purpose fieldwork was conducted to obtain primary data from fishermen in the zone. The results indicate that effort applied to create different economic activities have no significant impact on the income of fishermen. Community Agreements for Responsible Fishing (CARF) could be an effective policy for management of the resource; nevertheless, their establishment can bring a loss of livelihoods when there are no clear alternative income sources, and may be incompatible with poverty alleviation objectives. Due to this, alternative sources of income should also be promoted in policy-making.

Keywords: Inland fisheries, Natural Resource Management, Rural Development.
JEL classification: Q22, I25, J15.

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1. Introduction

Although the problematic of deterioration affects both marine and inland fisheries, the main efforts for their protection have been focused on the former (Allan et al., 2005).

In the case of small-scale fisheries, this problematic is no doubt complex. On the one hand, some authors state that main reasons for degradation of fishing resource are caused by the open access, common property nature of the fisheries (Hardin, 1968; Pearce, 1982; Copes, 1989), and the seeking of rent-maximizing equilibrium for offsetting opportunity costs and investments (Gordon, 1954). As a consequence, rent dissipation is common and the fishermen fall into a poverty trap caused by competition.

On the other hand, some authors state that degradation of resources in small-scale fisheries is caused by the lack of opportunities for obtaining direct incomes from alternative economic activities (Anderson 1980; Smith 1979; 1981; Panayatou, 1988; Cunningham, 1993). Particularly in developing countries, small-scale fisheries are usually located in rural remote areas, with very few alternative employment opportunities (Smith, 1979; Panayotou, 1988). Due to this, fishing could be the only economic activity for providing income and food to local populations (Bailey and Jentof, 1990). In any case, there is a global consensus, that the status of fish stocks is worsening rather than improving and catch weights are declining despite the increase in total fishing effort (FAO, 2014).

In the case of Amazon inland fisheries, Siren (2006) indicates that these different causes for explaining the resource degradation are not necessarily mutually exclusive and instead may interact with each other. Besides these causes, some other pressures can also be attributed such as the market, new fishing gear, and the destruction of aquatic ecosystems (Smith, 1985; Pinedo and Soria, 2008). Despite the high productivity of Amazonian fisheries, their scarcity periods are more frequent every day (Castro and McGrath, 2010).

This research focuses on the components that define the income of inhabitants of Inirida Fluvial Confluence (IFC) located in the Colombian Amazon. For this purpose, the hypothesis that the population relies on small-scale inland ornamental fishing[2] due to lack of more profitable alternatives is adopted (Smith, 1979). Failure to diversify economic activities to secure their livelihoods is assumed (Vedeld et al., 2012).[3]

For developing this analysis, we test whether alternative livelihood sources generate significant income for local inhabitants and identify whether mechanisms for protecting the resource are found outside the fishing sector by creating alternative or supplementary livelihood sources (Kooiman, et al., 2005; Allison and Horemans, 2006).

This research attempts to provide a contribution to the literature regarding the activity of inland ornamental fishing, thus reducing the absence of scientific evidence and generating

[2] According to FAO (2014) ornamental fishing and aquaculture species can be considered as ones captured and kept alive for decorative and pet purpose. Zuluaga and Franco-Jaramillo (2014) based on the Data Base of United Nations Commodity Trade Statistics Database estimate that the world value of exported decorative fish was USD 142,734,000 million during 2012. According to Ajiaco-Martinez et al. (2012), South Asian countries are the main providers with 85% of the market share, whereas the remaining 15% is distributed between Brazil, Colombia and Peru.

[3] Particularly Vedeld et al. (2012) state that households tend to diversify their sources of income when options outside their main agricultural activities (i.e. fishing) are more profitable.

input for enhancing institutional response in the zone.[4] The remainder of this document contains section 2 where the context of the fishermen population in IFC is explained. Section 3 presents a theoretical model for explaining the behavior of fishermen. Section 4 presents the empirical analysis and findings. Finally, in section 5 some conclusions and final remarks are made.

2. Context of case study

This section presents the population on whom this research is conducted, and for whom it is proposed to apply the Community Agreements for Responsible Fishing.[5] This section provides a broad insight of the social and economic characteristics of the studied communities based on primary sources of information and experiences collected and published by Zuluaga and Franco-Jaramillo (2013), and Zuluaga and Franco-Jaramillo (2014) during their research in these communities. This research was carried out in the indigenous communities of Yuri, Santa Rosa, La Ceiba, and Almidon, located in Inirida's rivera, and Playa Blanca located in Atabapo's rivera. These communities belong to the IFC of Orinoco hydrographical basin, and to the municipalities of Inirida in the department of Guainia, and Cumaribo in the department of Vichada. These two departments are located in the northeast Amazon, along the frontier between Colombia and Venezuela.

2.1 Economic activities [6]

According to Agudelo et al. (2011), in the Colombian Amazon, 52% of the regional production of fish is based on small-scale artisanal fishing. On the one hand, 335 of captured species are considered ornamental, and represent 50% of this commodity exported from Colombia (Ramirez-Gil and Ajiaco-Martínez, 2001).[7] During 2005, royalties from the exportation of these species were estimated at around USD $7,000,000 (INCODER, 2008; in Mancera and Alvarez-Rodriguez, 2008). However, this practice faces a progressive decrease due to overfishing among other causes (Zuluaga and Franco-Jaramillo, 2014), although users' perception recognizes no such decrease (Ajiaco-Martinez et al., 2012). Moreover, according to local inhabitants and researchers in the zone, the prices of this commodity have remained constant over the past 10 years due to the bargaining power of local buyers. On the other hand, 132 species are destined for local consumption or marketed inside the communities (Lasso et al., 2010).

Other economic activities are performed such as small-scale agricultural harvesting of land crops called Conucos; non-timber fiber processing and manufacturing; and gold mining in some communities. This latter activity is poorly documented due to political and environmental problems involved, thus locals recognize it as profitable, but infrequent.

[4] According to Ajiaco-Martinez et al. (2012), for this activity there is an absence of scientific evidence regarding the biology of species and many institutional deficiencies that foster difficulties for controlling and monitoring the users of the resource.

[5] Section 2.2 explains the definition and basis of these Community Agreements for Responsible Fishing.

[6] Due to importance the economical, ecosystem and biodiversity importance, the IFC have been declared as objective for wetland protection since 2004 (Londoño-Calle, 2012). In July 8, 2014 the IFC was declared Ramsar wetland of international importance. Thus, the IFC becomes the sixth Ramsar site in Colombia and the first in the Orinoco-Amazon region in South America.

[7] Zuñiga (2010; in Zuluaga and Franco-Jaramillo, 2014) argues that 90% of this resource is harvested directly from their natural stock and are mostly managed by indigenous communities in the Amazon.

Ramirez-Gil and Ajiaco-Martínez (2001) estimated that there were 194 fishermen in the IFC. For 2010, the World Wildlife Foundation (WWF) estimated an approximate number of fishermen in these communities which has been summarized in Table 1 below:

Table 1: Population of fishermen in study zone

Community	Families	Approximate count of fishermen	Distance to Urban Zone (Km)
Almidon	8	16	6.20
Santa Rosa	12	40	25.13
La Ceiba	28	28	26.91
Yurí	83	180	36.04
Playa Blanca[8]	16	15	-

Source: WWF (2010)

2.2 Community Agreements for Responsible Fishing

The creation of the Community Agreements for Responsible Fishing (CARF) has been motivated for controlling the increasing human pressure and market demand for fish, which threatens the biodiversity of the IFC and compromises the local food security, nutrition, and equitable development of the local people. CARFs are based on the model proposed by Conservation International (2007), promoted by the National Authority for Aquaculture and Fisheries (AUNAP for its acronymin Spanish) of the Ministry of Agriculture of Colombia and executed by WWF. They began their formulation in 2012 by identifying different fishing sites, objective species, and socio-economic implications/effects of the fishery.

In a broad sense, the CARF aims at the regulation of fishing gear and intensity of effort, delimitation of territory and access to fishing areas. Basically a CARF will limit access to prior natural capital for obtaining livelihoods in communities located in IFC. Then, local communities will receive little income, but substantial costs related to resource access restrictions. However, because CARFs are yet not applied there is no clear understanding of their overall impact and how the impacts differ in different contexts, at individual or household levels; i.e. perceiving whether protection is effective by imposing legal constraints rather than offering economic opportunities (Shemweta and Kideghesho, 2000). Therefor, the evaluation of CARF impacts on livelihoods is beyond the scope of this investigation.

There have been relatively few studies that evaluate the impacts of programs aiming at creating protected areas and conservation incentives on livelihoods (Thapa, 2013). Nevertheless, their findings show that they are believed to play an important role in the alleviation of poverty by supplying ecosystem services, developing ecotourism, and providing conservation benefits for social and economic development (Fortin and Gagnon, 1999; Brockington and Igoe, 2006; Ferraro and Hanauer, 2011); However, these benefits have not been found to offset the costs involved by the creation of protected areas (West et al., 2006), and their establishment also brings adverse effects on neighboring

[8] The accurate distance of Playa Blanca to urban zone is not available; nevertheless, locals consider this community as the furthest from urban municipality.

communities mainly through displacement, a reduction in food security, and a loss of livelihoods (Brockington and Schmidt-Soltau, 2004; Cernea and Schmidt-Soltau, 2006).[9]

Therefore, it has been argued that local impacts of establishing resource protection policies can lead to sub-optimal results, especially when faced with a limited set of opportunities for obtaining additional incomes, which should also be targets for governance reform. Due to this, small-scale fisheries management is also about creating opportunities instead of merely solving problems (Kooiman et al., 2005; Allison and Horemans, 2006). In consequence, any agreement should contain governance reform aiming at providing small-scale fishermen with a set of opportunities and capabilities to improve their livelihoods and diversify them in order to utilize their household assets more fully, thus enhancing the possibilities for development (Vedeld et al., 2012).

3. Theoretical framework

3.1 Determination of fishermen's income

This analysis is based on the theoretical model proposed by Anderson (1980) with a slight modification, which does not alter the main conclusions. First, lets assume that all the arguments that define the income of a fisherman are expressed in terms of the income received by ornamental fishing I_O and a supplementary activity I_A, which in the case of IFC are commercial activities such as selling agriculture products, non-timber manufactures, and fish-food marketing.

$$I = I_O f(L) + I_A f(L) \tag{1}$$

In this model, incomes depend on the effort applied to the activity plus the opportunity that incomes involve, expressed as a psychic return to the activity defined as *worker satisfaction bonus* (WSB). Assuming an open-access equilibrium in a two-activity model, the net real income is equal in both industries (2).

$$I_O + WSB_0 = I_A + WSB_A \tag{2}$$

In this case, there will be no incentive for agents to change activities (2). Furthermore as Anderson (1980) states, as WSB seems to be less variable than monetary incomes, it is probably the latter that drives the fishery to equilibrium. Then, the reason for explaining why fishermen remain in the activity is because fishing provides a total net income higher than the other activities due to a rent earned from the fish stock (3).

$$I_O + WSB_0 > I_A + WSB_A \tag{3}$$

In the contrary case, it can be assumed that fisherman will leave the fishing activity and reduce the pressure on the resource (4).

$$I_O + WSB_0 < I_A + WSB_A \tag{4}$$

9 A closer experience in La Pedrera, located in the Colombian Amazon shows that conservation agreements applied during 2007 ensured the recovery of the fishing resource during 2009 to 2010 (Mora et al., 2010). Although communities involved in the program experienced a decline in revenue due to the implementation of these agreements (Moreno-Arias and Moreno-Arias, 2010)

As a final remark, Anderson (1980) concludes that optimal management of the fishery can increase net fishing income, but it seems to be based on a confusion of wealth and income effects.

3.2 Sustainable livelihoods and diversification

According to Ellis (2000), livelihood diversification as a phenomenon that characterizes rural household survival strategies. The author argues that livelihood diversification should considered as an objective for long term policy making for reducing poverty in low income economies, and not as merely a transient phenomenon reflecting disequilibrium in labor markets in the process of development thus ensuring the survival of rural economies and reducing the vulnerability of peoples' livelihoods.

Different motivations for livelihood diversification are seasonality, risk, labor markets, credit markets, asset strategies, and coping behavior (Ellis, 2000). These determinants are mediated through social relations and institutions, and shaped by interactions with the physical environment, and by changes in the economy over time due to liberalization policies. Thereby the role of diversification in reducing the intensity of poverty promotes a process of continuous adaptation for avoiding labor market failures and for attaining a better income distribution in rural economies.

As a conclusion, Ellis (2000) argues that having diverse alternatives income sources can make the difference between sustainable livelihoods and extreme poverty.

4. Empirical analysis

This section presents the analysis of the data collected during August 2014. The information is obtained from 45 male fishermen through a semi-structured survey. This section also presents a brief descriptive analysis of the information and the statistical estimations.

4.1 The Data

This sample takes into account only artisanal ornamental fishermen from 5 communities located inside the IFC. These fishermen also perform alternative activities for obtaining income.

Table 2. Sample of fishermen

Community	Fishermen	Average size of household
Almidon	8	6.0
Santa Rosa	12	3.6
La Ceiba	8	6.4
Yuri	14	4.4
Playa Blanca	3	5.3
Total	45	5.14

Source: Own elaboration.

The survey collected data related to average weekly income from ornamental fish sales, commercializing fish-food and non-timber manufactures, and working for other employers. The latter activity entails full or part time waged-occupations that provide income by selling labor inside or outside the communities. Data regarding the weekly hours destined to different activities was also obtained.[10]

Table 3: Economic activities of sample fishermen

Activity	Average weekly [a] income	Average weekly hours	Principal activity	Supplementary activity
Ornamental Fishing	$127,200	49.86	32	13
Fish-food	$75,000	37.06	1	10
Conucos	$37,500	33.68	12	16
Non-timber manufactures	$25,000	43.5	-	4
Working for other	$75,000	40	-	2
Full-income	$231.000	-	-	-

[a] The exchange rate by the date for dollar was 1,880 COP/USD. For euro was 2,450 COP/€

Source: Own elaboration.

Data collected also contains information about mobilization, indicating whether the fisherman powers the boat using oars or an outboard motor. The variable '*tv* ownership' indicates the richest households. The variable *ow* indicates whether fishermen are owner-operators of their vessels, then distinguishing between returns of labor and capital. Cunningham (1993) states that if a fisherman is capitalist rather than a laborer, he finds it difficult to leave the fishery. Regarding the education of fishermen, it is observed that everyone has some level of schooling. Variable *dhs* indicates whether a fisherman has attended any level of high schooling.[11] Particularly in this zone, the schooling coverage in every community is up to 5 grades of elementary school. In order to continue with formal education, inhabitants of the communities have to travel up to the urban area of the municipality of Inirida. For this purpose they have to travel by water transport, which entails a high cost. This is one reason there is high abandonment of high school by fishermen. Information about family composition was also collected; the variable *cs* indicates whether a fisherman is married or not. This variable indicates when fisherman is the head of household. Finally, *fpa* indicates when fishing is the principal activity of the fisherman. This variable contains information about self-recognition in the activity, and most important, this variable tries to obtain information about the bargaining power of the fishermen when faced with the local buyers. Table 4 summarizes this information.

[10] Previous interviews, focus groups, and communication with local leaders in the zone were performed before conducting the survey.

[11] Formal elementary schooling in Colombia is 5 years. High schooling is 6 years. Technician tertiary schooling entails up to 3 years of schooling. Tertiary professional is up to 5 years for obtaining a Bachelor Diploma.

Table 4: Socio-economic characteristics of simple

Variable	Definition	Quantity	Percentage of sample
tv	Television ownership	25	55.56%
r	Row mobilization	32	71.11%
ow	Vessel ownership	34	75.56%
dhs	High-schooled fishermen	24	53.33%
cs	Civil status	36	80%
fpa	Fishing as principal activity	32	71.11%

Source: Own elaboration.

4.2 Estimations

In order to measure the relation between the effort and the average income of the livelihood of a fisherman, an OLS model was estimated with the information obtained from the survey. This estimation considers the weekly average income obtained from fishing and alternative activities as a dependent variable. As independent variables, it considers *f* as the weekly hours exclusively applied to ornamental fishing and *oa* as the weekly hours applied to commercializing alternative commodities, fish-food included. These weekly hours also contain the time for traveling to the urban market in Inirida. Additionally, some other variables are taken into account such as of rowing for transport *r*, which takes the value of 1 if a fisherman moves using rowing, 0 if using an outboard motor. The ownership of vessel is indicated by the variable *ow*, which takes the value of 1 if a fisherman owns the vessel, 0 otherwise. The variable *dhs* defines the schooling of fishermen; this variable takes the value of 1 if a fisherman has received any kind of secondary schooling, 0 otherwise. Civil status *cs*, which is a dummy variable, takes the value 1 if a fisherman is the head of household, 0 otherwise. Dummy variable *fpa* takes the value 1 if fishing is a principal activity for the agent, 0 otherwise. Finally, controls for the activities *ff*, *ch*, *nm*, and *w*, and distance to urban market expressed by the communities *sr*, *lc*, *y*, and *sr* are applied to identify differences on income. These descriptors are presented in Table 6.

Table 6: Descriptors of income composition

Variable	Descriptors	Expected sign
f	Weekly effort on fishing	+
oa	Weekly effort on other activities	+
r	Row boats (mode of transport)	-
ow	Vessel ownership	+
dhs	Some high-school experience	+
cs	Civil Status	+
fpa	Fishing as principal activity	+
ff	Fish-food	-
ch	Conucos	-
nm	Non-timber manufactures	-
w	Working for others	-
sr	Santa Rosa	-
lc	La Ceiba	-
y	Yuri	-
pb	Playa Blanca	-
Constant		+

Source: Own elaboration.

Descriptors such as *sr*, *lc*, *y*, and *pb* are presumed to exhibit lower incomes compared to Almidon due to those fishermen living in Santa Rosa, La Ceiba, Yuri, and Playa Blanca which are further from urban market buyers and subject to local buyers with greater bargaining power. The results of this estimation are presented in Table 7.

Table 7: Income composition in IFC

Variable [a]	Descriptors	Coefficient
f	Weekly effort on fishing	-831.99
		(929.01)
oa	Weekly effort on other activities	-682.19
		(804.81)
r	Row boats (mode of transport)	-48836.43**
		(23590.04)
ow	Vessel ownership	37571.8*
		(21551.61)
dhs	Some high-school experience	34059.37**
		(16697.51)
cs	Civil Status	36951.73**
		(18310.22)
fpa	Fishing as principal activity	51612.44**
		(25431.5)
ff	Fish-food	-21608.16
		(55641.45)
ch	Conucos	-626.49
		(52079.14)
nm	Non-timber manufactures	-1932.45
		(63226.39)
w	Working for others	34988.72
		(54672.89)
sr	Santa Rosa	8812.15
		(28923.09)
lc	La Ceiba	22645.15
		(20018.72)
y	Yuri	-30448.32
		(21971.93)
pb	Playa Blanca	-6395.41
		(32601.53)
Constant		97986.61**
		(47156.81)

[a] Weekly income *i* as independent variable. R^2=0.3132, F=0, n=90.
Test regarding normality exhibit no statistical evidence to reject the normality of errors. Problems of heterosckedasticty are corrected in the estimation. Tests are presented in Appendix.
*Significance at 10%. ** Significance at 5%. *** Significance at 1%.
Source: Own elaboration.

Table 7 shows that neither *f* nor *oa* exhibit significant statistical relationship to the income of fishermen.[12] One of the reasons for explaining the non-statistical relationship between the income and the effort applied to fishing is the dynamic of distribution. The fishermen are paid once the commodity arrives at the final buyer having no control over the supply chain and the species that arrive alive; thus facing the total mortality of the commodity.[13]

[12] In order to deal with the analysis of the effect of effort on performance in terms of income, interactions within variables such as *f*ow* and *oa*ow* were estimated, though they are non-statistically significant.
[13] The estimation of mortality is 2.2% in capturing, 1.7% during community buying, and 1,2% to urban buyers. Nevertheless, this mortality varies from 0,7% up to 16% depending on species and season (Ramirez-Gil and Ajiaco-Martinez, 2001).

Moreover, the different activities represented by *ff*, *ch*, *nm*, and *w*, provide non-statistically significant higher incomes than ornamental fishing in IFC.[14]

This result presents some evidence to consider that IFC households rely on fishing due to lack of more profitable alternatives outside the fishing activity. According to authors such as Townsley (1998), Bailey and Jentouf (1990), and Panayotou, (1988), fisheries constitute a last resort for rural households when there are few alternative sources of income, or access to other economic activities. As a consequence they are often unlikely to subsist by other activities rather than fishing (Dunn, 1989). Besides, according to Payne (2000), Mackenzie (1979), Bailey (1988) and Cunningham (1993), both marine and inland small-scale fisheries tend to include non-skilled, poor, and landless people; thereby fishermen rely for their livelihood only on fishing, which is maintained as their principal activity (Bailey, 1988; Vedeld et al., 2012).

Regarding the non-significant difference between alternative activities income of fishermen, some possible explanations arise. According to Sachs and Warner (2001), full dependence on the natural resources tends to crowd out other economic activities that could promote economical growth. The authors define the situation as the *Resource Curse,* which is based on the criterion that a population dedicated to exploit natural capital tends to neglect other activities because the high original revenues obtained from exploitation. Table 3 shows that ornamental fishing provides, on average, almost twice the income than selling fish-food and working for other, which are activities with the higher income after ornamental fishing.

Results regarding the fishing technology indicate that those fishermen who power their boats by rowing have significantly lower incomes. In this case, it is assumed that those fishermen who have outboard motors can travel longer distances and find less exploited fishing zones, thereby capturing more fish.

The ownership of the vessel indicates that those fishermen who perform the activity as capitalists rather than employers have incentives to earn higher incomes to recompense their opportunity costs. This is an important result considering that Panayotou (1982) argues that fishermen may continue fishing even if they earn far less than their opportunity costs. In this case, those who own a boat have an explicit opportunity for referencing whether the activity is profitable or not, thereby these owners perceive ornamental fishing as a business.

Furthermore, according to Copes (1989), Ikiara and Odink (2000), and Doulman (2004), the opportunity cost of fishing for most fishermen is very low, thereby the opportunity cost of other activities is relatively higher than fishing. In this way they rely less on other activities leaving them underdeveloped or for sporadic engagement. It is also necessary to remark on the schooling of fishermen. It means, that despite 26 fishermen having received some kind of secondary school experience, 42 of 45 fishermen have not completed the official basic schooling of 11 grades, and only 3 of them have a tertiary schooling. As an explanation it is presumed that due to schooling provided in the communities of IFC reaches only 5 grades, which means that as fishermen have to travel to the urban zone of Inirida in order continue their schooling at a high opportunity cost; thereby a high abandonment of schooling is plausible. Taken into account this abandonment, possible consequences are slow human capital accumulation, low skills formation, and lower

[14] Inhabitants declare that trading manufactured and agricultural products, and other related activities do not provide enough income to inhabitants of IFC communities.

specialization in technical activities. According to Gylfason (2001), populations involved in exploitation of natural resources tend to have low schooling enrolment rates due to their reliance on the revenues from this activity. As a consequence, lower levels of growth and development are present. This is linked to findings from Sachs and Warner (2001), where populations involved in natural resource exploitation face a curse.

However, some explanations arise regarding the schooling of fishermen and why the more-schooled ones obtain higher incomes. Firstly, due to the isolation of fishing communities in IFC, more-schooled agents are not necessarily linked to alternative employment opportunities, although the concept of a *quality of life* effect promoted by educational achievement generally encourages them to obtain higher incomes (Smith, 1979). Secondly, the level of education of a fisherman is important to determine his opportunity cost and opportunities outside the fishing sector, respectively (Ikiara and Odink, 2000). Thereby, informational or educational power results in knowledge for obtaining better selling prices and sales alternatives (Smith, 1979). Thirdly, Gylfason (2001) argues that relying on natural resources brings risks. Moreover, the cost of collecting and processing information about the risks and returns for an asset might be lower for more educated individuals (Black et al., 2015), More-schooled fishermen can perceive the risks associated with the full dependence on one resource, thereby being encouraged to obtain higher incomes in order to compensate for the risks involved in the primary activity.

The coefficient of variable *cs* indicates that those fishermen who are head of household obtain higher incomes than those that are not head of household. In this case, it can be presumed that those fishermen who face obligations for supporting a family are encouraged to obtain higher incomes. Nevertheless this is an assumption that requires to be proved.

The variable *fpa* includes information about the *know-how* of the activity. Considering these results, it can be asserted that those fishermen who perform the activity as their principal one, are more frequent on it; thereby they ensure better methods for avoiding fish mortality due to better techniques or equipment, proximity to the local buyer, or just because they are experienced. Moreover, this result also can provide an approximation of the bargaining power of fisherman, because those who perform the activity more frequently can ensure better payments for the quality of their catch in terms of the health of the fish.

Moreover, the estimations regarding *fpa* provides an insight into the *WSB*, which is an individual-level feeling that reflects if a fisherman's needs are being met by the activity they perform. According to Pollnac and Poggie (2008), fishing is often more than just another occupation and most fishermen have a strong attachment to it. The authors argue that fishing is an occupation that can be characterized as active, and adventurous, which satisfies the needs of the person. This explains the extent to which fishermen are willing to give it up for alternative professions (Bavinck et al., 2012). Thereby fishing being a satisfactory occupation, fishermen tend to be more productive, creative and committed to this activity (Syptak et al., 1999).

Regarding the distance to urban market buyers, control variables exhibit no significantly higher income over those communities located further from Almidon. This is because fishermen inhabiting isolated communities are subject to the bargaining power of local buyers and face mortality risks of the fish. Particularly, the estimation signs for Yuri and

Playa Blanca are negative, though non-significant, corresponding to that of the furthest communities.

4.3 Livelihoods diversification in IFC

Considering that diversification focuses on different income sources and their relationship to income levels (Ellis, 1998), non-fishing earnings to on-fishing earnings can be compared. For analyzing this, a dummy variable *di* is created taking the value 1 when more than 50% of a fisherman's income is obtained from activities other than fishing. On the other hand, taking value 0 when 50% or less of income is obtained from other activities, i.e. when a fisherman relies 50% or more for his livelihood on fishing. This is an approximation to diversification behavior. A probit model is estimated considering *di* as a dependent variable and some socio-economic characteristics as independent variables.

Table 8: Determinants of diversification in IFC

Variable [a]	Description	Coefficient	dy/dx
dhs	High-schooled fishermen	0.727*	0.244*
		(0.398)	(0.131)
ph	Household size	0.11	0.038
		(0.085)	(0.029)
cs	Civil status	0.36	0.116
		(0.551)	(0.165)
tv	Television ownership	0.063	0.022
		(0.406)	(0.14)
ow	Vessel ownership	-0.746*	-0.272*
		(0.446)	(0.165)
Constant		-1.249	-
		(0.848)	-

[a] Dummy of diversification di as dependent variable.
Pseudo R^2= 0.1028, Prob > Chi^2 = 0.241, n = 45.
*Significance at 10%. ** Significance at 5%. *** Significance at 1%.
Source: Own elaboration.

In this analysis it is observed that those more-schooled fishermen have more probability to diversify than those that only have basic schooling. This confirms, as Ellis (1998; 2000) and Vedeld et al. (2012) argue, that in IFC the lack of education is a constraint inhibiting diversification and development of alternative activities for securing livelihoods. It limits inhabitants to depend on ornamental fishing.

Interestingly Ellis (2000) argues that diversification allows actors to reduce risk involved in the seasonality of activities, i.e. fishing. In this case, those more-schooled fishermen exhibit this behavior, which entails a strategy for reducing risk represented by a smaller probability of income failure. Thereby off-fishing revenues are considered as complementary revenues, sometimes representing higher average incomes.

Moreover, owners of vessels tend to diversify less. This we consider reasonable considering the explicit opportunity cost involved in this activity. It is notable that, neither belonging to a big household, being head of household, nor the level of wealth have any statistical influence on diversifying livelihoods in IFC.

5. Conclusion and final remarks

5.1 Discussion

This research focuses on the analysis of the income of fishermen in their main activity and the possible alternative activities without considering the exploitation costs Nevertheless it considers the lower opportunity cost compared to other activities (Copes, 1989; Ikiara and Odink, 2000; and Doulman, 2004). Open access equilibrium, sustainable yield, or overexploitation outcomes related to common-pool resource management are beyond the scope of this analysis. However, the understanding of strategies for secure sustainable livelihoods does not necessarily require exhaustive analysis about the evolution of labor dynamics in fishing. The results allow judgment that reducing extractive effort applied to the fishing resource proposed by the CARF is not enough to ensure effective management of the ornamental fishery and sufficient social support for fishermen in their struggle for survival and for improving their standards of living.

According to Smith (1979), households intensify efforts and pressure on fishing due to the lack of opportunities in the rural sector leading to overexploitation of resources and reduction of incomes, even though the conventional wisdom of common-pool resources findings states that open access is the mechanism that leads to the overexploitation of the resource (Hardin, 1968; Pearce, 1982). This may be due to fishing effort efficiency that seeks rent-maximizing equilibrium for offsetting capital investment (Gordon, 1954), regardless the lack of alternative opportunities. Additionally, Smith (1979) argues that as long as the resource remains open-access, long-term solutions to the dual problem of overexploitation of the resource and low fishing incomes lie outside the fishing sector in the form of alternative or supplementary income sources.

Furthermore, it is necessary to recognize that the improvement of fishermen's income is one of the objectives that authorities such as AUNAP pursue. Nevertheless fishing development is a multi-objective activity where it is necessary to adopt specific labor market supply-side measures to ensure that the value of fishermen is improved. This may be achieved through demand-side measures in communities by promoting investment and providing alternative employment opportunities (Cunningham, 1993).

5.2 Conclusions

There is evidence to state that the lack of alternative income opportunities in the IFC leads inhabitants to rely for their livelihoods on fishing (Smith, 1979; Ellis, 2000; Vedeld et al., 2012), and for obtaining higher incomes. The non-significant relationship of effort f on fishermen's income allows us to consider that reducing access to natural capital not necessarily brings a direct decrease of the income of fishermen. However because fishing provides higher incomes, fishermen have monetary incentives to remain in the activity because supplementary activities are less profitable than ornamental fishing.

Owners of vessels perceive their activity in a businesslike way and are subject to higher opportunity costs that require to be recompensed. Transport technology allows fishermen to travel longer distances and find less exploited fishing zones, thus obtaining more species for sale.

Moreover, those fishermen who perform the activity as a principal one have a higher bargaining power, by providing consistent and healthier species to local buyers. Besides, fishing being a satisfactory occupation, fishermen tend to be more productive, creative and committed to this activity, thereby ensuring higher payments for the commodity and thus higher incomes.

Finally, distance to urban markets, though not statistically significant, exhibits evidence that isolation provides lower income to inhabitants of IFC. This is because fishermen living in isolated communities are subject to local buyers bargaining power.

5.3 The importance of education in IFC

Several studies concur that education is a great facilitator of livelihood diversification, and somehow, the lack of education constrains finding alternative means for obtaining income. Thereby, less educated agents are more dependent on income obtained from the natural environment, i.e. fishing. Besides, lower education levels are often found to correlate to fewer available income alternatives (Vedeld et al., 2012).

In this research, findings indicate that the increase of incomes related to higher schooling is not necessarily related to human capital accumulation and the substitution of effort in fishing with other activities that promote economic growth. According to Gylfason (2001), a population involved in exploitation of natural resources fully relies on the revenues obtained from these activities. Nevertheless, schooling provides information to fishermen for perceiving opportunities and opportunity costs involved in the activity, the risk involved in the activities, and the strategies for securing their livelihoods (Ellis, 1998; 2000).

5.4 Policy implications and recommendations

Although there is no understanding whether impacts of CARF will impose constraints or offer economic opportunities, it has been argued that these programs frequently lead to sub-optimal results, especially when populations face a limited set of opportunities for diversifying livelihoods.

However, protection of wildlife and the physical environment should not be seen as a critical constraint for poverty alleviation and creation of protected areas should not be seen to increase poverty. Instead of this, conservation strategies should be used as a means to sustain the environment and the resources within it (Adams et al., 2004). Thus, the CARF can be an effective policy to manage the resource in the short run. Nevertheless, the entitlements provided by these agreements should include investments outside of the fishery sector to enhance the set of opportunities in education, sanitation, communication, transportation, and supplementary livelihood activities in order to strengthen the income of small-scale fishermen (Cunningham, 1993; Vedeld et al., 2012); thus, ensuring a form of community development will happen, including a reduction of their vulnerabilities (Bailey and Jentoft, 1990; Bene and Friend, 2009; Kraan, 2009).

Appendix

A.1 Test for normality of error term

The test for normality exhibits evidence that errors are not distributed normally. However, considering 90 observations we can apply the Central Limit Theorem, allowing us to assume that a large and ramdom sample approaches normality regardless the shape of the population distribution.

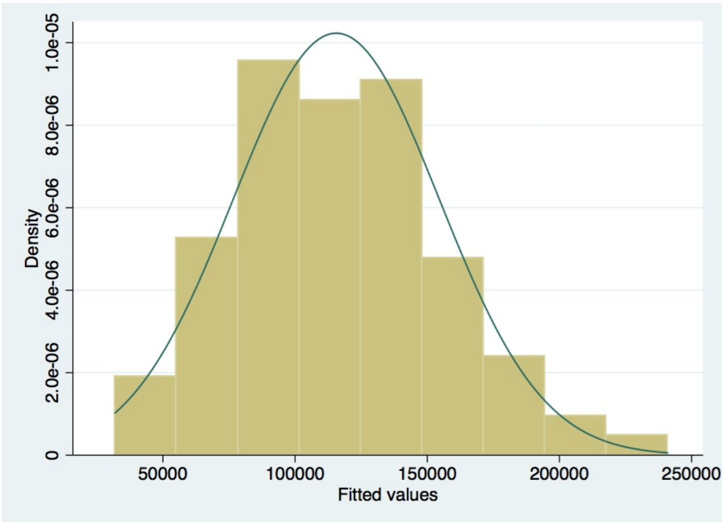
Table A1: Test for normality

Variable	n	p- value (Skewness)	p-value (Kurtosis)	Joint chi2(2)	Joint Prob>chi2
errors	90	0.0425	0.4329	4.75	0.0932

Source: Own elaboration

However, the histogram of distribution of errors shows no large deviation from a normal distribution.

Figure A1: Distribution of errors



Source: Own elaboration.

A.2 Test for heteroskedasticity

Breush-Pagan test exhibits evidence of heteroskedasticity. For correcting this, we ran a regression controlling by clustering variable id, which means each fisherman. Then we corrected this problem in the regression

Table A2: Breush-Pagan test

Breush-Pagan	
$chi^2(1)$	3.59
p-value (BP)	0.0581

Source: Own elaboration.

A.3 Test for Multicollinearity

Correlation between variables exhibits evidence of multicollinearity between effort applied to fishing *f* and fishing as a principal activity *fpa*, which seems credible given that fishermen who perform the activity as a principal one are more active on it. However, due to these variable are objective of theoretical and empirical analysis, we decided to estimate the effect on income separately.

Table A3: Correlation matrix of variables

		f	*oa*	*r*	*ow*	*dhs*	*cs*	*fpa*
Effort on fishing	*f*	1						
Effort on other activities	*oa*	-0.8463	1					
Row boats	*r*	0.0444	0.0863	1				
Vessel ownership	*ow*	0.0570	0.0940	0.7783	1			
High-school experience	*dhs*	0.0131	-0.0184	0.0898	0.1900	1		
Civil Status	*cs*	-0.0206	-0.0302	-0.1551	-0.1961	-0.2450	1	
Fishing as principal activity	*fpa*	0.7792	-0.6535	0.3145	0.2686	-0.0031	-0.0928	1

Source: Own elaboration.

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Chapter 2:

Influence of human capital on the trial and error learning process in a CPR game[15]

Abstract

This paper presents a study regarding the behavior of Pacific-Colombian fishermen 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, fishermen 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.

Keywords: Common-Pool Resources, Non-cooperative games, Learning.
JEL classification: I12, C72, D83.

[15] This research was conducted within the project *Biodiversity Conservation of Utria National Park through the sustainable management of buffer zones*, executed by MarViva in cooperation with Word Wildlife Fund (WWF Colombia), Natural Heritage (Fund for Biodiversity and Protected Areas) and the United States Agency for International Development (USAID). The project aims at defining activities for artisanal fishing management agreements in the Gulf of Tribuga, Colombia. Results of this research contribute to the design of programs for sustainable fishing in the area and for strengthening governance in local communities.

1. Introduction

ZEPA (acronym in Spanish for Exclusive Areas for Artisanal Fishing) and 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, Diaz, and Diaz, 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 fishermen.

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

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

However education, both formal and informal, turns out to be an effective management tool in marine protected areas. Education 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 and Marrero, 2010) and be able to make informed and responsible decisions concerning marine resources (Cava et al., 2005).

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, Gardner and Walker (1994). These studies have provided findings regarding how the perceived inequality in the group constrains the effectiveness of communication (Cardenas, 2003); how the modest enforcement of the cooperative equilibrium outperform face-to-face communications (Cardenas, 2001); and how the combination of internal communication and external non-coercive intervention leads to better results in terms of community organization (Moreno-Sanchez and 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.

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-Sanchez and 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, Chong and Ñopo, 2009; Brañas, Cardenas and Rossi, 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, Stranlund, and Murphy, 2009).

Considering this gap in the behavioral and experimental economics literature, we attempt to explain how higher levels of schooling guide the individual behavior to a cooperative-collusive solution through a *Trial and Error Learning Process* (Huck, Normann and Oechssler, 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 fishermen 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 fishermen. 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 [16]

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, 2002; Burks, Carpenter and Verhoogen, 2003; Schramm, 1998; Tan and 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

[16] 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).

errors.[17] 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).

Considering the lack of evidence from CPR games, we are interested in analyzing how villagers with different levels of schooling make decisions when facing a payoff structure that simulates a dilemma between the cooperative-collusive and competitive solutions.

3. Theoretical Framework: Learning Process

A *Learning Process* is defined as a searching among strategies and payoffs (Huck, Normann and Oechssler, 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; Vainsteina, Silva and Arenzon, 2007). After several repetitions, players learn how to direct their actions towards an overall higher payoff (Huck et al., 1999; 2004b; Selten and 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 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 and 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 fisherman 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

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

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 fishermen. The total private benefit is expressed in equation (1)[18]

$$\pi_i = w + ax_i - bx_i^2 - \varphi \sum_{j=1}^{n} x_j \quad (1)$$

Now, when optimizing the former expression, we obtain:

$$\frac{\partial \pi_i}{\partial x_i} = a - 2bx_i - \varphi = 0$$

and the resulting competitive harvest:

$$x_{com} = \frac{a-\varphi}{2b} \quad (2)$$

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 fishermen 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 fisherman:

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

when optimizing it we obtain:

$$\frac{\partial \pi}{\partial x} = a - 2bx - \varphi n = 0$$

and the resulting solution for imitation:

$$x_{imi} = \frac{a-\varphi n}{2b} \quad (3)$$

Note that the former expression requires that all fishermen 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 fishermen, 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:

$$x_i = \frac{a-c_i-\varphi}{2b}$$

and for x_j:

$$x_j = \frac{a-c_j-\varphi}{2b}$$

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

[18] The theoretical model implemented is adapted from Cardenas (2001).

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, Samuelson, Shaked, 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 (Kirkchamp and 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, Huck et al. (1999) which 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 and 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:

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

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

$$sign\,(\Delta) = \begin{cases} -1 \; if \; \Delta < 0 \\ 0 \; if \; \Delta = 0 \\ 1 \; if \; \Delta > 0 \end{cases} \quad (5)$$

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 (2001). 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 fisherman 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 simulate the payoff structure, we follow expression (1) and replace w=1530, a=130, b=5 and φ=50. We use these parameters to ensure a strictly positive harvest and to calibrate the payoffs to local daily earnings. 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 $(x_i, \sum x_j - xi)=(1,4)$. 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; 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. 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 B and C). 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 media.

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.[19] We also obtained information from 75 who had only attended up to any level of elementary school. We defined these as ES players. Additionally, we collected information on age, gender experience in fishing and civil status. Participants have received earnings from the fishing activity at least once in their lives. The socioeconomic information obtained is summarized in Table 1:

Table 1: Socioeconomic information

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

[a b] Proportion of male fishermen are generally higher in these communities.
[c d] Proportion of fishermen who are head of households.
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

[19] 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.

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.

4.2 Descriptive Analysis

For understanding the behavior of players, we analyze independently the group of HS players from the ES one. Table 2 summarizes the performance of the game.

Table 2: Harvest behavior during game

Variable [a]	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

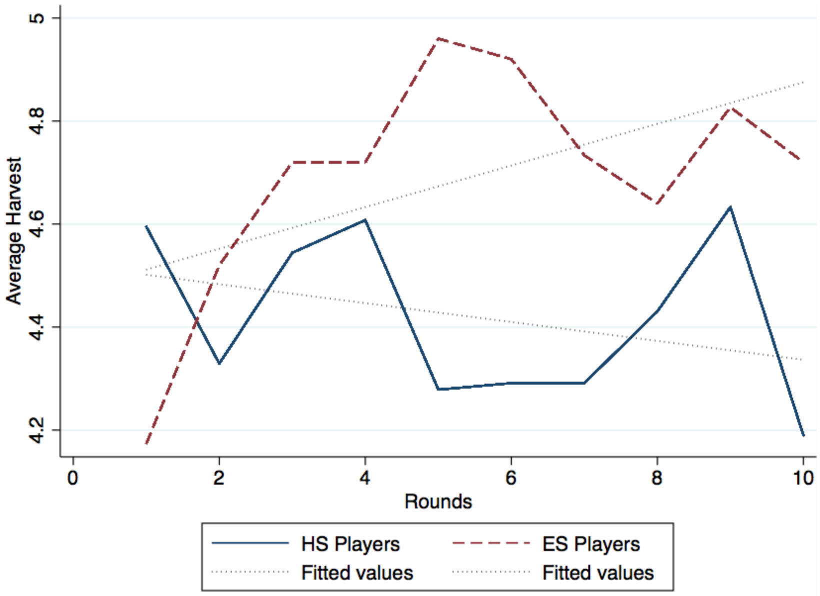
[a] Average calculated by round

Source: Own elaboration

The table shows that 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 5%.[20] 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 illustrates this situation.

[20] Mann-Whitney test indicates that difference between averages is statistically significant at 5%; *p-value*=0.015.

Figure 1: The average harvest of ES and HS players

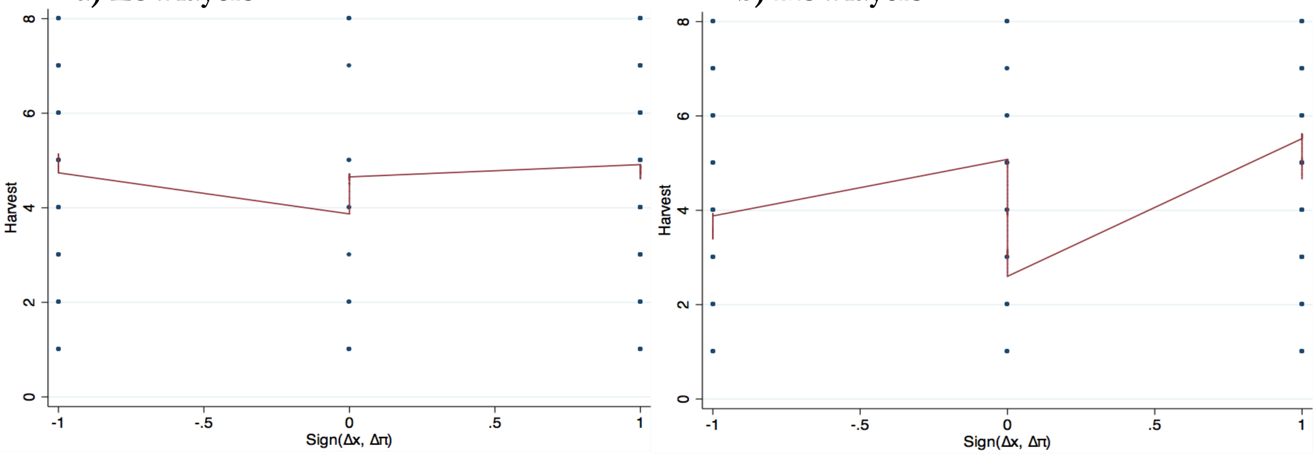


Source: Own elaboration

Moreover, by analyzing the feedback processing through non-parametric local regressions, we can address some differences between behaviors of the two types of players. Behaviors are presented in Figure 2.

Figure 2: Feedback processing

a) ES Players **b) HS Players**



Bandwidth: 0.06
Source: Own elaboration

Panel *a* shows that ES players tend to increase their harvest despite quantity-payoffs, i.e. feedback, and move either the same or contrary directions. Particularly, they tend to increase the highest when feedback is negative. Panel *b* shows that 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 figures shows also that HS players seem to reverse their decision when being competitive does not generate rewards.

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), 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 and 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 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 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;[21] 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. Estimations are presented in Table 4.

[21] 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.

Table 4: ES vs. HS. Learning processes.[22]

Variable a	Schooling	OLS	OLS (n.c.)b	RE	RE (n.c.)c	PCSE	PCSE (n.c.)d
$x_{it\text{-}1}$	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)
	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)

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

Table 4 shows 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 HS players, fxp_i exhibit a statistically significant relation indicating that their successful decisions made in the past round are repeated in the current

[22] Rounds *t* are estimated interacting with *dhs* as an explanatory variable in each model. Estimations for ES show a positive effect, and for HS a negative one during rounds. However, these estimations are not statistically significant, thus not included in the final model.

round. These estimations also indicate that HS players identify and rely on feedback from past rounds (Archibald and Elliot, 1989). Accordingly, HS players move forwards on a monotonic path, evidencing that players conclude that 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 (Kirkchamp and 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 and 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 and 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. Let's assume that in some rounds player's feedback is equal to zero, meaning that player did not find a way to improve their profit; therefore, 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. 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*. Additionally, we estimate level of schooling *dHS* as an independent variable to identify if players' behavior is motivated by the gains during the game. Finally, we control for gender *s*. Estimations are presented in Table 5:

Table 5: Payoffs

Variable[a]	Schooling	RE	RE n.c.[b]
x_{it}	ES	36.95***	36.94***
		(1.44)	(1.43)
	HS	35.22***	35.21***
		(1.54)	(1.53)
z_{it}	ES	-46.16***	-46.19***
		(0.91)	(0.91)
	HS	-47.13***	-47.14***
		(0.65)	(0.65)
domHS	ES	-6.37	-7.5
		(14.56)	(14.11)
	HS	-30.21	-31.19
		(19.82)	(20.29)
dHS		32.47*	33.08*
		(19.71)	(19.91)
s		-8.64	-
		(17.64)	-
g		-64.34***	-63.34***
		(11.75)	(11.39)
Constant		1666.83***	1658.84***
		(19.1)	(12.45)

a Dependent variable, π_{it} . Panel regression, controlling for Random Effects.
[b c d] This model is estimated without non-significant controls to verify robustness
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. However, marginally, ES players receive more than HS players when harvests increase.

Estimations also indicate that when rivals' aggregate harvests increase, individual payoffs decrease for both ES and HS players. Besides, the effect of the decrease is higher for HS players. This occurs due to aggregate defecting, which provides greater losses when a player individually approaches the cooperative-collusive solution. As a conclusion, harvesting close to the cooperative-collusive is risky because aggregate defecting can bring greater losses; thus, making competitive behavior safer.

Regarding *dHS* variable, we find that overall payoffs are higher for HS players. Under these results, we can observe that there are differences between average payoffs received by ES and HS; thus harvesting close to cooperative-collusive solution can be profitable overall.

From estimations on *domHS* we observe that the environment not necessarily yields differences in payoffs during the game; however, 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, the *Constant* in this model provides an insight into average payoffs during these games. This value ranges from $1{,}658 \leq \pi \leq 1{,}658$ depending on the estimation.

5. Final remarks

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, Kolinsky and Lachmann, 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. 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).

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 and 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 and 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, Müller and Normann, 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.

5.3 Discussion on 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 and 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 and Jennings, 2009).

However, confidence in judgment due to cognitive skills is not a regular economistic attribute in *homo economicus* (Archibald and Elliot, 1989). Therefor, 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 characteristics aforementioned 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.

5.4 What about the territorial context?

Laws for complying with FAO's Code of Conduct for Responsible Fisheries (FAO, 1995) led to the creation of Law 13 in Colombia, in 1990. From this law, ZEPA and DRMI were established to ensure the management of fishery resources towards sustainability (Vieira, Diaz and Diaz, 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, Uchida and Wilen, 2007; Gaspart and Seki 2003); although the sustainability of fisheries is subject to on-going debate (Nguyen ThiQuynh et al., 2017).

Clearly, 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 the fishermen to be more aware of the resources they exploit (Adler, 1996), and help them to understand how the ocean and humans are interconnected (Plankis and Marrero, 2010). Only by so doing, would coastal communities be able to make informed and responsible decisions concerning the ocean resources.

5.5 Conclusions

The 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 and Buchta, 1998). Particularly, we can observe that the 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 and 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.

Estimations indicate that overall payoffs are higher for HS players, though marginal payoffs are higher for ES players. This revenue motivates HS players harvesting closer to cooperative-collusive solution where higher payoffs can be obtained, even when defection from rivals produces higher losses.

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 and 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.

The territorial context can help to explain the behavior of fishermen 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 take an active role by investing more in education in the region.

Appendix A. 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				

Appendix B. Payoffs Sheet 4-player group

		MY HARVEST							
AGGREGATE HARVEST OF RIVALS		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

Appendix C. Payoffs Sheet 5-player group

		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

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Chapter 3:

Human capital depreciation: Impoverishment of mangrove shellfishing in Tumaco, Colombia[23]

Abstract

This research studies a set of mangrove shellfishers on the South-Pacific Coast of Colombia. Results show the impoverishment and lack of human capital of shellfishers. Findings indicate that the age of shellfishers is negatively correlated to human capital formation. As a consequence, senior shellfishers exert higher levels of effort to maintain livelihoods. By estimating seemingly unrelated regressions, we identify that shellfishers with higher human capital harvest lower shellfish quantities, implying that the less educated shellfishers engage in the activity as a last resort. Furthermore, women are more frequent in the activity, though exhibiting non-significant differences in productivity compared to men.

Keywords: Human Capital, Fisheries, Natural Resources, Rural Economics.
JEL classification: I2, Q2, R1.

[23] This research was conducted within theProject entitled *Productive Potential of Natural Populations of Anadara tuberculosa and Anadara similis, within a Space-time Perspective on the Colombian Pacific coast, in the category of Environment and Sustainable Development*. The project was funded by the Ministry of Agriculture and Rural Development MADR, coordinated by the Institute of Marine and Coastal Research INVEMAR and supported by the Association of Shellfishers from Nariño ASCONAR, WWF Colombia, the System of Natura National Parks UAESPNN and Universidad del Valle UV.

1. Introduction

Primary commodity sectors such as agriculture are generally related to low-skilled laborers with low human capital[24] accumulation (Blanco and Grier, 2012; Sitjins, 2006); partly because laborers neglect to ehance their skills, relying on natural resource abundance for their livelihoods and financing their consumption through rapid depletion of natural capital (Gylfason, 2008). This is partly because employers may see few reasons to expand educational opportunities or promote economic diversification (Wade, 1992); thereby demanding labor at lower wages. Despite the reasons, generally, low-skilled laborers in the natural resource sector cannot fulfill the requirements of firms looking for skilled labor force (Gylfason, 2001).

Moreover, some exceptions report positive and significant relationships when mining firms require a large amount of investment in human and physical capital (Blanco and Grier, 2012), and spend part of their revenue in capital-enhancing projects for procuring education and health care for their workers (Davis, 1995; Stijns, 2006). However, the evidence shows mixed findings over the impact of exploitation of natural resources on human capital accumulation; it depends on how natural resources are measured (Stijns, 2006), and whether they are divided into petroleum and non-petroleum categories (Blanco and Grier, 2012).

Nevertheless, there is a general consensus that agricultural sectors such as marine and inland small-scale fisheries tend to include non-skilled laborers (Townsley, 1998), reflecting a general lack of development of rural communities within these domains (Bene, 2004). These communities are often characterized by overcrowded living conditions and inadequate services (FAO, 2000). This impoverishment is dictated by circumstances such as lack of credit, poor organization and political representation, and lack of access to other natural resources (Bene, 2004). Such conditions fail to provide satisfying incomes and human capital enhancement, resulting in continued poverty and exclusion (Thorpe, 2004).

Thereby, small-scale fisheries are often considered last resort source of livelihood, implying that people easily involve in open access fisheries because they cannot make a living anywhere else, either due to limited experience, low capital investment capacity, or other obstacles for seeking a livelihood (Ikiara and Odink, 2000; Bailey and Jentoft, 1990).

Accordingly, this research aims to improve the general understanding of the nature of impoverishment in small-scale fisheries in Colombia. Based on data collected in fieldwork, this research will demonstrate that part of this impoverishment is caused by depreciation of human capital involved in fishing, where shellfishers with more depreciated human capital have to exert more effort in fishing. This document contains a Section 2 concerning the population context. Section 3 presents a theoretical framework explaining the dynamics of exploitation of a natural resource. Section 4 presents data analysis and estimations. Section 5 presents the conclusions and final remarks.

[24] 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).

2. Context

2.1 Shellfishing activity

Tumaco is located 300 kilometers from Pasto, capital of the department of Nariño, Colombia. It has an area of 3,778 square kilometers, and its height is 3 meters above sea level (DANE, 2010). It is located on the border with the Republic of Ecuador and contains 21 kilometers of shore along the Pacific Ocean. It has an estimated 160,034 inhabitants, of which 84,668 belong to urban areas and 75,366 to rural areas. The average number of people per household is 4.3 people and the literacy rate is 76.9%[25] (DANE, 2005). According to Castiblanco (2002), approximately 600 persons are involved in *Anadara tuberculosa* shellfishing in the municipality of Tumaco.[26]

Shellfishing is performed by extracting the resource from the roots of the red mangrove in the marine estuaries, which are located on the mainland areas and offshore archipelagos. This activity, mostly performed by women (Borja and Cruz, 2003), lasts between 3 and 6 hours depending on tides.

The harvest per unit of effort for 1995 in Tumaco was 250 shellfish/person-day, whereas for 2005 it was less than 140 shellfish/person-day (González, 2006). The decrease in harvest per unit of effort is attributed to the significant increase in the amount of shellfishers involved in the activity (González, 2006).

In the region, there are many studies regarding the *Anadara tuberculosa*. These studies present evidence regarding its biology, population structure and its growth and mortality rates (Squires, Estevez, Barona and Mora, 1975; Portilla, 2005; Borda and Cruz 2004a). In addition, they present evidence on how the shellfishing activity and its commercialization are performed (Ardila 1989; Contreras 1985; Borda and Cruz 2004b). Other studies evaluate the degree of its exploitation and the effect of human pressure on the resource (Portilla and Arizala 1997; Borda and Cruz 2004c); finally, the evidence also presents findings on gender issues and child employment (Borda and Cruz 2003). However, there is not evidence explaining the relationship between the low levels of schooling and the age of shellfishers with the increase in their daily fishing effort. Due to this, our motivation is to explain that this phenomenon arises from the depreciation of shellfishers' human capital.

2.2 Population aging and human capital depreciation

According to some authors, cognitive abilities, inductive reasoning, and retentiveness start to decline around the age of 50 along with physical capabilities. Thus older laborers require more time to receive and act on signals, accelerating the loss in productivity due to aging. Nevertheless, interactive skills do not depreciate with age (Maitland, Intrieri, Schaie, and

[25] Literacy rate for urban area is 84,1%; for rural area is 56,2% (DANE, 2005).

[26] *Anadara tuberculosa* is a bivalve shellfish that lives and reproduces in the muddy areas of the mangroves. It is buried up to 25 centimeters deep and adhers to the roots of the red mangrove (Von Prahl et al., 1990). Shellfish sizes range from between 36 millimeters (Contreras, 1985) to 56 millimeters length (Ardila, 1989). The shellfish reaches its commercial size of 44 millimeters after 12 months, when it is considered an adult, since it has accomplished its first reproduction cycle (Borda and Cruz, 2004a). WWF et al. (2005) estimated that this municipality provides 94 million of *Anadara tubeculosa* shellfish/year and represents 31.65% of this species exported from Colombia to Ecuador.

Willis, 2000; Park et al., 1999; Skirbekk, 2002; 2003; Verhaegen and Salthouse, 1997; Waldman and Avolio, 1986;).

Besides, every day older laborers turn less competitive compared to middle-aged and younger because the continuous technological progress and the change in educational systems (Autor et al., 2003). This situation denominates *human capital depreciation*, which constitutes a negative change in the value of an assets used for production. This value declines because of their physical deterioration, obsolescence and accidental damage; this value also depends upon the expected benefits from using it in production over the remainder of its service life (Ahmad et. al, 2005; Graham and Webb, 1979; Wei , 2008)

Nevertheless, laborers may undertake additional education for obtaining new skills, improving their health, or searching for better working and reward conditions (Wei , 2008). However, improving human capital differs from improving physical capital because an additional year of capacitation improves productive capacity, but comes at the cost of one less year available to work, as every worker has a finite working life.

When capital becomes obsolete it cannot move to another activity or is too costly to move. This mobility, that captures the idea that workers do not last forever in a position, encourages workers to find themselves a new job, either as a result of their old position being terminated, or as a result of receiving another more profitable position. Accordingly, empirical evidences has demonstrated that younger laborers tend to be more mobile than older laborers, having also different returns to human capital (Rubinstein and Weiss, 2006).

As a consequence of deterioration of intellectual ability to perform more complicated and productive tasks, and having little or no education, older laborers with little hope of shifting to other occupations (Bailey, 1988; Smith, 1979) become involved in shellfishing, which constitutes a last resort (Bailey and Jentouf, 1990; Panayotou, 1988). Those unlikely to subsist by other activities rather than fishing (Dunn, 1989) are expected to work longer (Ruzik-Sierdzinska et al., 2013) and to exert higher levels of effort; whereas young shellfishers migrate to other more profitable economic alternatives outside fishing.

3. Theoretical Framework

The model presented is proposed by Bravo-Ortega and de-Gregorio (2007) and its framework considers a small open economy with a natural resources and an industrial sector. However, natural resources are not considered essential for the production of industrial goods. Both sectors utilize human capital along with other specific inputs required for each sector. The natural resources sector presents decreasing returns to human capital, and the industrial sector presents constant returns to scale. All production is sold on the international market. The prices of the commodities are exogenous and determined by the market. The price of the industrial commodity for consumption is p_I and the price of the natural resources commodity is p_R. Production functions for both sectors are expressed as follows:

$$Y_R = RH_R^{\varphi} \; Y_I = aH_I \qquad (1)$$

The capital in the natural resources sector is *R*. It measures the endowment of natural resources, considering many factors such as the quality and abundance of fishing banks, soil, and even climate conditions. The capital in the industrial sector is interpreted as technology and denoted by *a*. The subscripts on H and Y indicate the productive sector to which inputs are allocated. Then, the economy faces the following constraint:

$$H = H_R + H_I$$

L represents the total labor in the economy. This is constant and normalized to 1. The remaining variables are expressed in per capita terms. $L_R = H_R/H$ is the proportion of inputs allocated to the natural resources sector and $L_I = 1 - L_R = H_I/H$ to industrial sectors. Thus the laborer solves the following problem and decides how to distribute the labor across sectors and how much to invest in human capital:

$$Max \int_0^{\infty} u(c_t).e^{-\beta t}\, dt$$
$$\dot{H}_t = Y - p_I c_t$$
$$Y = aH_I + p_R R H_R^{\varphi}$$
$$LH = H = H_R + H_I$$

Obtaining H_R from the first-order conditions and solving for L_R[27]:

$$L_R = \frac{1}{H}\left(\frac{p_R R\varphi}{a}\right)^{\frac{1}{1-\varphi}}$$

Where L_R is a proportion of the labor force employed in natural resource sector. This is inversely proportional to *H,* which is the level of human capital per capita. Now, transforming into natural logarithms:

$$lL_R = l\left(\frac{p_R R\varphi}{a}\right)^{\frac{1}{1-\varphi}} - lH \qquad (2)$$

As a conclusion, as long as human capital increases in the natural resource sector, the labor force decreases proportionately, and the total output obtained from this sector will decline.

4. Methodology

4.1 Data and Descriptors

This research is based on the capture record of shellfish registered during January to November 2009. These records contain information from 59 shellfishers - 32 women and 27 men - during 261 days of activity. Socioeconomic characteristics such as schooling and age were also obtained; although, by the time information was collected, 21 of shellfishers were enrolled in school, whereas the other 38 were not attending any kind of schooling. In order to take into account the active shellfishers, the records containing information of people who harvested at least once a month on average were used.

27 The complete analysis for solving the model is presented in Bravo-Ortega and de-Gregorio (2007).

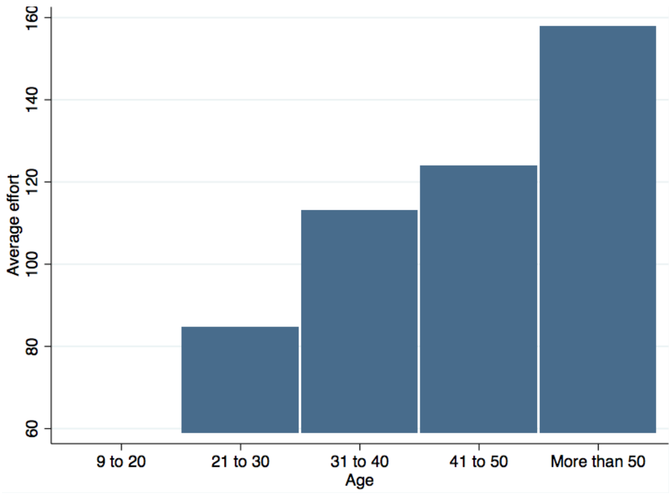
Table 1: Descriptors of information

Variable	Description	Average[a]	Min.	Max.
y	Harvest	12,014	447	38,973
L	Effort	104.56	11	244
ag	Age	34.39	9	77
sc	Years of schooling	3.27	0	11

[a] Average calculated per person-day during 261 days of harvest.
Source: Own elaboration.

The harvest per unit of effort calculated is 114.1 shellfish/person-day. When disaggregating this information, we observe that the evolution of effort exerted varied according to the age of shellfishers. Figure 1 presents how average effort increases from 58.9 to 157.91 days as the age of shellfishers increases.

Figure 1: Effort applied according age of shellfisher



Source: Own elaboration

4.2 Human capital formation in shellfishing

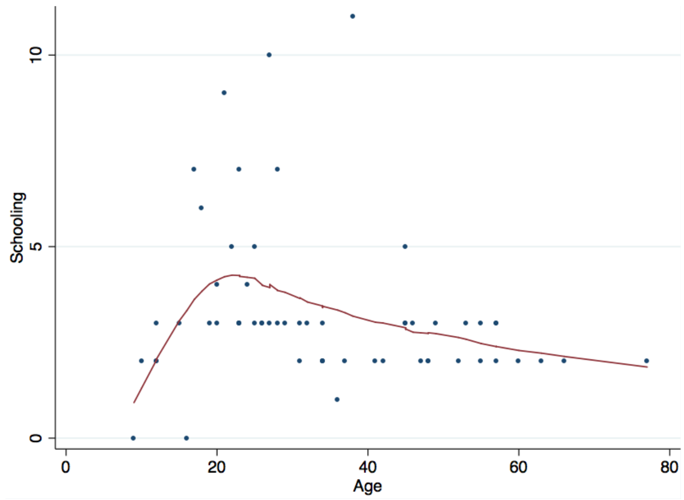
According to Diewert (2003), the *cross-section depreciation* per unit of an asset is defined as:

$$\delta = V(k_i) - V(k_j) < 0 \quad (3)$$

Being k_i an asset acquired in t-1 with similar characteristics than k_j acquired in t. Thus, cross section depreciation captures the difference between the value of an asset purchased at t and another asset with similar characteristics but purchased one year earlier. This analysis relies on comparing the value of several assets of different age at the same point in time. It is important to recognize that this analysis is only possible when assets are similar except for their age (Ahmad et al., 2005).

For analyzing the accumulation of human capital among shellfishers, we run a local regression of schooling against their age, then identifying the net formation of core and cognitive-analytic skills. The non-parametric analysis indicates that the human capital tends to increase up to when shellfishers turn around 20 years of age; nevertheless from this age, human capital tends to decrease. Figure 2 shows a negative trend, as shellfishers get older.

Figure 2: Human capital formation



Bandwidth 0.6
Source: Own elaboration

In order to obtain to analyze the net human capital formation by education, we estimate the schooling-age elasticity. Following expression (4) we measure the change in the additional lifetime school qualifications.

$$lsc_i = \alpha + \delta lag_i + u_i \tag{4}$$

From expression (4) we estimate an OLS regression controlling for standard errors; the results are presented in table 2

Table 2: Human capital formation

Variable[a]	Description	Coefficient
lag	Nat. Log. Of Age	-0.281**
		(0.126)
Constant		2.063***
		(0.441)

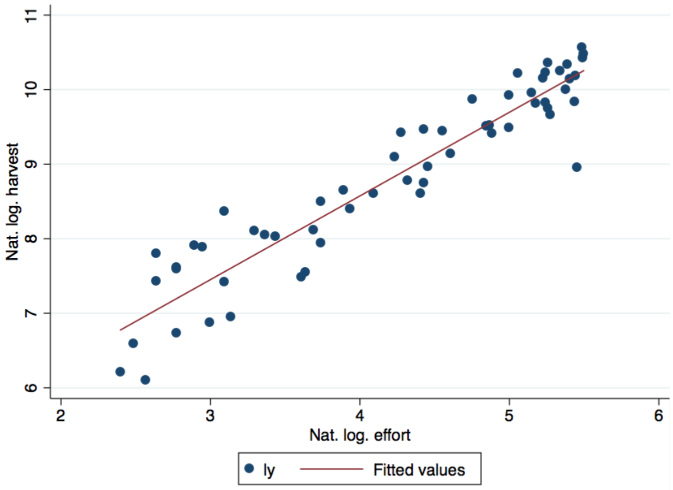
[a] Dependent variable: Natural Logarithm of Schooling *lsc*; R^2=0.0823, *F*= 0.03.
Significance: *10%, **5%, ***1%.
Source: Own elaboration.

Then, considering the shellfisher to be a labor-intensive asset, and taking into account expression (3), when the age of a shellfisher increases by 1%, the human capital decreases. These results permit us to conclude that, as long as the population involved in shellfishing gets older, human capital diminishes, exhibiting evidence of cross-section depreciation. However, cross-section depreciation does not adequately capture obsolescence when shellfisher capacity cannot fulfill the requirements; then turning costly to upgrade their capacity and cheaper to replace them. Then, reaching the end of their service lives before they are worn out, because their actual service lives are less than their potential physical lives, they have a lower value than they would otherwise. Besides, cross-section depreciation as is defined and interpreted, assumes that the age-efficiency function of an asset is independent from its age, which is not entirely true due to comparing identical assets of different ages may be the cause of obsolescence (Ahmad et al., 2005).

4.3 Shellfishing and the effect of schooling

Figure 3 presents how shellfish harvest increases proportionally as long as effort increases. Notwithstanding this data are only for 11 months of performance, they allow us to understand how shellfishing harvest is performed.

Figure 3: Shellfish harvest



Source: Own elaboration

Now, recalling the production function expressed in (1), and the solution expressed in (2), we proposed expression (5) for estimating the shellfishing production function.

$$ly = \beta_0 + \beta_1 lL_i f(l\hat{sc}_i, s_i) + \beta_2 s_i + v_i \quad (5)$$

The production function is estimated through a two-staged, seemingly unrelated, regression. First stage estimates the effect of human capital formation $l\hat{sc}$, which are fitted values from the regressions in expression (4), on the natural logarithm of effort *lL* applied to harvesting. For estimating the effect of motivation to be involved in shellfishing, a dummy variable *ds* is introduced taking value 1 when shellfishers are in school, 0 otherwise. The second stage estimates the production function of shellfishing, considering as independent the harvest *ly* transformed into a logarithm. Finally, estimations are controlled by a dichotomous variable *s* taking value 1 when the shellfisher is a woman, 0 otherwise. Results are presented in table 3.

Table 3: Shellfish production function

	Variable	Description	Coefficient
First Stage [a]	$\hat{lsc}$	Nat. Log. Human Capital Formation	-4.150***
			(1.098)
	ds	School attending	1.086***
			(0.321)
	s	Sex	0.673***
			(0.238)
	Constant		8.061***
			(1.167)
Second Stage [b]	*lL*	Nat. Log. Effort [c]	1.009***
			(0.127)
	s	Sex	-0.006
			(0.139)
	Constant		4.570***
			(0.497)

[a]Dependent variable first stage: Natural Logarithm of effort *lL*.R^2=0.293F=0.0.
[b] Dependent variable second stage: Natural Logarithm of harvest *ly*. R^2=0.879, F=0.0.
[c] Linear test indicates $ß_L$ is not statistically different than 1.
Significance: *10%, **5%, ***1%.
Source: Own elaboration

First stage estimation presents evidence to conclude that the population involved in shellfishing exerts higher levels of effort as long their human capital depreciates. It means that shellfishers with lower levels of human capital are more involved in shellfish activity than those with higher levels of human capital.

This result exhibits some evidence of the impoverishment of shellfishing, where people with low or little education, and with few non-fishing skills, have few opportunities of shifting to another occupation (Smith, 1979). Moreover, mobility declines quickly with experience and aging imposes substantial costs to mobility across sectors (Rubinstein and Weiss, 2006). Thus shellfishers are basically locked in to the activity exerting as much effort as possible to sustain their livelihoods.

Variable *ds* for schooling, indicates that shellfishers who are still receiving education exert more effort on shellfishing. This result exhibits findings regarding the behavior of shellfisher to be contrary to expectations. Here, the result shows that shellfishers who are in school perform more frequently the activity. This can be explained as being due to their need for earnings, to afford their tuition, school supplies and other expenditures such as transportation and food. .

Estimation regarding gender in the first stage shows that women exert more effort than men in shellfishing. This result is consistent with Borda and Cruz (2003), who state that women are more involved in the activity.

Second stage estimations present a positive relationship between individual effort applied to shellfish harvesting. The estimated coefficient for *lL* indicates that activity brings constant returns to labor and will go on proportional increasing as long effort increases. Nevertheless, this function is estimated assuming efforts applied by shellfishers are independent and does not take into account the effort of competition, natural stock of shellfish and levels of autonomous regeneration of the natural stock.

Estimations regarding gender in the second stage show that men and women have no significant differences in shellfish harvesting. This means that there are no gender differences in productivity.

The conjoint results allows the conclusion that, as long as human capital is increasing, the total output obtained from shellfishing will decrease as Bravo-Ortega and de-Gregorio (2007) state.

5. Discussions and final remarks

5.1 Education and effort

The results presented in this research connect to the discussion proposed by Smith (1979) on whether education and training programs designed primarily for children of fishermen result in a reduction in fishing effort. However, fishing pressure has not only been expanded by increasing efforts. Accordingly, there is a consensus about the collapse of traditional fishery management structures, policy and regulatory failures, and about limited opportunities for alternative employment, being structural circumstances that promote depletive fish harvesting practices (Anderson 1980; Cunningham, 1993; Smith 1979; Panayatou, 1988).

Findings from these research reports indicate that fishermen are in their current activity because the unavailability of finding alternative employment and their lack of education. Then, fishing becomes their only source of income. Notwithstanding, fishing is not seen as a profitable activity that yields higher profits than the alternatives (Ikiara and Odink, 2000).

In particular, fishermen with higher level of education determine the better their opportunity cost and opportunities outside the fishing sector. This cost is crucial in the exit-from-fishing decision considering that the opportunity cost of remaining in fishing is very low (Ikiara and Odink, 2000), such that they will continue fishing even if they earn far less than their opportunity costs (Panayotou, 1982).

Thus, training programs do not necessarily reduce efforts in fishing. However, education enhances human capital and democratic rights that solve failures to provide satisfying incomes, and which alleviate poverty in fishing communities. Furthermore, fishermen with higher levels of education tend to diversify their livelihoods, reducing the risk of relying only on fishing (Guerrero, Franco-Jaramillo and Rosell, 2017). In addition, the beneficial effects of schooling promotes quality of life of fisher families (Smith, 1979), encourages labor mobility and knowledge of alternative occupations (Panayotou, 1982).

5.2 Education and natural resource exploitation

Although human capital may not necessarily translate into marketable skills, it plays a vital role in driving economic growth. However, some findings in literature conclude that resource-abundant economies tend to crowd out the human capital due to their dependence on the resource. This effect is mainly a crucial transmission mechanism of the resource curse (Gylfason, 2001; Papyrakis and Gerlagh, 2004; Sachs and Warner, 2001).

Somehow, in resource-abundant countries, the proportion of natural capital in national wealth is negatively related to indicators such as public expenditure on education, secondary school enrolment and expected years of schooling for girls (Gylfason, 2001). Countries that tend to invest on average less in education than other countries (Birdsall et al., 2001), seemingly have no incentive to invest in basic skills.

Nevertheless, lower levels of human capital are a conditional variable for the occurrence of the resource curse (Kurtz and Brooks, 2011), and investing in human capital enhancement mitigates the curse, promotes efficient management of natural resources, eliminates the negative effect caused by resource booms, and encourages technological improvement (Bravo-Ortega and de-Gregorio, 2007; Kurtz and Brooks, 2011).

However, crowding-out of human capital and the resource curse are not inevitable, yet it is conditional on the possibility of substitution between production factors and economic activities (Shao and Yang, 2014). Basically, in a resource-based economy, human capital accumulation, economic growth, and resource abundance can go in the same direction if the rate of return of investment in education is increasing.

Finally, education is required for increasing the efficiency of the labor force, and thus creating better conditions for securing economic development (Barro, 1997) and reducing dependence on natural resource exploitation (Martin, 2007).

5.3 Conclusions

In this research we find that older shellfishers exert more effort in fishing for shellfish. For 261 observations, the average effort increases from 58.9 to 157.91 days as long shellfishers get older. Estimations provide evidence of the presence of cross-section depreciation among shellfishers in Tumaco.

First stage estimation indicates shellfishers exert higher levels of effort as long as their human capital depreciates. Shellfishers rely on this activity to compliment expenditures on schooling and supplies. Estimations on gender indicate that women exert more effort than men; this result is consistent with Borda and Cruz (2003).

Second stage estimations indicate that harvests increase as long as effort increases and the production function tends to present constant returns to scale. Estimation on gender in the second stage shows that men and women harvest equally.

Results are consistent to the theoretical analysis of Bravo-Ortega and de-Gregorio (2007); as long as human capital increases, the total output obtained from natural resource sector decreases.

Finally, discussions indicate that fishermen remain in the activity because it is their only livelihood source. This is a consequence of their lack of education and the unavailability of alternative employment (Ikiara and Odink, 2000). Moreover, fishermen with higher levels of education tend to diversify their livelihoods (Guerrero et al., 2017) and move to alternative occupations (Panayotou, 1982).

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