Socio-Economics of Artisanal Fishery in Chile.

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For my parents Carlos & Mery, who first taught me to be persevering and appreciate the value of the education.

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Chapter 1

Introduction

The Chilean fishery fell into a crisis in 1980 as a result of the overexploitation of the marine resources under the open access system. In order to promote sustainable fishery activity, the Chilean government established the General Fisheries and Aquaculture Law (GFAL) in 1991 and the territorial Use Rights for Fisheries (TURF) in 1992. The latter is the framework for two of the three research chapters in this thesis.

The fishery activity in Chile is regulated by the GFAL, which aims to preserve the hydro-biological resources following the open access regimen, which led to overexploitation. The GFAL determines specific rules for each one of the six types of fisheries developed in Chile: Extractive, Aquaculture, Research, Recreational, Areas and species protected and Coastal areas belonging to ethnic groups. The law enforcement is controlled through three main governmental agents: SUBPESCA, which is responsible for fishery policy making based on biological, social, economic and environmental research evidence; SERNAPESCA, which protects the marine environment and controls the law enforcement defined by SUBPESCA; and IFOP, which collects systematic statistics and leads research projects to design more accurate fishery policies.

The law also distinguishes between the industrial and artisanal subsectors according to the size of the vessels and the extractive methods applied. Industrial fishery includes fleets with a length of over 18 metres, implemented for capturing high volumes of resources using a technologized fishing system. In contrast, artisanal fishery accounts for fishermen using traditional fishing gear and fleets that only operate under the exclusive access right within the first 5 miles of the coastline. It also includes those organisations working under territorial common rights to harvest molluscs in a specific marine area; these are concentrated mostly in the Lagos and Bio-Bio regions, located in the Centre-South of Chile (SERNAPESCA, 2016).

According to official statistics, the industrial sector has systematically reduced its landings in the last two decades. On the one hand, some relevant species, such as the horse mackerel and the anchovy, have been dramatically reduced due to their overexploitation in the past five decades. On the other hand, the impact of the weather, natural climatic changes and disasters, such as the 2010 tsunami, have negatively impacted on the resources available. Moreover, governmental regulators have constantly reduced the industrial fishery quotas, seeking the sustainability of the resources, but affecting fish landings (SERNAPESCA, 2016).

In contrast, the artisanal sector has become very important at the national level during the last decade. Whereas the sardine, one of the most important resources in the Chilean fishery, was captured by industrial sector in the 1990s, it is currently landed by the artisanal sector. Moreover, some molluscs and algae are harvested exclusively by artisanal organisations under a territorial common rights system (TURFs), which gives exclusive harvesting rights for a specific marine area. Compared to the industrial overexploitation under the open access system, the common rights have positively impacted on the sustainability of the resources and the artisanal organisations' economic performance, although there are some problems related to the monitoring of poaching and illegal harvesting, which require further research.

The artisanal fishery sector is the common frame for the three empirical chapters included in this thesis. I focus in particular on a particular management system that is internationally recognised as Territorial Use Rights for Fishing (TURFs), which is applied in Chile to regulate the artisanal organisations' harvesting. The TURFs regime, established in Chile in 1998, grants exclusive rights to artisanal organisations to harvest benthonic resources, which include invertebrate species such as molluscs and algae. In particular, this thesis is interested in those artisanal organisations that are harvesting Loco (Concholepas-Concholepas), the most profitable mollusc exploited in Chile and mostly concentrated in the Lagos region (SERNAPESCA, 2016).

Chapter 2 and Chapter 4 cover different aspects of the TURFs management in order to propose guidelines to improve the organisations' harvesting decisions and monitoring strategies, whereas Chapter 3 examines the link between multidimensional poverty and natural disasters, focusing on those who are working in the artisanal sector and not only under the TURFs.

More specifically, Chapter 2 examines the determinants of the harvesting decisions made by artisanal organisations operating under the TURFs system in the Chilean abalone fishery. Some questions addressing this chapter are: What harvesting variables should be considered for optimising organisations' pay-offs?, What are the strategies implemented by the artisanal organisations for increasing their pay-offs?, Do the artisanal harvesting decisions change in a dynamic context? Although the biological gains from recovering the benthonic resources are broadly recognised, the effects of specific harvesting decisions on the TURFs' effectiveness are still not fully understood. This work evaluates the harvesting decisions of artisanal organisations accounting for the loco's stock and price, harvest, governmental approval quotas, and catchability. In the first part, a theoretical model explores harvesting decisions through a dynamic model for two periods of time. The predictions include a positive effect of higher assigned quotas on harvest and a positive effect on harvest of a higher loco price, stock and catchability. In the second part, a set of data is created from the annual reports of artisanal organisations. Then, the predictions of the theoretical model are empirically tested through regressions. The empirical model supports the theoretical predictions found, except for the loco's price effects. The main conclusions support the assumption that there is an interior solution in a dynamic context and reinforce the importance of quota and stock as key harvesting decision variables. Some policy guidelines are provided according to the findings.

Chapter 3 evaluates the effects of natural disasters on multidimensional poverty in Chile and distinguishes between the fishermen and non-fishermen populations. I am interested on answering questions such as: Are fishermen poorer than the overall population after earthquake and tsunami accounting for all the dimensions included in the multidimensional poverty measurement? Which people's quality of life aspects are more affected by such natural disasters in the short and long-term? and What guidelines can be proposed for policy design in the fishery sector?. Because natural disasters are commonly associated with important human and economic losses, it is not a surprise to find that an extensive body of international literature focuses on the poverty and natural disasters nexus. Nevertheless, most of the studies measuring poverty only take into account Gross Domestic Product or household income. Moreover, little is known about the effect of natural shocks within specific population groups over time, especially those who are more socioeconomically vulnerable before the shocks. Data from the national fishery census applied in 2008-2009 indicate that artisanal fishermen have lower educational attainment and access to the social security system compared with the overall population, showing a greater social vulnerability.

I contribute by evaluating the impact of the 2010 Chilean earthquake and the later tsunami on households' multidimensional poverty, emphasising short and long-term differences within the overall Chilean population and the artisanal fishery sector. To do so, I account for the unique multidimensional poverty index (MPI) used in Chile for policy purposes, which includes four dimensions: housing, work and social security, education and health. I use data from the CASEN survey to calculate a pre-disasters MPI in 2006-2009, the short-term effects in 2011 and the long-term effects in 2013. The ONEMI database allowed for identifying those localities only affected by the earthquake and those also impacted by the later tsunami. I estimate the effect of both disasters on multidimensional poverty for fishermen and non-fishermen using a difference-in-difference methodology. The main findings indicate significant differences between fishermen and the overall population. The first group were affected more in the work and social security dimension for both disasters, but especially due to the tsunami in the short and long-term. On the contrary, fishermen showed a quicker recovery in the housing dimension and no significant effects on education. Some policy guidelines are offered to tackle future disasters in the artisanal sector. I also propose some ways to plan for post-disaster recovery in which fishermen's well-being is promoted.

Chapter 4 evaluates the effects of monitoring in fisheries management in combination with regulators for fishermen working in artisanal organisations. I focus on the effects of fines, which are defined by the regulator and/or organisation, to induce compliance with a quota. The questions in this chapter are: What do sceneries maximise fishermen's enforcement and compliance? and What is the best sanction for inducing compliance accounting for the minimum burden to fishermen?

Recent studies show that the enforcement and compliance decisions under the TURFs regime are particularly relevant for the Chilean case due to illegal fishing. This research evaluates three theoretical models to identity the minimum fine to reach the first best to induce compliance among organisations and fishermen with the assigned quota. The first model considers exogenous monitoring in a static version, whereas the second considers exogenous monitoring in a dynamic version. The third model accounts for endogenous monitoring in a static version. The results show that the extraction efforts are higher when fishermen work only with the artisanal organisation. Moreover, the regulator's fine is lower and the organisation's fine is higher when fishermen are working together with the organisation and the regulator.

Finally, Chapter 5 provides the main conclusions obtained from the three empirical chapters worked through this thesis.

Chapter 2

Optimal Harvest Decisions under a Dynamic Context: Chilean artisanal Organisations' management of the Territorial Use Rights for Fisheries (TURFs).

2.1 Introduction

An open access system underpinning the word's fisheries in the last five decades has led to an overexploitation of marine resources. As a result, some alternative regimes have been implemented to achieve both fisheries' recovery and more sustainable activity in the future. The two regimes that are most commonly mentioned in the literature are the individual fishing quotas system (IQs) and the territorial use rights for fisheries (TURFs), which grant rights to a group of individuals.

In the Chilean case, both regimes have been implemented to regulate the benthonic resources exploitation. IQs were introduced in 1992, establishing a total allowable catch (TAC) in each national region and splitting this into individual transferable quotas among registered users. It was expected that a designated quota would reduce overexploitation; however, IQs led to increases in the number of users, an illegal trade in IQs and weak enforcement capability (Orensanz et al., 1998; Falcon, 2000). To confront those negative outcomes of the IQs regime, in 1997 Chile introduced the TURFs system as a solution to the increased depletion of marine resources. In particular, the TURFs regime was implemented to regulate the harvesting of the most important benthonic resource in Chile, the abalone, locally called “loco”.

As was expected according to international experiences, the TURFs regime allowed a higher loco recovery rate in Chile, while also making artisanal fishery a more sustainable activity (Stotz, 1997; Gelcich et al., 2007; González et al., 2006; Cancino, 2007; Martin et al., 2010; Gelcich et al., 2010; Zuñiga et al., 2010). Despite the evidence showing the positive biological and economic effects of the implementation of the TURFs, there is a lack of knowledge related to those key factors affecting the harvesting decisions made by Chilean artisanal organisations operating under the territorial use rights for fisheries (TURFs). I contribute in this line, analysing the determinants of the harvesting decisions made by artisanal organisations working under the territorial use rights for fisheries (TURFs), in the Chilean context.

My work explores the assumption that the artisanal organisations might harvest less than the official approved quota, in order to have higher stocks and quotas in the future. I develop a theoretical model through which artisanal organisations decide their quantity of harvest, considering a two-period horizon. I hypothesise that fishermen strategically define their effort, which has an effect on harvests and stocks, in the hope of maximising their pay-offs. In this regard, a dynamic model involving more than one period of time and multiple variables related to the TURFs management seems more accurate than a static model. This choice is supported by the idea that fishermen harvesting decisions account for information on different periods of time in order to increase their economic performance.

The predictions developed by the theoretical model include a positive effect of higher assigned quotas on harvest; a positive effect on harvest due to increases in the loco’s price; a positive effect on harvest due to higher resource stock; and a positive effect of catchability (measured inversely by the effective area) on harvest. To empirically test these predictions, a dataset was created using the annual report of artisanal organisation, identifying similarities, differences and further steps to improve the theoretical model according to how well it fits the data.

The empirical findings strongly support an association between assigned quotas and harvest, reinforcing the biological gains of the TURFs introduction. The evidence here also highlights a positive effect of resource stock on harvest, whereas estimations show a negative impact of the loco's price on harvest, with the exception when it is controlled by degree of competition. The results show that catchability, measured by an inverse relation of the size of the area as a proxy, is a significant variable for most of the estimated models.

This paper first presents in section 2.2 a brief description of the TURFs regime in Chile. This is followed by section 2.3, which is a literature overview based on TURFs studies in Chile and elsewhere. Section 2.4 discusses the two-period model of fishing. Subsequently, section 2.5 describes the database used to empirically test the theoretical model and descriptive statics. Then section 2.6 is focused on the empirical model, estimating those predictions supported by the theoretical model. Finally, section 2.7 discusses the main results, highlighting the contribution of this work, its limitations and further research.

2.2 The TURFs system in Chile

Although Chile's benthonic resources are extensive and diverse,[1] accounting for around 50 different species (Cancino, 2007; Gelcich et al., 2009), the most relevant fishery operating under the TURFs system is the Chilean abalone, which is scientifically known as *Concholepas-Concholepas* and locally named the loco. In fact, the overexploitation that affected resources under open the access in the 1980s was the main reason for introducing the TURFs system. Because the depletion of the loco was clear in 1988, the Chilean authorities closed the fishery from August 1989 through to December 1992. Instead of the loco's recovery, this regulation brought increases in illegal catching and economic vulnerability to those communities that depended on this resource.

After 1992, the Chilean government introduced the benthonic extraction regime in

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[1] Benthonic resources are defined as those "hydro-biological resources integrated by those species of benthic invertebrates and algae" (Chilean Regulation for TURF 1995), being its extraction an exclusive right for the artisanal organisations operating under TURFs system.

an effort to solve the problems created by the open access (Homans and Wilen, 1997). Under this regime a total allowable catch (TAC) was established for each national region and this was split into individual quotas (IQs) among registered users. Regional TACs were established, accounting for the size-based stock assessment; however, the benthonic regime failed due to unsatisfactory assessments, increases in the number of users, the illegal trade of IQs, a lack of incentive for conservation and weak enforcement capability (Orensanz et al., 1998; Falcon, 2000). In 1997, the TURFs system was implemented, together with open access to all registered fishermen in the region, subject to resource specific regulations. In 1999, TURFs for the loco fishery coexisted with IQs but in different places, leaving behind the open access modality. Finally, in 2000, fishing in the loco fishery was allowed only within the TURFs system, excluding past regimes.

The Chilean authorities introduced the TURFs in 1997 after seeing its successful outcomes at the international level in terms of both sustainability and economic performance (González et al., 2006; Cancino, 2007). The TURFs were locally named the Management and Exploitation Areas of Benthonic Resources (AMERBs). Under this regime, artisanal organisations have become exclusively responsible for managing the exploitation of the natural resources enclosed in a specific geographical area.[2] Figure 2.1 summarises the administrative steps followed by those artisanal organisations interested in managing an area under the TURFs regime.

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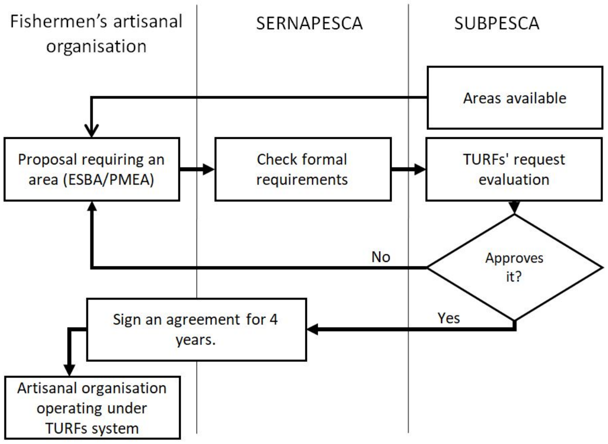
[2] Artisanal organisations are those operating through vessels length under 18 meters and loading a maximum of 50 tons. The five-mile zone from the coast is reserved exclusively for artisanal fishery.

Figure 2.1: Administrative steps to begin a TURFs



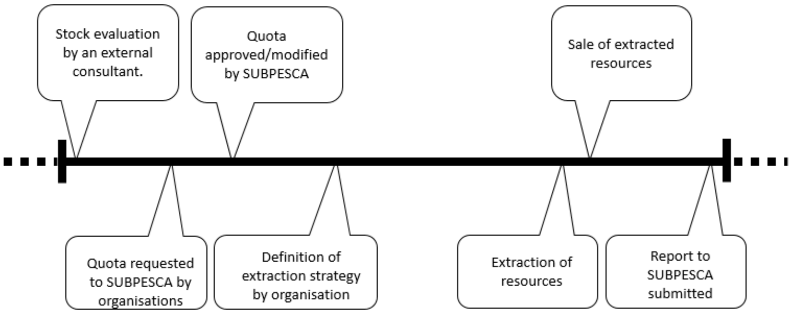
Note: Prepared by the author based on regulations for TURFs.

Firstly, artisanal organisations design a proposal requesting a specific maritime area from the National Fishery and Aquaculture Service (SERNAPESCA). Those requested areas are predefined as available to exploit under the TURFs system by the Fishery Under secretariat (SUBPESCA), which is responsible for fishery policy making decisions. The proposal must contain a Baseline study (ESBA) and a Management and Exploitation Area Plan (PMEA), both of which are conducted by an external consultant agency and include a broader range of biological, organisational and economical informative indicators.

The TURFs claim is submitted by the artisanal organisations to SERNAPESCA, which checks that every formal requirement has been fulfilled. If the claim is completed, SERNAPESCA passes the information to SUBPESCA, which finally rejects or approves the organisational rights over the area required. In the first case, a rejected claim comes back to the artisanal organisation applicant in order to make modifications or clarifications before a second request round. In the second case, an approved request implies that the artisanal organisation has obtained renewable and non-transferable rights for four years. They must write an annual report stating the total or partial fulfilment of their originally proposed ESBA and PMEA and pay an annual fee for the rights acquired.

Figure 2.2 summarises the annual timeline for the assignation of quotas to those organisations responsible for one or more TURFs. Firstly, TURFs are directly evaluated in terms of the stock abundance, and the size and weight of the resources for each area. That evaluation is made by an external consultant and reported in a document. Secondly, the consultant proposes an extraction quota for a specific period based on the previous biological evaluation of the area. This quota is required by the responsible national authority, SUBPESCA. Thirdly, SUBPESCA approves or modifies the proposed quota required by the artisanal organisations. Once the quota has been determined, the artisanal organisation defines its extraction strategy, which may be to harvest to the level of the quota, or a part of the quota, or not to harvest. The organisations are free to choose where and when they sell their resources, although most of them are sold in the local market. Finally, after each period, each organisation operating under TURFs must submit a report detailing its extractions activity to SUBPESCA.

Figure 2.2: Timeline for quota's assignation



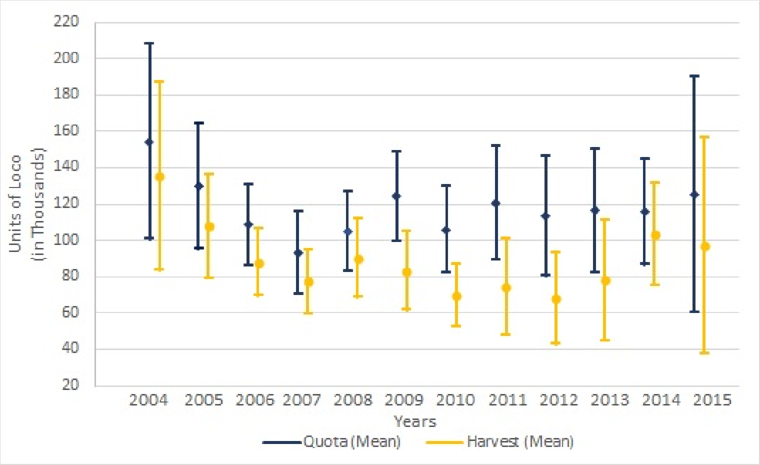
Note: Prepared by the author based on regulations for TURFs.

Despite a higher diversity of benthonic resources in Chile, the TURFs system is mainly operating for the loco. Compared to other resources, the loco is the only resource that is completely regulated by the TURFs system, having been broadly recovered and conserved from 2003 to the present (González et al., 2006; Gelcich et al., 2007). According to SERNAPESCA (2015) loco extraction represents 60.35% of the total benthonic resources extracted by TURFs at the national level and 87.82% for the Lagos region. In this regard, this paper is focused on those factors affecting loco harvesting decisions made by the artisanal organisations operating in the Lagos

Region.[3]

In the context of loco fishery, an interesting fact to take into account in the harvesting decisions analysis is that the average amount of loco harvested was systemically lower than the official approved quotas from 2004 to 2015 in the Lagos region. Figure 2.3 shows both the annual average per harvest and the approved quota calculated among all of the TURFs' assets per year. The information is based on the annual reports of artisanal organisations provided by SUBPESCA for the years 2004-2015 in the Lagos region. The data show a gap between the loco harvested and the approved quota, suggesting that no over-catching occurs for the loco fishery operating in that region.

Figure 2.3: Approved quota and harvest in the Loco Fishery under TURFs with 95% Confidence Interval, 2004-2015.



Note: Prepared by the author based on SERNAPESCA for the Lagos region

In particular, the data highlight a decrease in the average approved quota and the average harvest at the beginning of the period studied, between 2004 and 2007, from 154 thousand to 93 thousand units of loco in the case of the average approved quota and from 135 thousand to 77 thousand units of loco for the average harvest. Moreover, from 2007 onwards, the data reveal relative stability in regard to the abundance of the

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[3] Chile is divided into 15 regions, which are the country's first-level administrative division. The regions are divided into provinces and then into communes. A commune is the smallest administrative subdivision in Chile. It may contain cities, towns, villages, hamlets as well as rural areas. A commune could have several TURFs.

resource over time. The average approved quota moved between 100 thousand and 120 thousand units for the period 2007 to 2015, whereas the average harvest reached around 80 thousand units for the period 2007 to 2013 and around 100 thousand units for 2014 and 2015. In overall terms, the introduction of TURFs in the loco fishery has been positive for the sustainability and conservation of the loco; nevertheless, it is a challenge to identify how this regime has also impacted on other dimensions beyond the biological aspect.

According to the national report (SERNAPESCA, 2016), artisanal organisations, vessel number and fishermen are mainly concentrated in the Los Lagos region, with a 35%, 32% and 37% respectively of the total nationwide. In the next section a literature review is offered to underpin the contribution of the present work.

2.3 Literature Review

A review of the studies focused on the TURFs system reveals a greater emphasis on empirical rather than theoretical approaches. Most of the empirical research has been focused on the biological gains obtained through the TURFs in contrast to previous regimes such as open access or ITQs. The main explanation is that cooperative harvesting activities lead to more sustainable extraction behaviour and a responsible use of the resources (Moffitt and Cajas-Cano, 2014; Schlager and Ostrom, 1992; Deacon, 2012; Quynh et al., 2017).

Taking into account the biological gains obtained by the TURFs, fishery research has moved to identify those basic conditions that are necesary for greater TURFs effectiveness. The effectiveness of the TURFs in achieving sustainable fishing practices has been evaluated through three dimensions: biological (measured by target and non-target fish stock conditions); economic (evaluated by fish catch, fish price, fishing effort and income); and social (including the level of cooperation among fishermen, aid to fishermens families and the level of trust between fishermen and governmental institutions). There is some consensus that TURFs seems to be more suitable for sedentary species because the mobility of some resources limits its effectiveness

(Criddle et al., 2001; White and Costello, 2011). TURFs can bring economic benefits to users, increasing prices and incomes because the programmed harvest allows resources to be sold at higher prices. Moreover, greater cooperation between organisations positively influences local resource conservation and reduces disputes among users (Molares and Freire, 2003).

Wilen et al. (2012) summarise four basic conditions to ensure effective TURFs' performance. Firstly, an exclusive and closed class of users should be identified as "insiders", incentivising investments in the TURFs because no entry for other fishermen is allowed. A second condition is the ability of the members of the TURFs to enforce the boundaries against illegal actions in the area beyond the well or badly established rules of national law controlling poaching practices. A third feature found in successful TURFs is the capacity for adopting internal coordination and distributive strategies to give adequate incentives to those members involved in the TURFs management. Finally, territorial rights ceded for long periods of time incentivise users to invest in the area, as they can confidently expect future pay-offs, and therefore a sufficient duration of rights should be granted. The loco resource is mainly static, so that should be good in terms of TURFs implementing these conditions.

The literature also suggests that TURFs are a flexible management tool because multiple fishery features such as several species and unreliable biomass can be controlled in a specific territorial space (Deacon, 2012; Quynh et al., 2017; Gelcich et al., 2009). Nevertheless, better outcomes have been obtained in small-scale fisheries with ill-defined property rights; areas based on sedentary species; and areas managed by communities rather than governmental agencies.

In methodological terms, Quynh et al. (2017) highlight the importance of undertaking analysis beyond the perceptions of fishermen, an dinvolving biological, economic and social dimensions in a multidimensional approach rather than a separate analysis. Moreover, the majority of the empirical studies have employed a simple statistical analysis except for some efforts to apply discrete time deterministic models (Criddle et al., 2001), multivariate analysis (Gelcich et al., 2008, 2012) and covariate matching methods (Uchida et al., 2012). I contribute by using a two stage dynamic model, evaluating an optimal harvesting quota as a pioneering study in the Chilean case.

A review of the empirical studies based on the Chilean TURFs' management reveals a strong consensus on the positive effects of this system. It has increased the loco's abundance, measured by the average density of locos per square metre (González et al., 2006). In other cases, the positive impact of the TURFs on the loco's stock has been evidenced by comparing this regime with the previous ones (Stotz, 1997; Martin et al., 2010; Gelcich et al., 2010). Moreover, there is evidence of the positive effect of the TURFs in terms of stabilising or even increasing the stock of the loco over time (Cancino, 2007) and giving incentives to users to behave consistently with conservation preventing over-catching (Aburto et al., 2013).

Some studies have analysed the effect of the TURFs system on income performance. Most of them have analysed how this regime has affected the loco's prices and the fishermen's incomes. For example, it is known that the price paid per ton of loco has significantly increased since the implementation of the TURFs, and is higher compared with prices under open access (Defeo and Castilla, 2005; Gelcich et al., 2007). In other cases, findings suggest that the resource price, effective area, other resources present in the area, the organisation's age and the experience of the organisational leaders are the most significant variables that influence the TURFs economic performance (Sobenes and Chávez, 2007).

Similarly, Gelcich et al. (2007) found that the economic performance of TURFs is improved by a higher loco price, the size of the resource and the number of buyers. Likewise, studies argue that the economic performance mainly depends on how productive the area is, in terms of the abundance of the resources; therefore, an organisation with one or more assigned productive areas will have more profits than those organisations with areas that are less productive in terms of volume and/or quality of the species extracted (Castilla, 2000; Chávez et al., 2010).

Although the biological and economic effect of the TURFs on the loco fishery have been emphasised in the Chilean research, they are not different from the international trend. According to Quynh et al. (2017), the majority of TURFs studies have been concerned with these dimensions, omitting other aspects related to the TURFs' management. For example, in the Chilean case, some conflicts between governmental agencies and traditional users have increased since the introduction of the TURFs (Orensanz and Parma, 2010). In other cases, greater competing problems over access and control over coastal resources between organisations have been detected (Gallardo Fernández and Friman, 2010) as well as the erosion of traditional practices by the fishing community after the establishment of TURFs (Gelcich et al., 2007). Poor organisational capabilities in terms of managing TURFs effectively have also been pointed out as organisational features that negatively affect economic performance (Barriga et al., 2007; Martin et al., 2010; Rosas et al., 2014).

The summary of the literature previously described in TURFs highlights the need to shift from traditional biological and economic performance measurements to a better understanding of how TURFs are managed internally by users. I pay special attention to how artisanal organisations establish their optimal harvest, assuming that those harvesting decisions occur in a complex context in which several variables are taken into account.

Studies addressing a similar aim were found only at a theoretical level. For example, Sethi and Somanathan (1996) developed a theoretical model based on the evolutionary game theory framework in order to determine the dominant extractive strategy in a context of commonly owned renewable resources. Later, Bjorndal and Munro (2001) proposed a dynamic model to identify those strategies oriented towards maximising fishermen's pay-offs while operating under open access. In both studies, the theoretical models are based on non-cooperative harvesting systems and use individual agents as the unit of analysis. In contrast, I develop a theoretical model that accounts for artisanal organisations as the key agents.

Other theoretical studies focused on defining an optimal harvesting strategy have examined changes in harvesting decisions according to several prawn stock sizes and effort (Dichmont et al., 2008) as well as the income from catches and the costs of the effort (Doyen et al., 2013). Considering these studies, the model proposed includes a profit function to determine the optimal harvest depending on the effort and stock.

Nevertheless, instead of a linear estimation of future efforts, such as that in Dichmont et al.'s work (2008), I use a dynamic stock function, taking into account the fact that the future stock depends on the current fishing effort. I propose that harvesting decisions in the TURFs context are made involving key information from more than one period of time. Additionally, I also consider the recommendation proposed by Doyen et al. (2013) about using the maximum sustainable yield (MSY) as a constraint in any model testing optimal harvesting decisions. I involve as a constraint the maximum quota approved by the Chilean Government; therefore, the model allows an optimal harvest measured in two stages at the organisational level, accounting for a dynamic stock and the maximum approved quota as a constraint.

2.4 Theoretical Model

In this section, I describe a two-stage model to determine the optimal effort made by artisanal organisations, making their decisions in a dynamic context. Using Perman et al. (2011) as a baseline model, I define harvest as a function of stock and effort, and dynamic stock as a function of natural growth and harvest. The model has two stages in which organisations define their optimal strategy for the present period and for the next one. In other words, the artisanal organisations take into account that their strategy for the first period will affect the evolution of the stock available for their future harvest.

Organisations maximise their profit function for period 1 (current) and the next period (brought to at present value) defining an optimal harvest for each period. The harvest should be equal to or less than the quota defined by the government. It is solved by backward induction.

The fish stock at the initial time is given by $\bar{S}_1$. In period t, $t = 1, 2$, the stock changes according to:

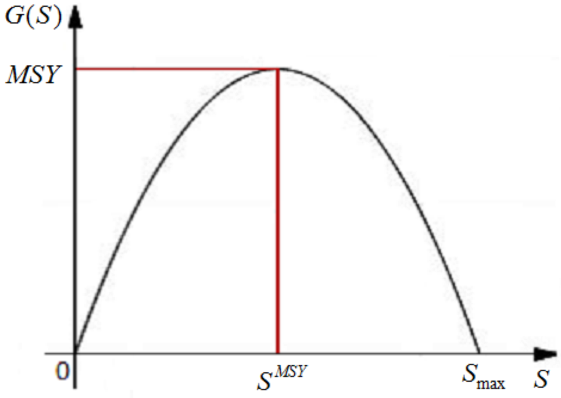
$$S_{t+1} = S_t + G_t(S_t) - H_t(X_t, S_t), \tag{2.1}$$

where G_t is natural growth, H_t is harvest and X_t is fishing effort. The natural growth rate of replacement (G_t) is a logistic biological function, which is a standard assumption and it depends on S_t according to:

$$G_t(S_t) = g_t\Big(1 - \frac{S_t}{S_{max}}\Big)S_t, \tag{2.2}$$

where S_{max} represents the maximum stock size that can be supported in the environmental milieu and g_t is the potential growth rate of the population. Figure 2.4 shows the relationship between stock and the natural growth rate. The maximum sustainable yield (MSY) is obtained when the curve reaches its maximum point at $S_{MSY} = S_{\max}/2$.

Figure 2.4: Natural Growth



Harvest is a function of effort and stock level as below:

$$H_t(X_t, S_t) = e_t X_t S_t, \tag{2.3}$$

where e_t represents the catchability.

Substituting (2.2) and (2.3) into (2.1) yields:

$$S_2 = \bar{S}_1 + g_1\Big(1 - \frac{\bar{S}_1}{S_{max}}\Big)\bar{S}_1 - e_1 X_1 \bar{S}_1. \tag{2.4}$$

with:

$$\frac{dS_2}{dX_1} = -e_1\bar{S}_1 < 0 \tag{2.5}$$

It is assumed:

$$\bar{S}_1 + g_1\Big(1 - \frac{\bar{S}_1}{S_{max}}\Big)\bar{S}_1 \leq \frac{S_{max}}{2}. \tag{2.6}$$

From (2.4), we can see that even if $X_1 = 0$, the second period stock S_2 is still below $S_{MSY} = S_{max}/2$ and growth is still increasing in the stock, as Figure 2.4 shows.

One of the main goals for Chilean fisheries management is to promote the sustainable development of fishing. Therefore, it is assumed that the quota $\bar{H}_t$ is set at or below the sustainable level, which means that the stock for the second period is at least the same as for the first one ($S_{t+1} \geq S_t$). In harvest terms this implies that $H_t(X_t, S_t) \leq G_t(S_t)$. Then the quota is the maximum between zero and the natural growth multiplied by a constant $\alpha_t \in [0, 1]$. Thus, the quota constraint is:

$$H_t \leq \bar{H}_t = max(0, \alpha_t G_t(S_t)). \tag{2.7}$$

The harvesting cost C_t used has a standard definition in the fishery models, and is a linear function of effort:

$$C_t = w_t X_t \tag{2.8}$$

where w_t is the unit cost of effort.

The organisation's profit function in each period t is given by

$$\pi_t = p_t H_t(X_t, S_t) - C_t(X_t) = p_t e_t X_t S_t - w_t X_t. \tag{2.9}$$

Where p_t represents the price at time t. The second equality follows from (2.3) and (2.8).

The fishery organisation maximises the discounted sum of the profits (equation 2.9) over the two periods, where β is the discount factor:

$$\max_{X_1, X_2} \pi = p_1 e_1 X_1 \bar{S}_1 - w_1 X_1 + \beta(p_2 e_2 X_2 S_2 - w_2 X_2) \tag{2.10}$$

subject to (2.4) and (2.7).

There will only be fishing if the profit margin in each period $\partial \pi_t / \partial X_t$ in (2.9) is positive. To ensure that this is the case in periods 1 and 2 respectively, I assume that:

$$\frac{\partial \pi_1}{\partial X_1} = p_1 e_1 \bar{S}_1 - w_1 > 0 \tag{2.11}$$

$$p_2 e_1 \left[\bar{S}_1 + (1-\alpha_1)G(\bar{S}_1)\right] - w_2 > 0 \tag{2.12}$$

Condition (2.11) is a necessary condition for $X_1 > 0$ for period one, but not sufficient, because the effort in period one negatively affects the profit in period two. From (2.4) and (2.7), the LHS of (2.12) is the profit margin in period two in the worst-case scenario where fishing in period 1 is up to the quota. Then, condition (2.12) is a sufficient condition for $X_2 > 0$.

2.4.1 In stage 2

Differentiating the stage-two profits from (2.9) with respect to effort X_2 yields:

$$\frac{\partial \pi_2}{\partial X_2} = p_2 e_2 S_2 - w_2 > 0$$

The above inequality follows from (2.3), (2.4), (2.7) and (2.12). Thus in stage two the organisation maximises its profit by fishing up to the quota. Substituting the functions given for harvest from equation (2.3) and the growth rate from equation (2.2) into the quota equation (2.7), the relation can be rearranged to give:

$$e_2 X_2 S_2 = \alpha_2 g_2 \left(1 - \frac{S_2}{S_{max}}\right) S_2. \tag{2.13}$$

The optimal effort for the second period is then:

$$X_2^* = \frac{g_2 \alpha_2}{e_2}\left(1 - \frac{S_2}{S_{max}}\right)$$

Substituting (2.4) yields:

$$X_2^* = \frac{g_2 \alpha_2}{e_2}\Big(1 - \frac{\bar{S}_1 + G(\bar{S}_1) - e_1 X_1 \bar{S}_1}{S_{max}}\Big) \tag{2.14}$$

Therefore, the harvest for period two is obtained from (2.3), (2.4) and (2.14):

$$H_2^* = g_2\alpha_2\Big(1 - \frac{\bar{S}_1 + g_1\Big(1 - \frac{\bar{S}_1}{S_{max}}\Big)\bar{S}_1 - e_1X_1\bar{S}_1}{S_{max}}\Big)(\bar{S}_1 + g_1\Big(1 - \frac{\bar{S}_1}{S_{max}}\Big)\bar{S}_1 - e_1X_1\bar{S}_1) \tag{2.15}$$

Substituting (2.3) into (2.9), the period-2 profits can be written as:

$$\pi_2(H_2^*, S_2) = p_2H_2^* - \frac{w_2H_2^*}{e_2S_2} \tag{2.16}$$

with H_2^* given by (2.15) and:

$$\frac{\partial\pi_2(H_2^*, S_2)}{\partial H_2^*} = p_2 - \frac{w_2}{e_2S_2} > 0 \tag{2.17}$$

$$\frac{\partial\pi_2(H_2^*, S_2)}{\partial S_2} = \frac{w_2H_2^*}{e_2S_2^2} > 0 \tag{2.18}$$

The inequality in (2.17) follows from (2.12).

2.4.2 In stage 1

In stage one, the fishery maximises the discounted sum of the profits (2.10) over the two periods:

$$\begin{aligned}\frac{d\pi}{dX_1} &= \frac{\partial\pi_1(X_1)}{\partial X_1} + \beta\Big[\frac{\partial\pi_2(H_2, S_2)}{\partial H_2}\frac{dH_2}{dX_1} + \frac{\partial\pi_2(H_2, S_2)}{\partial S_2}\frac{dS_2}{dX_1}\Big] = \\ &= \underbrace{\frac{\partial\pi_1(X_1)}{\partial X_1}}_{(+)} + \beta\Big[\underbrace{\frac{\partial\pi_2(\bar{H}_2, S_2)}{\partial\bar{H}_2}}_{(+)}\underbrace{\frac{\partial\bar{H}_2}{\partial S_2}}_{(+)} + \underbrace{\frac{\partial\pi_2(\bar{H}_2, S_2)}{\partial S_2}}_{(+)}\Big]\underbrace{\frac{dS_2}{dX_1}}_{(-)} = 0\end{aligned} \tag{2.19}$$

The second equality follows from $H_2^* = \bar{H}_2$ and (2.7). The signs of the derivatives follow from (2.11), (2.17), (2.2) and (2.6), (2.18), (2.5) respectively.

This shows that the effort in the first period (X_1) has an effect in both periods. The period-1 profit is increasing in fishing effort. However, more harvesting in period one reduces the stock in period two. That decreases the period-2 profits in two ways. Firstly, less stock means a lower quota. Secondly, less stock means that more effort is needed to catch a given amount of resources.

Substituting (2.2), (2.5), (2.11), (2.17) and (2.18) into (2.19) yields:

$$\frac{d\pi}{dX_1} = (p_1 e_1 \bar{S}_1 - w_1) + \beta\Big[\Big(p_2 - \frac{w_2}{e_2 S_2}\Big)\alpha_2 G_2'(S_2) + \frac{w_2 H_2^*}{e_2 S_2^2}\Big](-e_1 S_1) = 0 \tag{2.20}$$

Solving for the variable X_1 gives:

$$X_1^* = \frac{S_{max}}{2\beta e_1^2 g_2 \alpha_2 p_2 \bar{S}_1^2}\Big[e_1 p_1 \bar{S}_1 - w_1 - \Gamma\Big(\frac{w_2}{e_2 p_2} - 2G(\bar{S}_1) - 2\bar{S}_1 + S_{max}\Big)\Big] \tag{2.21}$$

where,

$$\Gamma = \frac{\beta e_1 g_2 \alpha_2 \bar{S}_1 p_2}{S_{max}};$$

and X_1^* represents the optimal effort for the first period. Then, substituting equation (2.21) into equation (2.3) gives:

$$H_1^* = \frac{S_{max}}{2\beta e_1 g_2 \alpha_2 p_2 \bar{S}_1}\Big[e_1 p_1 \bar{S}_1 - w_1 - \Gamma\Big(\frac{w_2}{e_2 p_2} - 2G(\bar{S}_1) - 2\bar{S}_1 + S_{max}\Big)\Big] \tag{2.22}$$

This represents the optimal harvest for period one in terms of the parameters.

2.4.3 Interior Solution

In this subsection I examine the conditions for the existence of an interior solution $0 < H_1 < \bar{H}_1 = \alpha_1 G_1(\bar{S}_1)$ for harvest in period one. In terms of fishing effort, this implies that $0 < X_1 < \alpha_1 G_1(\bar{S}_1)/(e_1 \bar{S}_1)$ by (2.3). From (2.20), the condition for $X_1 > 0$ is:

$$\frac{d\pi}{dX_1}\bigg|_{X_1=0} = p_1 e_1 \bar{S}_1 - w_1 + \Gamma\Big[(2\bar{S}_1 + 2G(\bar{S}_1) - S_{max}) - \frac{w_2}{e_2 p_2}\Big] > 0$$

From (2.20), the condition for $X_1 < \alpha_1 G_1(\bar{S}_1)/(e_1 \bar{S}_1)$ is:

$$\frac{d\pi}{dX_1}\bigg|_{X_1=\frac{\alpha_1 G_1(\bar{S}_1)}{e_1 \bar{S}_1}} = p_1 e_1 \bar{S}_1 - w_1 + \Gamma\Big[(1-\alpha_1)(2\bar{S}_1 + 2G(\bar{S}_1) - S_{max}) - \frac{w_2}{e_2 p_2}\Big] < 0$$

Therefore, there is an interior solution for X_1 if and only if the inequalities above hold. This means that for $X_1 = 0$ there is no harvest at all in the first period, and thus the stock will be larger for the second one. $X_1 = \alpha_1 G_1(\bar{S}_1)/(e_1\bar{S}_1)$ means that the harvest is at the same level as the approved quota, and accordingly the stock for the second period will be equal to that in the first one if $\alpha_1 = 1$.

If $H_1 = \bar{H}_1$, then the stock for the second period should be at the maximum $S_1 + (1-\alpha_1)G_1 = S_{MSY}$ and $\alpha_1 = 1 - \frac{S_{MSY}-S_1}{G_1}$. This means that when S_1 tends to be equal to S_{MSY}, α_1 should be equal to one.

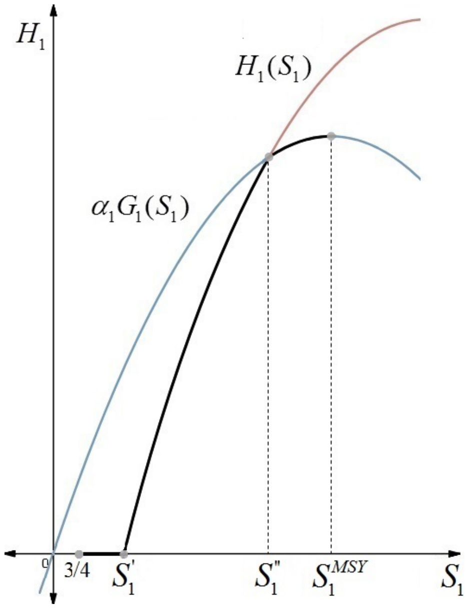
In order to illustrate graphically the interior solution, equation (2.22) is rewritten in the form $H_1(S_1) = aS_1^2 + bS_1 + c/S_1 + d$, where the coefficients of the equation are:

$$a = -\frac{g_1}{S_{max}};$$
$$b = g_1 + 1;$$
$$c = -\frac{w_1 S_{max}}{2\beta e_1 g_2 \alpha_2 p_2}; \text{ and}$$
$$d = \frac{S_{max} p_1}{2\beta g_2 \alpha_2 p_2} - \frac{w_2}{2e_2 p_2} - \frac{S_{max}}{2}.$$

From (2.7), the constraint is given by $\bar{H}_1 = \alpha_1 g_1 \left(1 - \frac{\bar{S}_1}{S_{max}}\right)\bar{S}_1$. When $\alpha_1 = 1$, the harvest constraint is equal to the natural growth $\bar{H}_1 = G(S_1)$.

The following parameters give a numerical example of the interior solution for period one, but this example also works with different numbers. $\beta = 0.9$; $p_1 = p_2 = 4$; $e_1 = e_2 = 1$; $w_1 = w_2 = 3$; $g_1 = g_2 = 3$; $\alpha_1 = \alpha_2 = 1$; and $S_{max} = 10$. From condition (2.11), S_1 should be larger than 3/4. Figure 2.5 illustrates the harvest function and harvest constraint.

Figure 2.5: Harvest function for the first period



Note: Plots of harvest and growth as a function of S_1, while the other parameters remain fixed. The black line represents the solutions.

Figure 2.5 shows the three solutions for the first harvest period: First, $H_1 = 0$ for the interval $S_1 \in [3/4, S^{'} = 1.27]$, which represents a corner solution, meaning that the organisation does not harvest at all because the level of stock is too low; second, for the interval $S_1 \in (S_1^{'}, S_1^{''} = 3.88]$, the harvest is according to the function $H_1(S_1)$, which represents an interior solution; and third, the harvest is given by $\alpha_1 G_1(S_1)$ for the final interval $S_1 \in (S_1^{''}, S_{MSY}]$, which is a corner solution, meaning that the organisation harvests at the same level as the quota strictness. Intuitively, for low stock levels S, the stock's growth $G'(S)$ is higher; therefore, it will generate a greater abundance of resources and a higher quota for the second period. These solutions are represented by the black line in the figure above.

2.4.4 Comparative Statics

In this section, I calculate the effects of changes in the parameters on the level of harvest using a first order condition of harvest (equations (2.15) and (2.22)) and the parameters: quota strictness (measured through α_t in equation (2.7)), price, stock and catchability for each period. These relationships are empirically examined in the next sections.

Comparative statics on quota strictness

In the first period, H_1^* from equation (2.22) represents an interior solution, which is not a function of quota strictness in the first period. Therefore, the partial derivative is equal to zero, which means that the harvest is not restricted by the quota strictness in period one.

$$\frac{\partial H_1}{\partial \alpha_1} = 0$$

In the second period, from (2.15) differentiating harvest with respect to α_2:

$$\frac{\partial H_2}{\partial \alpha_2} = g_2(1 - \frac{S_2}{S_{max}})S_2 + \alpha_2 g_2(1 - \frac{2S_2}{S_{max}})\Big[\frac{S_{max}}{2\beta\alpha_2^2 e_1 g_2 p_2 \bar{S}_1}\underbrace{(e_1 p_1 \bar{S}_1 - w_1)}_{>0}\Big] > 0$$

The first term on the right hand side represents the growth in stock for the second period and the second term shows the quota for the second period multiplying a fraction of the profit for the first period. Both terms are positive, since $S_2 \leq S_{max}/2$. This intuitively implies that an increase in the quota share in the second period increases the harvest for the second period.

Comparative statics on price

From (2.22), the derivative of harvest function with respect to the price (in the first period) is positive:

$$\frac{\partial H_1}{\partial p_1} = \frac{S_{max}}{2\beta\alpha_2 g_2 p_2} > 0$$

From (2.7), (2.4) and (2.21), the derivative of harvest in the second period with respect to the price in the previous period is:

$$\frac{\partial H_2}{\partial p_1} = \frac{\partial H_2}{\partial S_2}\frac{\partial S_2}{\partial X_1}\frac{\partial X_1}{\partial p_1} = \alpha_2 G'(S_2)(-e_1\bar{S}_1)\frac{S_{max}}{2\beta\alpha_2 e_1 g_2 p_2 \bar{S}_1} < 0$$

Since $S_2 \leq S_{max}/2$ and $G'(S_2) > 0$, this implies that $\partial S_2/\partial X_1$ is negative, and therefore $\partial H_2/\partial p_1$ is negative.

Thus the partial derivative of harvest in the second period related to the price in the first one is negative, but in the first period, price has a positive effect on harvest. Intuitively, an increase in price p_1 produces two effects on the harvest. On the one hand, it produces a direct (positive) effect, because it increases the marginal effect per unit. On the other hand, it produces an indirect (negative) effect on the harvest for the second period, since p_1 increases the effort in period one, and that effort in turn reduces the stock for period two.

From (2.15) and (2.21), using the chain rule for H_2 with respect to price in the second period gives:

$$\frac{\partial H_2}{\partial p_2} = \frac{\partial H_2}{\partial X_1}\frac{\partial X_1}{\partial p_2} = \frac{1}{2\beta e_1 e_2 p_2^2 \bar{S}_1 S_{max}^2}(-2\bar{S}_1^2 g_1 - S_{max}^2 + 2\bar{S}_1 S_{max} + 2\bar{S}_1 g_1 S_{max}$$
$$- 2\bar{S}_1 X_1 e_1 S_{max})(e_2 w_1 S_{max} - e_1 e_2 p_1 \bar{S}_1 S_{max} + \beta\alpha_2 e_1 g_2 \bar{S}_1 w_2)$$

The numerator of the fraction involves positive and negative terms; therefore without further restriction it would not be possible to determine the sign of the ratio.

Comparative statics on stock

From equation (2.22) in the first period, the derivative is positive since $\bar{S}_1 < S_{max}/2$.

$$\frac{\partial H_1}{\partial S_1} = \frac{S_{max} w_1}{2\beta\alpha_2 a_1 g_2 p_2 s_1^2} + g_1 \underbrace{(1 - \frac{2\bar{S}_1}{S_{max}})}_{\geq 0} + 1 > 0$$

From (2.3) and (2.14), the derivative of harvest in the second period is:

$$\frac{\partial H_2}{\partial S_2} = g_2\alpha_2(1 - \frac{S_2}{S_{max}}) + g_2\alpha_2 S_2(\frac{-1}{S_{max}}) = g_2\alpha_2 \underbrace{(1 - \frac{2\bar{S}_2}{S_{max}})}_{\geq 0} > 0$$

Since $S_2 \leq S_{max}/2$, the relationship between harvest and stock is positive for the second period.

The partial derivatives of harvest with respect to the stock are positive in both periods. Since the harvest is a direct function of the stock, the implication is that and an increase in the stock has a direct (positive) effect on the quota and then on the harvest, for both periods. This implies that this effect is ambiguous.

Comparative statics on catchability

From equation (2.22), the derivative of harvest with respect to catchability is positive in the first period, because all of the parameters in the fraction are positive:

$$\frac{\partial H_1}{\partial e_1} = \frac{S_{max} w_1}{2\beta\alpha_2^2 g_2 p_2 \bar{S}_1 e_1^2} > 0$$

However, from (2.7), (2.4) and (2.21), the derivative of harvest with respect to catchability is negative in period 2. It is given by:

$$\frac{\partial H_2}{\partial e_2} = \frac{\partial H_2}{\partial S_2}\frac{\partial S_2}{\partial X_1}\frac{\partial X_1}{\partial e_2} = \alpha_2 G^{'}(S_2)(-e_1\bar{S}_1)\frac{w_2}{2e_1 e_2^2 p_2 \bar{S}_1} < 0$$

Since $S_2 \leq S_{max}/2$ and $G'(S_2) > 0$, $\partial H_2/\partial e_2$ is negative.

In relation to the catchability parameter, the results change through the periods. Although catchability has a positive effect in the first period, this changes to a negative effect in the second period due to endogeneity in the quota strictness. Intuitively, an increase in the catchability produces two different effects on the harvest: on the one hand, the harvest in the first period increases in the catchability in the first period (e_1), this result suggests that for a higher catchability less effort is needed to catch a certain amount of fish. On the other hand, e_2 produces an increase in the effort, X_1; this is because fisherman knows that in period one that the catchability will change contrary in the period two, which implies a decrease in the stock for the second period.

2.4.5 Predictions

The predictions examined by the later empirical model are based on the comparative statics from the first period, because it was assumed that the fishermen take future effects into account. Four predictions are examined:

I expect a positive effect of higher assigned quotas on harvest, because the quota is measured through the coefficient alpha, which represents a proportion of the maximum sustainable yield for the area and it has a positive marginal effect on the harvest in both periods.

I expect an increase in the loco's price has a positive effect on the harvest, because harvest has a direct and positive relationship with price in the first period.

I expect that higher resource stock increases the organisation's harvest. As it was previously assumed that $S_2 \leq S_{max}/2$, the partial derivative of the harvest with respect to the stock has a positive impact in both periods analysed. That means that stock has a positive effect on harvest in both cases, when it is directly measured and when it is measured through the variable effort in the second period.

I expect that catchability has a positive effect on the harvest (effective area of the TURFs) even though the comparative statistic differs as a consequence of an endogenous quota in the second period.

2.5 Data and Descriptive Statics

Datasets were requested through the information transparency online platform[4] managed by the Undersecretariat (SUBPESCA) and the National Service of Fisheries (SERNAPESCA).

The Undersecretariat for fisheries (SUBPESCA) stores three types of information: the Baseline studies (ESBA), the annual organisational reports, and official statistics from SERNAPESCA. The ESBA studies contain panel data for 108 organisations operating under TURFs in the Lagos Region from 2004 to 2015. In the second case, a total of 687 annual reports give information on all of the organisations operating

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[4] www.portaltransparencia.cl

under TURFs in the same region from 2004 to 2015. The information covered by these reports includes the number of members and their roles, the harvest level, biomass analysis, effective area, average resource size, TURFs economic performance, and the requested and approved quota, among others. This information was provided as pdf files, which were transcribed into a Stata database file. Finally, SUBPESCA gives information about the average beach and industrial loco price for 2004 to 2015.

The National Service of Fisheries (SERNAPESCA) also manages data including information on artisanal fishermen, area identification, and harvest destination. The Artisanal Fishing Register (RPA) contains data such as RPA number, names of fishermen, as well as their unique tributary number (RUT), address, birth date, sector, city, and fisherman category. Similarly, SERNAPESCA also stores organisational information such as the organisation's name, address, legal representative person, registration date, date of incorporation and number of members. Finally, other specific TURFs data available from 1996 to 2008 includes the code area and name, resource, destination type, destination name, destination plant code (if applicable) and trade name destination (if applicable). Additionally, data from the census 2005 developed by the National Institute of Statistics (INE) of Chile was used to obtain the total population for each locality.

The data for an unbalanced panel were obtained from 69 artisanal organisations managing the loco under the TURFs regime in the Lagos Region. Table 2.1 provides a summary of the descriptive statistics for a group of key variables.

It is interesting to note that the approved quota, price, and stock show a within standard deviation that is higher than that between artisanal organisations. This feature suggest that the main variation occurs over time rather than organisations. Moreover, catchability has a between standard deviation higher than within artisanal organisations, indicating that the main variation is between organisations rather than over time. In addition, an analysis of the overall standard deviation indicates that the loco's price, the average loco's size and the area size have a lower dispersion in contrast to the stock and the approved quota. Other organisational features show that artisanal organisations have an average of 57 members and manage around two

TURFs. There is not official information available on the illegal catch, this might impact on the stock available in the area. However, the stock is evaluated each period by the Government to define the new quota.

Table 2.1: Descriptive Statistics

Variable		Mean	Std. Dev.	Min	Max	Obs.
Harvest	overall	92.956	86.854	0	587.140	524
(thousand units)	between		16.835			
	within		85.605			
Quota	overall	111.505	98.564	0	613.929	653
(thousand units)	between		18.266			
	within		97.399			
Price	overall	662.106	325.447	202	2023	402
(Chilean pesos)	between		219.773			
	within		254.674			
Stock	overall	461.838	638.838	2.758	8577.508	623
(thousand units)	between		116.204			
	within		632.304			
	within		656.156			
Catchability	overall	0.023	0.024	0.002	0.160	662
(hectares^{-1})	between		0.024			
	within		0.006			

Note: Author's calculation of annual reports for artisanal organisations data, in the X region, for the period 2004-2015.

2.6 Empirical Model

An empirical model is estimated to determine those aspects influencing harvesting decisions underpinned by the assumptions in the theoretical section. The theoretical model suggests a set of predictions to be empirically tested. The present section uses a baseline model and different robustness checks on harvest, quotas, resource stocks and prices, putting the theory into practice.

Harvest level is understood here as an organisational management decision proxy, defined as a dependent variable. It denotes a sub-index i for organisation level as the unit of analysis, a sub-index j for the TURFs level and t for the time, from 2004 to 2015.

From the theoretical model, a set of independent variables on harvest are included in the model: the approved quota by the Government, the price of the resource, and the stock and the size of the area as a proxy of catchability.

2.6.1 Baseline estimations

The empirical baseline model is represented by equation (2.23), which shows the harvesting decisions at the organisational level.

$$
\begin{aligned}
ln(Harvest_{ijt}) = \beta_0 + \beta_1 ln(Quota_{ijt}) + \beta_2 ln(Price_{ijt}) + \beta_3 ln(Stock_{ijt}) \\
+\beta_4 ln(Catch_{ijt}) + \beta_5 \delta_t + \beta_6 \lambda_{ij} + \varepsilon_{ijt}
\end{aligned}
\tag{2.23}
$$

Where $Harvest_{ijt}$ represents the total harvest of loco per year t, in organisation i, managing TURF j; $Quota_{ijt}$ is the approved quota by the Government for each year; $Price_{ijt}$ shows the real price of the loco;[5] $Stock_{ijt}$ is the number of locos in the TURFs per year; $Catch_{ijt}$ represents the catchability in the area defined as an inverse function of the area ($1/area$); and ε_{ijt} is the error term. In order to obtain the elasticities in the estimations, a natural logarithm was applied on these variables. Time fixed effect δ_t to capture year specific effects; and pairwise fixed effect λ_{ij}, which captures the relationship between organisation and fishermen.

Table 2.2 shows the correlations between the key variables involved in the regression models. All of them have an acceptable level of association; however the highest correlation occurs between approved quota and stock.

Table 2.2: Correlations

	Quota	Price	Stock	Catchability
Quota	1.000			
Price	0.058	1.000		
Stock	0.508	0.064	1.000	
Catchability	-0.329	-0.096	-0.248	1.000

Note: Author's calculation of annual reports for artisanal organisations data.

Table 2.3 shows different regressions with a fixed effect to isolate the effect of the

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[5] Using consumer price index 2009 as baseline, from the Chilean Central Bank.

correlation between approved quota and stock. The first estimation contains all of the variables; the second runs without the variable approved quota; and finally the third one excludes the stock variable. Regressions are carried out through Ordinary Least Squares (OLS) as a baseline model without fixed effects, then a pairwise fixed effects model, and a time/pairwise fixed effects.

Table 2.3: Baseline Estimations

Dependent variable: Harvest					
	(1)	(2)	(3)	(4)	(5)
Quota	0.921***		0.975***	0.727***	0.770***
	(0.053)		(0.032)	(0.074)	(0.066)
Price	-0.162**	-0.202***	-0.132**	-0.207***	-0.131
	(0.063)	(0.077)	(0.063)	(0.071)	(0.087)
Stock	0.059	0.694***		0.052	0.016
	(0.048)	(0.053)		(0.053)	(0.050)
Catchability	0.014	0.039	0.007	0.278**	0.114
	(0.043)	(0.062)	(0.042)	(0.130)	(0.122)
N	373	373	397	373	373
R-sq	0.755	0.557	0.749	0.856	0.878
Pairwise FEs				yes	yes
Time FEs					yes

Note: Estimated standard errors are in parentheses. *,** and *** represents significant values at 10%, 5% and 1% respectively.

The first column in the table 2.3 shows an OLS model, suggesting that harvest is positively and significantly influenced by the governmental approved quota. Moreover, negative and significant effects on harvest were found as a result of the loco price.

The value of the coefficient related to the variable quota (β_1) is 0.921, which suggests that a change of a 1% in the quota has an impact of 0.921% on the harvest. In the same way, the price has an effect of -0.162% on harvest when they change by a 1%.

The second and third estimations were tested including only one of the independent variables which are highly correlated. The second model excluded the impact of the approved quota on harvest and the third model omitted the available stock of loco. Contrasting the two models, the stock remains positive and has a significant effect on harvest in the second model as well as the approved quota in the third one. Nevertheless, the overall variance explained for both models suggests that the approved quota has a higher effect on harvest than the available stock.

The fourth estimation is controlled by a pairwise fixed effect, in order to capture those characteristics that might affect the harvesting decisions across organisations. Similar to the baseline estimation in the first column, a positive and significant effect on harvest by quota and a negative effect by price were found. Additional, catchability shows significance and a positive effect on harvest. These variations might be explained by some bias in the baseline model, which was better adjusted by the fixed effects model.

In the last model, a time fixed effect is included in order to control for time features. Similar to the baseline model, quota has significant effect on harvest. The results suggest that despite the time effect, the quota is always a relevant variable affecting harvesting decisions. However, price and catchability lose significance when time fixed effect is added.

Contrasting all of the models, the quota and price continue to have a significant effect on harvest in almost all of them. Catchability has a significant and positive effect on harvest when the model is controlled by pairwise fixed effect, whereas stock significantly and positively affects harvest when quota is dropped from the estimations. The models estimated suggest that the approved quota has a higher effect on harvest than the rest of the variables.

The variables quota, stock and catchability are according to the theoretical model predictions in almost all of the models estimated. However, price shows the opposite effect to the theoretical predictions, which means that price has a negative and significant effect on the harvest for all of the regressions estimated.

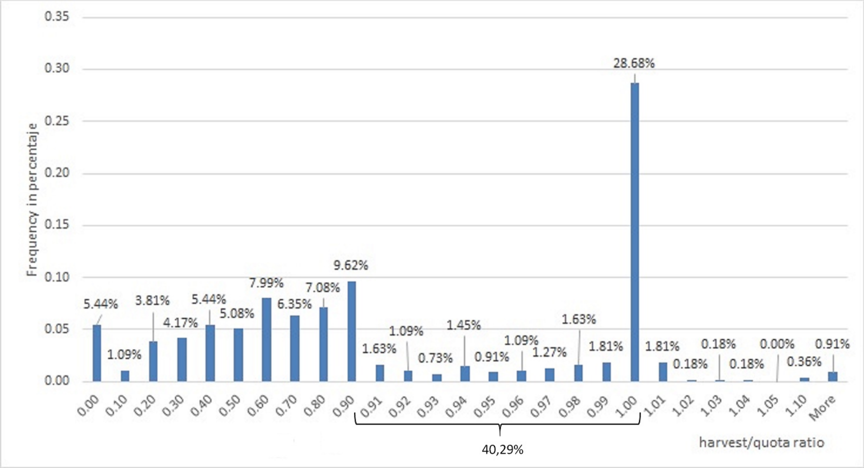
A degree of competition and its interaction with the price is evaluated in the model as an exploratory element; this is due to the fact that organisations working under the TURFs system usually sell their products in oligopolistic markets. Then, the degree of competition is defined as the number of organisations divided by the number of inhabitants in the locality. The results show that there is a positive and significant effect of the interaction of the degree of competition and the price on the harvest. This means that the price has a less negative influence when the organisation belongs to a more competitive location. These estimations are detailed in Appendix A.1.

2.6.2 Robustness checks

The robustness checks are done in three ways to analyse more deeply the relationship between harvesting decision and quotas. Firstly, I use the ratio between harvest and quota as the dependent variable, in order to investigate how bunched this ratio can be; second, a dummy variable is used as a dependent variable to ascertain the probability of being bunched in one; and third, an 2LSL model is estimated to analyse quota as an endogenous variable.

In order to analyse the relationship between the level of harvest and the approved quota, a histogram is shown below. The x-axis shows the ratio of harvest over approved quota and the y-axis reflects the frequency of the ratio for the whole sample accounted for in the baseline estimations.

Figure 2.6: Histogram



Note: Prepared by the author based on SERNAPESCA for the Lagos region

Figure 2.6 clearly shows that the harvest/approved quota ratio is bunched on one; therefore, the harvest is highly concentrated at the same level as the approved quota. The data indicate that 40.29% of the harvest over approved quota ratio is concentrated between the interval $[0.91, 1]$. A few ratios are above value 1, that implies they are harvesting above the allowed quota. However, the ratios are mainly below value 1, which is reliable with the figure 2.3, meaning that on average they harvest less than the allowed quota. In order to clarify those relationships, three robustness checks were defined: firstly, using the harvest/quota ratio as the dependent variable; secondly, defining a dummy variable as the dependent variable, which is equal to one for a harvest/quota ratio above 0.99; and finally, a two-stage least squares model.

The first robustness check is based on the following equation:

$$Harvest_{ijt}/Quota_{ijt} = \beta_0 + \beta_1 ln(Price_{ijt}) + \beta_2 ln(Stock_{ijt}) + \beta_3 ln(Catch_{ijt}) \\ + \beta_4 Controls_{it} + \varepsilon_{ijt}.$$

The second robustness check uses a logit model according to the following equation, where D is a dummy variable equal to 1 for a ratio above 0.99 and 0 otherwise:

$$D = \beta_0 + \beta_1 ln(Price_{ijt}) + \beta_2 ln(Stock_{ijt}) + \beta_3 ln(Catch_{ijt}) + \beta_4 Controls_{it} + \varepsilon_{ijt}$$

Table 2.4 compares an OLS regression using the haverst/approved quota ratio as the dependent variable in the first two columns. Then, a dummy is used as the dependent variable in columns (3) and (4). These estimations are controlled by fixed effects.

Table 2.4: Robustness Check Estimations

D. Variable	(1) H/Q Ratio	(2) H/Q Ratio	(3) H/Q Ratio	(4) Dummy	(5) Dummy	(6) Dummy
Price	-0.074**	-0.087**	-0.045	-0.482***	-0.337	-0.462
	(0.0314)	(0.0365)	(0.043)	(0.1568)	(0.2242)	(0.354)
Stock	0.007	-0.040**	-0.049*	-0.044	-0.170	-0.187
	(0.0149)	(0.0200)	(0.019)	(0.0761)	(0.1253)	(0.137)
Catchability	0.020	0.119*	0.035	0.204*	0.884	0.732
	(0.0225)	(0.0634)	(0.059)	(0.1126)	(0.4607)	(0.495)
N	375	375	375	376	295	376
R2/ Pseudo R2	0.064	0.457	0.560	0.039	0.206	0.106
Pairwise FEs		yes	yes		yes	yes
Time FEs			yes			yes
Regression	OLS	OLS	OLS	Probit	Probit	Probit

Note: Estimated standard errors are in parentheses. *,** and *** represents significant values at 10%, 5% and 1% respectively.

The OLS model in the first column suggests that the harvest/approved quota ratio is affected significantly by price. However, the variables stock and catchability do not have a significant impact on the harvest/price ratio. When the equation is controlled by a pairwise fixed effect in the second column, stock and catchability become significant variables in the model.

The third and fourth columns of table 2.4 show two probit models. The first one is estimated without a fixed effect, where the variable catchability is positive and significant, while the variable price is significant and affects on the dummy variable negatively. The results are similar to the fourth column, when the model is controlled by pairwise fixed effects.

So far, the quota has been analysed as exogenous; however, the effect of the quota on the harvest may be affected by bias brought by the association of harvest with approved quota, which is an outcome of the first one. This relationship between harvest and approved quota suggests that the later one should be treated as an endogenous variable. Evaluating the endogeneity, a two stage least square (2SLS) is tested according to the following equations:

first stage,

$$ln(Quota_{ijt}) = \beta_0 + \beta_1 ln(Stock_{ijt}) + \nu_{ijt};$$

and second stage,

$$ln(H_{ijt}) = \beta_0 + \beta_1 \hat{Quota}_{ijt} + \beta_2 ln(Price_{ijt}) + \beta_3(Catchability_{ijt}) + \beta_4 Controls_{it} + \varepsilon_{ijt}.$$

Table 2.5 shows the regressions for 2SLS. In the first stage, the variables stock has a significant effect on approved quota. In the second stage, the estimations are controlled by time fixed effects.

Table 2.5: Robustness Check Estimations for 2SLS

D. Variable	(1) Harvest	(2) Harvest	(3) Harvest
Second Stage			
$\hat{Quota}$	1.007***	0.828***	0.800***
	(0.041)	(0.073)	(0.066)
Price	-0.158**	-0.205***	-0.128*
	(0.063)	(0.063)	(0.074)
Catchability	0.011	0.242**	0.101
	(0.042)	(0.122)	(0.112)
First stage			
D. Variable: Quota			
Stock	0.788***	0.788***	0.788***
	(0.020)	(0.020)	(0.020)
N	373	373	373
R2	0.753	0.854	0.878
Pairwise FEs		yes	yes
Time FEs			yes

Note: *,** and *** represents significant values at 10%, 5% and 1% respectively.

The findings above reflect that the approved quota and price are significant variables for all of the regressions. The first one has a positive impact on harvest, whereas the second estimation has a negative impact on the dependent variable. In the second column, using simultaneously pairwise, all of the variables are highly significant. In the third column, time fixed effect is added, but the significance of the variables is decreased.

The instrument chosen is significant and the IV estimation is consistent. Both the statistics R^2 and adjusted-R^2 are around 0.67, reaching an acceptable level of precision. In order to evaluate whether the instrument is weak, a Wald test for endogenous regressors is used.[6] This characterisation states that the maximum bias of the 2SLS estimator will be no more than 10% of the bias of OLS. Considering a decision rule at the 5% significance level, the null hypothesis, that the instrument is weak, is rejected with a $F - statistic = 61.938$, which is larger than the critical value given by the 2SLS relative bias.

2.7 Discussion and Conclusions

According to the theoretical model proposed, three out of four predictions were supported for the data. Firstly, there is a positive effect of higher governmental approved quotas on harvest. Secondly, an increase in the resource stock has a positive effect on harvest. Thirdly, an increase in catchability has a positive effect on harvest. However, the estimations show a negative effect on harvest when the price increases.

Through a baseline model analysis using an OLS without fixed effects and a range of fixed effects estimations, these four predictions were examined. I find stronger empirical evidence supporting a positive significant effect of the approved quota on harvest. That means that the assumptions underpinned by the theoretical model are also supported by the empirical estimations.

Regarding the expected positive effect of the loco's price on harvest, the empirical estimations contradict that assumption. The estimations carried out showed that price has a significant negative on harvest. Later, a prediction was tested using a degree of competition as an exploratory idea. The results supported the notion that in those TURFs with a higher competition level, the price has less negative effects since the interaction between price and competition has a positive effect on the harvest.

In relation to the stock, it is a significant variable when the regressions are controlled by a pairwise fixed effect. In most of the estimation this variable has the expected sign, which means that the empirical estimations support the theoretical prediction for stock.

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[6] following the command ivregress

Conversely, catchability measured by the inverse size of the area supports the prediction of the theoretical model. The size of the TURF is significant in the baseline model controlled by pairwise fixed effects. As was initially expected, the negative sign was also shown in the robustness checks.

The findings suggest that the organisational variables analysed are not enough to understand the real impact of the organisational dimension on harvesting strategies. In this regard, greater data collection efforts need to be undertaken by the relevant Chilean institutions. The great diversity in terms of organisational features might explain these inconclusive results. Further studies might illuminate how harvesting decisions vary depending on a wider range of variables related to the organisational structure, internal organisations' management and decision making, and the geographical and socioeconomic characteristics of the territories in which the TURFs operate, among others.

Accounting for the empirical estimations, the first prediction, which expected a positive higher effect of the assigned quota on harvest is the most strongly supported hypothesis across all of the estimations. Similarly, this finding is also consistent with those national statistics exposed in Figure 2.3 in which both the approved quota and the harvest show an overall similar trend from 2004 to 2015. The evidence suggests that further research should aim for a better understanding of how organisations manage their TURFs effectively. Indeed, national statistics show that organisations can manage their harvest up to the maximum assigned quota because, on average, no over catching has been observed since the introduction of the TURFs. In this regard, the results here also reinforce the positive gains of this system for the resource's sustainability, as other studies have reported (Stotz, 1997; Gelcich et al., 2007; González et al., 2006; Cancino, 2007; Gelcich et al., 2010; Zuñiga et al., 2010).

In relation to the second prediction, the empirical estimations suggest that increases in the loco's price have a less negative impact on harvest when it is controlled by competition grade, because the negative effect can be short-cut with the effect of competition with price. Further studies should examine the price of the resource beyond an exogenous variable. In this regard, the influences on the loco's price of artisanal organisations' practices, such as cooperation among fishermen's collectives, previous agreements with specific buyers and harvesting strategies affecting the local selling prices, should be involved in future estimations.

Regarding the third prediction, the empirical estimations show enough evidence to support the notion that increases in stock have a positive impact on harvest. The findings confirm the idea that organisations could choose an interior solution of harvesting less than the quota, in order to increase their stock in the next period and the harvest. In this context, artisanal organisations could expect to maximise their revenues in future harvest periods, assuming that the stock will increase.

The fourth prediction is related to catchability; the empirical estimations support that it has a positive effect on the harvest. The catchability is measured as an inverse relation to the size of the effective area of the TURF, which means while that if the catchability parameter is higher, the TURF's area is smaller, making it easier to obtain the resources at a certain stock level.

A limitation of the analysis in the baseline estimation is that quota is used as an exogenous variable, instead of an endogenous one, increasing in the stock. For that reason, a 2SLS model was estimated, where the quota was defined as a function of stock in a first stage. As was shown, when that model is controlled by pairwise and time fixed effect, the results are similar to the previous one in the baseline estimations.

Additionally, in the empirical model, the quota was assumed to affect the harvest in the same way at any level of harvest. However, the data analysed shows that the quota often constrains the harvest. Further research could include a methodology to estimate the unconstrained harvest. Then, if the harvest exceeds the quota, the harvest needs to be reduced to (just below) the quota.

The research suggests that there are other elements that should be accounted for in fishermen's strategies instead of assuming that fishermen follow the Maximum Sustainable Yield quota defined by the authorities. This work shows that artisanal fishermen have incentives to catch less than the quota if their maximisation considers more than one period. These findings suggest that artisanal organisations are planning a different harvest strategy (in a dynamic instead of a static way), which is also consistent with the interior solution proved in the theoretical model and with the graphs shown in Figure 2.3.

The outcomes highlight feature the significance of examining harvesting decisions involving multiple variables related to the TURFs management. There are several aspects related to the organisational structure which are not involved in this chapter. For example, harvesting decisions might be influenced by leadership styles (authoritative, democratic, strategic, bureaucratic, etc.) and personal backgrounds (sex, age, educational attainments, etc.). Further research ought to present such control variables. In addition, there is evidence supporting the strong importance of social capital in common rights contexts. Future studies might evaluate the relationship between harvesting decisions monitoring and social capital. For example, including the cooperation with other similar artisanal organisations and networks between artisanal organisations and strategic actors such as buyers, trading companies, industrial fishery's companies, governmental regulators and non-governmental institutions.

Accounting for the context in which the TURFs operate, some geographical and socioeconomic characteristics should be included in next studies. For example, territorial settings such as connectivity with greater urban areas, fishery infrastructure, transport services and communication systems might impact on the harvesting decisions made

Further research should aim for a better understanding of the artisanal organisations' behaviour as a key input to evaluate how different agents' actions might produce different impacts on both, the ecosystem and their economic performance. Moreover, accounting for harvesting decisions in a dynamic context rather than analysing them period by period might provide more precise information for Chilean policy makers in relation to fishery management.

Appendices

A.1 Degree of Competition

Degree of competition is included in the model as an exploratory element to evaluate its interaction with the price. The equation to evaluate this degree of competition is given by:

$$
\begin{aligned}
ln(Harvest_{ijt}) = \beta_0 + \beta_1 ln(Quota_{ijt}) + \beta_2 ln(Stock_{ijt}) + \beta_3 ln(Catch_{ijt}) \\
+\beta_4 ln(Price_{ijt}) + \beta_5 Comp_{jt} + \beta_6 Comp_{jt} * ln(Price_{ijt}) \\
+\beta_7 \delta_t + \beta_8 \lambda_{ij} + \varepsilon_{ijt}
\end{aligned}
$$

Where $Comp$ represents the variable degree of competition and $Comp * Price$ shows the interaction between competition and price in the model. The degree of competition is defined as the number of organisations divided by the number of inhabitants in their localities.

Table A.1 shows the regressions using the degree of competition ($Comp_{lt}$); it denotes a sub-index l for locality level and t for time. A pairwise and time fixed effect is added to the estimations.

Table A.1: Degree of Competition

Dependent variable: Harvest			
	(1)	(2)	(3)
Quota	0.913***	0.727***	0.774***
	(0.054)	(0.062)	(0.060)
Stock	0.069	0.055	0.016
	(0.049)	(0.050)	(0.048)
Catchability	0.003	0.304**	0.131
	(0.047)	(0.148)	(0.146)
Price	-0.138	**-0.342*****	**-0.241****
	(0.096)	(0.098)	(0.107)
Competition	-0.258	-1.408	-1.210
	(1.075)	(1.392)	(1.369)
Competition*Price	0.019	**0.363****	**0.390****
	(0.164)	(0.183)	(0.176)
N	370	370	370
R-sq	0.756	0.857	0.879
Pairwise FEs		yes	yes
Time FEs			yes

Note: Estimated standard errors are in parentheses. *,** and *** represents significant values at 10%, 5% and 1% respectively.

Although the variable $Competition$ is not significant in any of the regressions, its interaction with price, represented by $Competition * Price$, is significant and positive, when fixed effect controls are added. This implies that in areas with more competition, the effect of price is less negative due to the positive coefficient of $Competition * Price$.

Chapter 3

The effects of Natural Disasters on Multidimensional Poverty in Chile: Differences between fishermen and non-fishermen populations.

3.1 Introduction

Natural disasters are commonly associated with important economic losses because they damage basic productive infrastructure, decrease economic activities and demand higher social expenditure on post-disaster responses (Strobl, 2012; Noy, 2009). Although there is an international body of literature that focuses on the poverty and natural disasters nexus (Park and Wang, 2017; Sawada and Takasaki, 2017; Van Bergeijk and Lazzaroni, 2015; Strobl, 2012; Noy, 2009) such a relationship has not been deeply explored for the Chilean case. Moreover, Chile is geographical positioned along the Atacama trench between the Nazca and the South America plates and as a result it is exposed to natural disasters such as earthquakes and tsunamis. Therefore, linking hazards and their impact on people's lives is a highly relevant task.

My research aims to evaluate the impact of the earthquake that occurred in Chile on 27th February in 2010 and the later tsunami on households' multidimensional poverty emphasising short and long-term differences within the overall population and those working in artisanal fishery.

One of the main contributions of my research is that it confronts the gap between an enriched current framework for understanding poverty as a multidimensional phenomenon and its restricted measurement in the current field of the environmental economy. Whereas there is a certain consensus that poverty cannot be measured using only income (Alkire and Santos, 2014; Alkire and Foster, 2011), I found that most of the studies measuring poverty only take into account GDP at the national level (Van Bergeijk and Lazzaroni, 2015; Strobl, 2012; Noy, 2009) or income at the household level (Park and Wang, 2017; Sawada and Takasaki, 2017). To tackle with that shortcoming, my research accounts for the unique multidimensional poverty index (MPI) used in Chile for policy making-decisions from 2006 onwards. The MPI is based on the methodology proposed by Alkire and Foster (2011) and composed of four dimensions and twelve indicators, allowing both an aggregated poverty measurement and single dimension analysis for housing, work and social security, education and health at the individual or household level.

In order to examine the effects of the 2010 earthquake and tsunami on households' multidimensional poverty over time, I use data from the most relevant survey to characterise households' socioeconomic conditions in Chile, which is carried out every two or three years from 1990 onwards (CASEN). Data collected in 2006 and 2009 are used to estimate pre-shock effects, whereas the data up to the year 2011 are used to examine post short-term effects and the data up to 2013 the long-run impacts.

I expect to contribute by providing a clearer link between households' poverty and natural disasters in Chile, understanding the first one as a multidimensional phenomenon beyond households' income. Taking advantage of the MPI, this research examines how specific household conditions such as work, health, housing and education were impacted by both natural disasters. In doing this, the results will allow for proposing more precise guidelines for policy purposes in Chile. In the last section I provide some recommendations based on those aspects of people's lives aspects after both disasters.

This research also contributes expanding our limited knowledge of the impact of the earthquake and tsunami on households' multidimensional poverty in Chile as two different exogenous shocks. Most of the studies assess the human losses and material damages produced by the earthquake and the tsunami that followed as a unique phenomenon (Contreras and Winckler, 2013; Astroza et al., 2012; Martin et al., 2010; Morales, 2010). Unlike them, I evaluate both disasters as independent shocks because that is especially relevant for studies focused on the artisanal fishery sector. The evidence shows that fishermen were more affected by the tsunami than the earthquake because the waves destroyed their labour capital and houses located in high risk areas (Contreras and Winckler, 2013; Marín et al., 2010; SERNAPESCA, 2010). I expect that the fishermen and non-fishermen population had an increased likelihood of falling into multidimensional poverty after both shocks, but fishermen were hit harder because of the tsunami. Taking into account the evidence, I also expect that fishermen were mostly affected in terms of their housing and work and social security dimensions as an effect of the tsunami rather than the earthquake.

To examine such hypotheses, I use data provided by the National Emergency Office and Public Security (ONEMI) in order to identify those localities only affected by the earthquake and those also impacted by the later tsunami. I propose a difference-in-difference methodology to estimate the effect of the earthquake and the tsunami on multidimensional poverty for two population groups: A treatment group that involves those fishermen-households located in the areas affected by the shocks with at least one member working in the artisanal sector, and a control group that includes the rest of the population.

I also deal here with the shortcoming that long-term effects of the natural disasters on households' poverty have not been covered in the Chilean case. The only related study accounts for changes in households' multidimensional poverty one year after the shock (Sanhueza et al., 2012). Otherwise, a few studies measure the long-term effects, but only on topics close to poverty such as social vulnerability and social capital (Engel, 2016; Marín et al., 2015; Dussaillant and Guzman, 2014).

My research addresses with such a limitation by examining the short and long-term effects on fishermen's and no-fishermen's multidimensional poverty as a result of the earthquake and the later tsunami. The short-term estimations account for the year following both shocks, whereas the long-term estimations involve the three years following the disasters. By doing that, this research contributes by providing a more precise image of the impact of two differentiated natural disasters on specific dimensions of Chileans' lives over time. It is expected that the overall population as well as the fishermen group were more likely to be poorer a year after the disasters compared with three years after. Whereas some post-disaster consequences are immediately visible such as housing damage and material losses, other impacts, for example on educational achievements and people's health status, might need longer time periods to be observed. In contrast to the body of national literature reporting immediate post-disasters effects (Mella, 2014; Larranaga and Herrera, 2010), my research increases the knowledge about the impact of both disasters on Chileans' households more than one year after their occurrence.

In the same line, I also expect that compared with the rest of the Chilean population, fishermen were more likely to be poor in terms of work and social security and housing in the short-term and lower but significant to the long-term. It is known that people depending on artisanal fishery activity are particularly vulnerable. They show lower educational attainments, incomes and occupational mobility opportunities compared with the rest of the population (Baquedano and Rosas, 2012; Chávez et al., 2010). Therefore, fishermen should have been more likely to be in poverty after both natural disasters because of their previous precarious socioeconomic condition and therefore their ability to successfully face the short and long-term effects of the shocks.

The rest of the paper is organised as follows: section 3.2 gives a literature review linking poverty and natural disasters and a framework of the 2010 earthquake and tsunami in Chile. Section 3.3 covers the data, its sources and some descriptive statistics; section 3.4 discuses the methodology used. In section 3.5 I go through the findings. Section 3.6 details the robustness and sensitivity analyses, while in section 3.7 the results and conclusions are discussed and some policy guidelines are provided.

3.2 Literature Review

3.2.1 Poverty and natural Disasters

Natural disasters are generally associated with considerable economic losses because they might destroy productive infrastructure, decrease economic activities and increase social expenditure on recovery (Strobl, 2012; Noy, 2009). A recent review covering several empirical papers focused on linking natural disasters and macro-economic impacts at the worldwide level found heterogeneous insights; nevertheless most of the studies found that the impact of disasters is significantly negative (Van Bergeijk and Lazzaroni, 2015). That evidence is strong for the two lines of research identified, the first one is focused on the direct costs of shocks, such as economic damage and number of people affected, and the second line is interested in the indirect costs of hazards quantified in terms of the effects on economic growth and incomes.

Another consensus is that the degree of the macro-economic impact due to natural disasters depends on the level of development of the country affected. According to Strobl (2012), although the number of natural disasters has increased worldwide in the last three decades, they are concentrated in developing countries. Between 1970 and 2002, out of a total of 6436 natural disasters 77% took place in developing nations, striking specific localities again and again. As a result, the gap between rich and poor nations has increased and poverty has become a significant economic matter for those geographical areas severely affected by natural events. Similar insights were previously offered by Noy (2009), who found that confronting disasters of a similar magnitude, developed countries face much shorter output declines compared with developing nations. Noy showed that countries with a higher literacy rate, better institutions, a higher income per capita, a higher degree of openness to trade and higher governmental spending are better able to cope with the immediate consequences of disasters and prevent future side effects on the macro-economy.

In contrast the large number of studies focused on the macroeconomic consequences of natural disasters, there is a much smaller body of literature on the effect of natural events at the household level. There is a set of international studies focused on the impact of natural disasters on households' income and poverty and another group interested in households' strategies in regard to facing the consequences of disasters. In the first group, some recent efforts have been carried out by Park and Wang (2017), who provide evidence of the impact of the 2008 Wenchuan earthquake on the welfare of rural households in China accounting for household income and assets before and after the earthquake as well as changes in wage labour supply, government transfers, private transfers and borrowing. Using multiple regressions, this work compared outcomes before and after the earthquake, applying geographic controls for both household and county levels. The impact of the earthquake was measured after 10 months of the shock occurrence. Jia et al. (2018) also described how the Wenchuan earthquake affected people's lives, but paid attention to health, housing, income, expenses and the destruction of cultivated land. For doing so, a descriptive analysis using several official databases is carried out, looking for trends since the earthquake occurrence to 10 years back. Similarly, Gignoux and Menendez (2016) put attention on the impact of several shocks on household located in agricultural areas, evaluating effects on individuals incomes, and ownerships such as land, plants, houses and financial assets. They also used a difference in difference strategy for comparing welfare for individuals who have experienced a ground tremor to the ones of individuals that did not have such experience.

The second group of studies have been centered on comparisons between poor and non-poor households were also carried out by Sawada and Takasaki (2017), who conclude that poor people are more affected after a disaster compared with non-poor people because of the weak ex-ante and ex-post strategies they have to face them. The authors highlight that poor housing does not account with previous labour insurances and personal savings as well as a post-disaster access to formal credit and informal networks for sharing capital and exchanges.

While the few studies investigating the effects of natural disasters at the household level should be recognised for their novel attempts, these studies measure poverty using household income as the main indicator, whereas the current literature on poverty highlights the importance of measuring it as a multidimensional phenomenon (Santos and Villatoro, 2018; Alkire et al., 2017; Dotter and Klasen, 2017; Alkire and Foster, 2016; Alkire et al., 2015; Alkire and Foster, 2011). National research follows a similar line; the few studies linking poverty and natural disasters in Chile also measure poverty using household income (Rojas et al., 2014; Mella, 2014) except for Sanhueza et al. (2012),), who examine the effect of the 2010 earthquake on households' multidimensional poverty calculated by the Alkire and Foster method. Sanhueza and collaborators compared household data in 2009 with a panel survey applied a year after the earthquake to a sample of individuals surveyed in 2009. Applying a difference in difference strategy, they examined variations in the dimensions of poverty comparing previous and after shock periods for the overall population, children and older people. Moreover, the analysis included those localities affected by the earthquake and zones with no impact.

The study above is the only attempt for measuring multidimensional poverty and natural disasters link in Chile. I propose the same difference in difference method, however, there are other contributions in my work. Using a different database, I estimated longer time periods than Sanhueza et al. (2012), accounting for data from 2009 to 2015. Moreover, I distinguishing between two disasters occurred in 2010, the earthquake and the tsunami as effect of the first one. This point is quite relevant because most of the studies in Chile are not able to separate the effect of both shocks on people's lives which is especially important for those household and localities impacted for both disasters. For policy purpose such distinction is essential for designing a more precise post-disaster response strategy and better resources assignments.

Overcoming a reductionist approach based only on income, I propose a multidimensional poverty measurement (see details in the next section) to evaluate the impact of both the earthquake and the tsunami in the short and long-term for the overall population, but also distinguishing impacts on artisanal fishermen as a key group. Therefore enriched guidelines can be suggested for anti-poverty policy design in Chile, taking into consideration the occurrence of natural disasters as a relevant input.

I also found that there are no studies in Chile that evaluate the long-term effects regarding the relationship between poverty and natural disasters. Sanhueza et al. (2012) take into account the impact of the 2010 earthquake on households' multidimensional poverty only one year after its occurrence and omit the tsunami's effects. Other attempts at measuring the long-term post-disaster consequences are focused on topics close to poverty, but not on multidimensional poverty. For example, Engel (2016) examines the impact of the earthquake on people's social vulnerability 3 years after the shock, but she uses a qualitative approach that is focused only on the middle classes for a specific territorial area. Dussaillant and Guzman (2014) assess the impact of the earthquake a year and half after the shock, but they focus on the effects on people's interpersonal trust, whereas Marín et al. (2015) evaluate the impact of the tsunami on fishermen's social capital three years after its occurrence.

This research addresses the limitations in regard to both the short and long-term effects on fishermen's and non-fishermen's multidimensional poverty as a result of the earthquake and the later tsunami. The short-term estimations account for the year immediately after both shocks, whereas the long-term analyses include estimations for the three years after the disasters. By doing that, this research contributes by providing a more precise image of the impact of two differentiated natural disasters on specific dimensions of Chileans' lives in the short and long-term. It is expected that these specific results will provide focalised policy guidelines for tackling future disasters.

3.2.2 Measuring Multidimensional Poverty in Chile

During the last 25 years, Chile has experienced significant progresses in poverty decrease and human development. Since 1990, Chile has gone through a long period of economic growth and greater social programs investments. As a result, income poverty decreased from 40% in 1990 to 14% in 2011. However, poverty and people's quality of life levels are related not only with monetary factors. Even though increases in income allow people a greater access to goods and services available in the markets, it is also real that other basic needs cannot be necessarily purchased in imperfect or missing markets. These include healthcare, social security, education and social capital among others. Therefore, income as a sole indicator of well-being is inappropriate and it should be complemented by other measures.

In contrast with traditional one-dimensional measures based on income or expenditure, multidimensional poverty measures distinguishing among poor and non-poor accounting for several dimensions and forms of deprivation. In that line, the past decade has experienced significant methodological progresses on multidimensional poverty measures (Bourguignon and Chakravarty, 2019; Chakravarty and D'Ambrosio, 2006; Chakravarty et al., 2008; Bossert et al., 2013; Alkire and Foster, 2011)

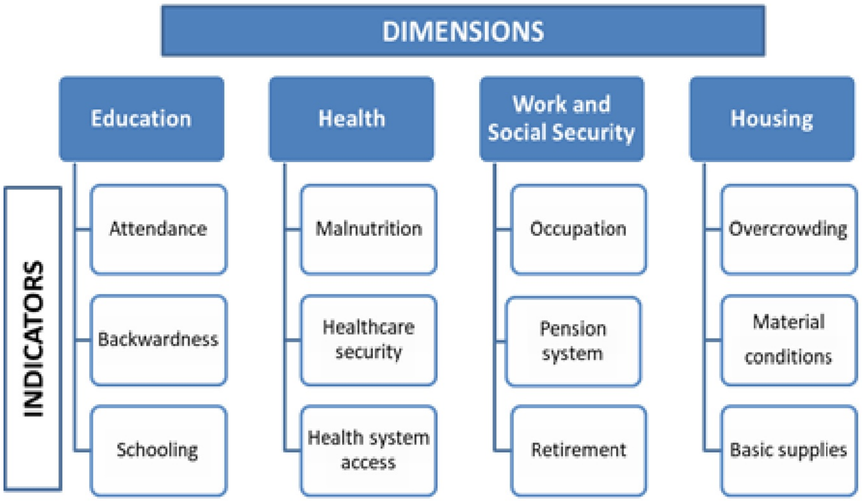
The Oxford Poverty and Human Development Initiative (OPHI) and the United Nations Development Programme (UNDP) calculated and launched the first Global multidimensional poverty index (MPI) for over a hundred countries in 2010. Its new version, released in 2014, includes 108 countries. The Global MPI is a composite of indicators based on household survey data. The index has three dimensions and ten indicators: two for health (malnutrition, and child mortality), two represent educational achievement (years of schooling and school enrolment), and six for evaluating standard of living (including both access to services and household wealth). The three dimensions are weighted equally to form the composite index, allowing information at household level, but not at intra-household level (Dotter and Klasen, 2017). A Later version conducted for measuring multidimensional poverty in the Latin America region is also based on the Global MPI bases (Santos and Villatoro, 2018).

Following such trend and looking for a better policy design and target resources, Chile implemented a multidimensional poverty measure in 2014 based on the Alkire and Foster (2011). Such method, proposes a dual cutoff index for identification and aggregation. This method represents a generalization of the Foster-Greer-Thorbecke (FGT) family of poverty measurements (Foster et al., 1984), where the first cutoff is the poverty line for each dimension or indicator (zi) and the second (k) corresponds to the percentage of dimensions or indicators that an individual is deprived. Alkire and Foster propose three main indicators: the multidimensional poverty headcount (H), the average deprivation for those identified as multidimensionally poor (A), and the multidimensional index $M\alpha$, which corresponds to the adjusted FGT class of multidimensional poverty measures.

Some reasons for choosing this methodology rely on its advantages over others measurements for undertaking empirical works. Alkire and Foster's method allows including qualitative information which is widely available in national household surveys. Moreover, the index can be decomposed by subgroups, therefore detailed analysis by dimension can be carried out for better policymakers recommendations.

Accounting for such advantages and data availability, Chile adopted the Alkire and Foster's method for measuring multidimensional poverty since 2014 at the present. Chilean MPI is calculated on four key dimensions and twelve poverty indicators. Due to the data availability in the CASEN survey, the MPI can be retrospectively calculated until the year 2006, allowing a pre-disaster overview. Figure 3.1 shows the four dimensions involved in the national multidimensional poverty index (MPI) and indicators for each of them.

Figure 3.1: Multidimensional Poverty Index Dimensions



Note: Adapted by the author from CASEN, 2013.

In the MPI, each dimension is equally weighted (25% of the total of 100%), and measured by a total of three indicators. Each indicator is a dummy variable in which one means that at least one individual in the household does not satisfy the criterion, whereas zero represents that the indicator has been satisfied. People are considered to be in "multidimensional poverty" when at least three of the 12 indicators take the value of one. In other words, multidimensional poverty means having the weight of a complete dimension unsatisfied (MIDEPLAN, 2014). Table 3.1 describes the indicators for each dimension.

Table 3.1: Multidimensional Poverty Index for Chile.

Indicators	**Deprivation indicators** (People who live in households with the following characteristics)	**Weights** (%)
	Education Dimension	25
Blackwardness	Households where there is at least one person aged 21 or below in primary/secondary education who is at least two years below his/her corresponding school level.	25/3
Attendancy	Households where there is at least one child or adolescent aged 4-18 not attending school who has not yet graduated (after completing 12 years of schooling).	25/3
Schooling	Households where there is at least one person whose level of education falls below the legal minimum for their cohort.	25/3
	Health Dimension	25
Malnutrition	Households where there is at least one child aged 0 to 6 years old who is overweight or obese or is malnourished or at risk of malnutrition.	25/3
Healthcare security	Households where there is at least one person who does not have any health insurance, either public or private (including complementary insurance).	25/3
Health system access	Households where there is at least one woman aged 21 or above who has not completed a pap test during the past 3 years.	25/3
	Work and Social Security Dimension	25
Occupation	Households with at least one member aged 18 or above who is unemployed and not attending school.	25/3
Pension system	Households with at least one working member aged 15 or above who is not contributing to the pension system and has not had any tertiary education.	24/3
Retirement	Households with at least one female member aged 60 or above, or a male member aged 65 or above, who is not receiving a pension or any retirement income.	25/3

	Housing Dimension	25/3
Overcrowding	Households in which the average number of household members sharing a room is higher than 2.5.	25/3
Material Conditions	A house whose floor, roof, or walls are in bad shape, or the house is made of unsound materials.	25/3
Basic supplies	A house without an interior piped water supply (urban areas) or access to a safe water supply (rural areas), or lacking a WC or septic tank (rural and urban areas).	25/3

Note: Adapted from CASEN 2013, Ministerio de Planificación Social, Chile.

According to official statistics, multidimensional poverty has systematically decreased over time, even since the earthquake/tsunami in 2010 (MIDEPLAN, 2013). A total of 22.2% of Chilean households experienced multidimensional poverty in 2009, 19.5% in 2011 and 16.0% in 2013. An analysis by indicator for the period 2009-2013 shows that over 30% of households are lacking in years of schooling and social security, whereas 17% are living in poor material housing conditions.

3.2.3 Earthquake and Tsunami in Chile

Chile was struck by an earthquake on February 27th, 2010 at 3:34 AM. The magnitude of the earthquake was registered as 8.8.[1] It was the fifth largest instrumentally recorded earthquake in the world, located at the central-south zone of Chile. The earthquake was followed by major tsunami waves that hit the coast in the next 14 minutes-2 hours (SHOA, 2013).[2]

The earthquake/tsunami affected around 80% of the national population living in the central-south of Chile, but was particularly destructive from the VI to the VIII regions. According to official sources both natural disasters left material damage amounting to around 30 billion dollars (Sanhueza et al., 2012; Marín et al., 2010). Regarding the national estimations, the total cost compared to GDP in 2009 was equal to 18% (Gobierno de Chile, 2010).

A total of 521 people lost their lives and 9% of the population of the country

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[1] Available at https://earthquake.usgs.gov/earthquakes/browse/largest-world.php

[2] The biggest one which occurred in 1960, reached a magnitude of 9.5 degrees on the Richter scale, making it the heaviest earthquake registered in the World. In 1988, another earthquake occurred in the centre of Chile, reaching 7.7 degrees on the Richter scale.

declared that they had lost their homes. Moreover, over 70% of healthcare and educational centres registered material damage across the affected territory (MIDEPLAN, 2013). The tsunami caused 156 fatalities and major destruction along 600 km of coastline, especially from the V to the VIII regions (Gobierno de Chile, 2010). Figure 3.2 gives a visual representation of the cities affected by the earthquake in 2010 and their intensities. [3]

Figure 3.2: Chile earthquake 2010

Note: Region number in parentheses. Based on BBC News 27 February 2010.

People working in artisanal fishery were particularly impacted by the event, losing their labour capital and basic installations for their work. According to Marín et al. (2010) the tsunami strongly affected the VIII region (Bio-Bio), leaving up to 60% loss and damage in terms of fishing capacity, including damage to vessels, gear and equipment, port infrastructure, and productive and commercial infrastructure. Therefore, small-scale landings of molluscs, seaweed and crustaceans in the Bio-Bio

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[3] An additional map is added in appendix B.1, showing the whole country divided by regions.

region decreased by around 55% in 2010 as compared with 2009 (SERNAPESCA, 2009, 2010). The decline has been explained as being due to the reduction in fishing capacity, the risks perceived by fishermen of going back to the sea and, to a lesser extent, the ecological effects of the disaster, such as the loss of marine resources (molluscs and seaweed) and rocky reef habitats (Jaramillo et al., 2012; Castilla et al., 2010).

3.2.4 Post-disasters governmental policies

Several international studies discuss the role of both public and private post-disaster responses and recovery strategies. The World Bank has proposed a policy guide for disaster risk management based on the experiences in East Asia and the Pacific (Jha and Stanton-Geddes, 2013). There are also some studies focused on a review of the post-disasters emergency, recovery and reconstruction actions in the USA (Fothergill and Peek, 2004) and some policy guidelines have been proposed for farming villages and fisheries communities mainly affected by earthquakes (Jia et al., 2018; Park and Wang, 2017; Tewfik et al., 2008).

Some studies show that an effective governmental and/or private response after disaster may make a difference when coping with the risks. For example, Park and Wang (2017) showed that the governmental provisions after the 2008 Wenchuan earthquake in China were so well-targeted to those people more affected by the shock that the mean income per capita after the earthquake was 17.5% greater than in 2007. This increase in average income per capita led to household poverty rates falling during the year of the earthquake from 34% to 19%. In contrast, according to the World Bank's study of poverty, after the 2004 tsunami in Aceh, Indonesia, the provision of government subsidies was quite modest and households' incomes and consumption severely decreased, while the poverty headcount rate increased from 28.4% before the shock to 32.6% one year after the tsunami (World Bank, 2008). The evidence shows that both public and private responses after disasters are a critical aspect for transforming a natural shock into an opportunity for re-investment and the upgrading of capital goods, which in turn can enhance an economy and improve people's well-being.

In the Chilean case, there are just a few studies that evaluate the role and effectiveness of the social policies after the 2010 earthquake in Chile (Sehnbruch et al., 2017) and propose some guidelines for tackling future shocks better (Bitar, 2010). On the contrary, most of our knowledge about the impact of the 2010 earthquake and the later tsunami come from official reports in which governmental post-emergency and recovery responses are described. The governmental planning after both disasters first implemented a set of emergency actions to tackle the immediate consequences, but also a set of measures for short-term recovery and long-term reconstruction (Gobierno de Chile, 2010).

The first actions included burying the deceased people and facilitating the means to find lost people. Due to a cut in basic supplies such as water, electricity and food, the government also worked on restoring access to those services and maintaining public order by putting army forces on the streets. In a second stage the actions were focused on building emergency houses for those specifically impacted by the tsunami, ensuring access to healthcare services, restoring those educational centres damaged to ensure children's attendance, and repairing and building roads and bridges to connect the national areas. As expected, most of the public resources were invested in housing, education, health and public works. According to official statistics the recovery planning from 2010 to 2014 cost a total of US $8.431 million, of which 27% was spent on housing, 25% on health infrastructure and 14% on public works (Gobierno de Chile, 2010).

The emergency responses were undertaken from the occurrence of the disasters until six months later, whereas the recovery was planned to last for one year afterwards or longer. The Chilean Government undertook well-targeted post-disaster planning, focalising the public resources on those territorial areas most impacted by the earthquake and the later tsunami (Gobierno de Chile, 2010; Lawner, 2010). For the fishermen population, such planning was successful and quickly supported them with temporary houses and later new homes later, but it was insufficient to attend their working needs (Lawner, 2010). People living in the coastal zones who experienced partial or total loss of their houses were a critical target group for the emergency policy; therefore, fishermen could use these resources. Nevertheless, no governmental actions were taken to confront those labour capital losses reported by fishermen working in the artisanal sector (Sehnbruch et al., 2017; Contreras and Winckler, 2013; Marín et al., 2010) Indeed, "Back to Sea", the most relevant initiative for recovering fishermen's equipment, was mainly funded by private resources with the aim of re-establishing the artisanal fishery activity. This evidence shows that housing and work and social security were the harder hit life dimensions for fishermen after both disasters.

The latter point above highlights the contribution of analyses based on specific groups within the Chilean population because these natural disasters affected them in several and different ways. In fact, a few studies focused on evaluating the effectiveness of the post-disaster responses in Chile have concluded that it is important to undertake particular actions for vulnerable groups such as fishermen (Sehnbruch et al., 2017; Bitar, 2010). Some recommendations for the artisanal fishery sector are improving the quality standards for building in coastal risk zones; determining security zones; and establishing an emergency fund for re-establishing damaged labour capital. Following a similar line, my research provides some policy guidelines according to the main findings and, as a result, some anticipatory actions might be taken.

3.3 Database and Descriptive analysis

The main database used is the National Socio-economic Characterisation survey (CASEN) which covers dimensions related to access to health, education, income, work and housing conditions.[4] This survey has a periodicity of 2 or 3 years. The selected years for estimations previous to the earthquake/tsunami are 2006, 2009 and 2011 for measuring short-term effects and 2013 for long-run impacts. The year 2015 is used for the robustness checks in section 3.6.

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[4] Available at http://observatorio.ministeriodesarrollosocial.gob.cl

The design of the survey (CASEN) depends on two probabilistic independent samples that share the same sample design. The sample configuration corresponds to a probability sample, stratified geographically and by population size. The sample selection is done in two or three stages in both urban and rural areas. The primary sampling units (PSU) are selected with probability proportional to size, and final stage units (households) are selected with equal probability within each PSU. The objective population of the survey is the people living in private homes throughout the country, excluding the areas of difficult access defined by the National Institute of Statistics (INE). Inside each chose family unit, all families and persons declaring residence were interviewed. The survey data are representative nationally and regionally, and embody statistical representativeness for urban and rural areas.

The advantages of this dataset are its extensive cross-sectional number of socioeconomic indicators as well as the longer time covered, allowing for a comparative analysis before and after the disasters. Moreover, the CASEN survey provides a level of disaggregation that allows for identifying the economics sector in which people are working and what type of job they are in. Finally, this database is representative at the national level and allows for measuring multidimensional poverty in the whole country.

Additional data about the characteristics of the earthquake/tsunami are provided by the National Emergency Office of the Ministry of the Interior and Public Security (ONEMI).

Table 3.2 summarises the means for the MPI aggregated index, the four MPI dimensions and the twelve indicators organised by dimension. The columns show the means by year, 2006 and 2009 are previous to the earthquake and the tsunami, whereas 2011, 2013 and 2015 are after the disasters.

Table 3.2: Summary statistics by year, dimensions and indicators.

	(1) Observations	(2) 2006	(3) 2009	(4) 2011	(5) 2013	(6) 2015
MPI	1,200,766	0.347	0.328	0.266	0.212	0.203
		(0.476)	(0.469)	(0.441)	(0.409)	(0.402)
Education dimension	1,200,511	0.579	0.538	0.438	0.416	0.398
		(0.493)	(0.498)	(0.496)	(0.493)	(0.489)
Attendance	1,200,511	0.104	0.081	0.055	0.046	0.037
		(0.305)	(0.273)	(0.229)	(0.209)	(0.189)
Backwardness	1,200,412	0.046	0.045	0.040	0.0388	0.035
		(0.209)	(0.207)	(0.197)	(0.193)	(0.185)
Schooling	1,199,508	0.544	0.500	0.404	0.385	0.372
		(0.498)	(0.500)	(0.490)	(0.486)	(0.483)
Health dimension	1,200,507	0.185	0.195	0.190	0.177	0.176
		(0.388)	(0.396)	(0.392)	(0.381)	(0.381)
Malnutrition	1,188,947	0.053	0.065	0.074	0.073	0.072
		(0.225)	(0.246)	(0.263)	(0.260)	(0.258)
Healthcare Security	1,197,122	0.120	0.075	0.071	0.071	0.067
		(0.326)	(0.263)	(0.258)	(0.257)	(0.251)
Health System Access	1,197,308	0.021	0.073	0.057	0.046	0.049
		(0.146)	(0.260)	(0.232)	(0.209)	(0.216)
Work and Social Security dimension	1,200,511	0.465	0.545	0.494	0.472	0.488
		(0.498)	(0.497)	(0.499)	(0.499)	(0.499)
Occupation	1,200,511	0.098	0.142	0.105	0.107	0.110
		(0.298)	(0.349)	(0.307)	(0.309)	(0.313)
Pension system	1,182,536	0.273	0.407	0.361	0.340	0.364
		(0.445)	(0.491)	(0.480)	(0.473)	(0.481)
Retirement	1,200,511	0.190	0.115	0.113	0.108	0.098
		(0.392)	(0.319)	(0.317)	(0.310)	(0.298)
Housing dimension	1,200,509	0.433	0.397	0.352	0.283	0.254
		(0.495)	(0.489)	(0.477)	(0.450)	(0.435)
Overcrowding	1,199,395	0.190	0.170	0.150	0.131	0.104
		(0.392)	(0.376)	(0.357)	(0.337)	(0.306)
Material Conditions	1,199,674	0.212	0.217	0.191	0.144	0.143
		(0.409)	(0.412)	(0.393)	(0.351)	(0.350)
Basic Supplies	1,200,222	0.214	0.153	0.110	0.075	0.061
		(0.410)	(0.360)	(0.313)	(0.263)	(0.240)

Note: Columns (2) to (6) show the mean for the respective year and standard errors are in parentheses.

The results show that the MPI and education, health and housing dimensions have systematically decreased over time, whereas work and social security shows some fluctuations. The means highlight that the Chilean population are poorer in terms of the education and work and social security dimensions and less poor in health. An analysis by indicator shows that Chilean households increase their likelihood of being poor because of insufficient schooling, low access to the pension and healthcare system and unsatisfactory housing material conditions. Additional tables with descriptive statistics for fishing families and the rest of the population are available in the appendix B.2.

3.4 Methodology

The methodology used is a Difference-in-Difference method at the household level, where I study the differential effect of a treatment group versus a control group. This methodology allows for calculating the effect of shocks on people's outcome (Multidimensional poverty index) by comparing the change in the outcome over time between the treatment group and the control group.

The treatment group consists of those households in which at least one member working in artisanal fishery and that are living in the localities impacted by the earthquake/tsunami. The control group includes households in the rest of the population.

Equations

The baseline equation to estimate the Multidimensional Poverty Index (MPI) is represented by equations (3.1) and (3.2), which show the impact of the earthquake/tsunami on the artisanal fishery households living in the areas affected.

$$P(Y_{ijt} = 1|x) = \beta_0 + \beta_1 \widetilde{Shock}_{jt} + \beta_2 Art_{ijt} + \beta_3 Art_{ijt} \times \widetilde{Shock}_{jt} + \lambda_t + \delta_j \tag{3.1}$$

where,

$$\widetilde{Shock}_{jt} = \{ShockE_{jt},\, ShockT_{jt}\}. \tag{3.2}$$

Where x denotes the full set of explanatory variables for each case, and $P(Y_{ijt} = 1|x)$ represents the response probability for Y_{ijt}. Thus, Y_{ijt} is a multidimensional poverty variable, which represents two types of dependent variable. The first is:

the aggregate multidimensional poverty index, MPI, composed by four dimensions, *"work and social security"*, *"housing"*, *"health"* and *"education"*, each of which is constituted by three indicators; that is to say, there are 12 indicators in total. This dependent variable is equal to one if at least three indicators are equal to one, meaning that the household has a lack in terms of that indicator. Second, each separate dimension is a dependent variable; in this case the dependent variable is equal to one if at least one of its three indicators are unsatisfied and zero when all the indicators are satisfied. These definitions are used to stay as close as possible to the overall definition of poverty as at least a quarter of the indicators are not satisfied. It has been denoting a sub-index i for household level, a sub-index j for locality and t for time. A Probit model is used in all of the estimations.

The variable $\widetilde{Shock}$ is defined in two different ways: one hand, $ShockE$ is a dummy variable accounting for the impact of the earthquake. It equals one when the household is located in one of the seven regions (V, VI, VII, VIII, IX, XIII and XIV) affected by the earthquake according to the official statistics of the Chilean National Emergency Office (ONEMI). On the other hand, $ShockT$ is a dummy variable but accounting for the impact of the tsunami. It equals one when the household is located in one of the localities (comunas) hit by the tsunami, and 0 when is not. According to Contreras and Winckler (2013)'s research (2013), which defined a list of localities impacted by the tsunami.

In order to make a comparison through time for both kinds of shock, the variable $\widetilde{Shock}$ is used with two lengths. The first is a short-term effect, which considers the year after the disasters. This means that $\widetilde{Shock}$ is one if $year = 2010$, otherwise it is zero. The second is a long term effect, which includes the year after and up to 3 years after, which means that the variable $\widetilde{Shock}$ is one if the $year \geq 2010$ and $year \leq 2013$, otherwise the variable is equals to zero.

The variable Art represents households with at least one member working on artisanal fishery.[5] The variables $Art \times ShockE$ and $Art \times ShockT$ represent the interaction

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[5] Artisanal fishery are those operating within five miles of the coast, with vessels length up to 18 meters long and carrying up to 50 tons.

between being in an artisanal fisherman household and receiving the shocks of the earthquake and the tsunami.

Moreover, time (λ_t) and region (δ_j) as fixed effects have been included in the regressions. The first one is a dummy variable for each year used in the estimations (2006, 2009, 2011 and 2013); the second one is a dummy variable for the fifteen regions of Chile. In order to capture the effects of the shocks on the dimensions of poverty, the time fixed effect is considered as a baseline in all of the estimations. A comparison between the short and long-term is made, using as the short-term one period after the shocks (earthquake/tsunami) and the long-term three periods after the shocks.

An assumption underlying the Difference-in-Difference method is that in that in absence of the shock, the treatment and control groups would have similar development in terms of the outcome variable. This seems to hold for both groups analysed. Details are available in the appendix B.3.

3.5 Results

The results are presented following the dimensions involved in the MPI index. Firstly, overall estimations based on the index are provided and then the findings are organised by dimension: work and social security, housing, health and education. All of them are considered dependent dummy variables. The rows in the next tables show those variables examining the effects of the earthquake or tsunami in the non-fishermen and artisanal fishermen populations, whereas the columns account for short-time effects from the first to the fourth columns and for long-term effects from the fifth to the eighth columns. Year and region have also been included as fixed effects.

Multidimensional Poverty (MPI)

Table 3.3 shows the baseline estimations for the overall MPI, as a dummy dependent variable in which 1 means that the household is on multidimensional poverty because at least 3 of the 12 indicators are equal to 1.

Table 3.3: Marginal effects of earthquake and tsunami on MPI.

	Short-Term				Long-Term			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Art	0.147***	0.131***	0.145***	0.130***	0.148***	0.133***	0.146***	0.131***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
$ShockE$	0.014***	0.020***			0.005***	0.014***		
	(0.002)	(0.002)			(0.001)	(0.002)		
$Art \times ShockE$	-0.007	-0.007			-0.025	-0.025		
	(0.037)	(0.037)			(0.023)	(0.022)		
$ShockT$			0.037***	0.030***			0.006**	0.001
			(0.005)	(0.005)			(0.003)	(0.003)
$Art \times ShockT$			0.043	0.059			0.005	0.017
			(0.051)	(0.051)			(0.031)	(0.031)
N	1200766	1200766	1200766	1200766	1200766	1200766	1200766	1200766
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes
Region FEs		yes		yes		yes		yes

Note: The dependent variable is Multidimensional Poverty Index (MPI). Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The results above indicate that living in multidimensional poverty is more likely for the overall population after the earthquake ($ShockE$) and also after the tsunami controlling for the year fixed effect ($ShockT$), for the short and the long term effects. Being an artisanal household (Art) also increases the likelihood to be poor, as there is a persistent positive significant effect in the case of both disasters for all the estimations. Nevertheless, when being an artisanal fisherman interacts with the earthquake ($Art \times ShockE$) and tsunami ($Art \times ShockT$), the effects are not significant at the artisanal level. Due to the lack of an interaction effect on the overall index and the high heterogeneity in the standard errors, below I turn in an analysis by dimension, in the search for more precise results.

Work and Social Security dimension

The work and social security dimension is measured by occupation, pension system and retirement indicators. Table 3.4 shows the baseline estimates for this dimension.

Table 3.4: Marginal effects of earthquake and tsunami on “Work and Social Security”.

	Short-Term				Long-Term			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Art	0.255***	0.252***	0.254***	0.252***	0.248***	0.245***	0.249***	0.247***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
ShockE	0.024***	0.004			0.019***	-0.001		
	(0.002)	(0.003)			(0.002)	(0.002)		
Art×*ShockE*	0.128**	0.122**			0.158***	0.150***		
	(0.052)	(0.052)			(0.032)	(0.032)		
ShockT			0.017***	0.010*			0.011***	0.005
			(0.006)	(0.006)			(0.004)	(0.004)
Art×*ShockT*			0.228***	0.234***			0.254***	0.254***
			(0.083)	(0.083)			(0.050)	(0.049)
N	1200511	1200511	1200511	1200511	1200511	1200511	1200511	1200511
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes
Region FEs		yes		yes		yes		yes

Note: The dependent variable is the dimension Work and Social Security. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The results show that the “work and social security” dimension is positive and significantly affected by the earthquake (*ShockE*) and the tsunami (*ShockT*) accounting for the entire population; however, the significance is lost when region is applied as a fixed effect in the long-term and for the earthquake in the short-term. The findings also show that having a lack in this dimension is 25.5% more likely for those people working in the artisanal sector compared to the rest of the population. Artisanal households (*Art*) are more likely to have a lack in terms of work and social security after the earthquake and the tsunami even controlling for region. Finally, the interactions between earthquake and artisanal (*Art*×*ShockE*) and tsunami and artisanal (*Art*×*ShockT*) are both positive and significant. In the first case, the probability of being poor and being an artisanal household affected by the earthquake increases from 12.8% in the short-term to 15.8% in the long-term in the “work and social security” dimension. In the second case, that probability increases from 22.8% to 25.4% when artisanal people are impacted by the tsunami.

Housing dimension

The housing dimension is measured by overcrowding, material condition and basic supplies indicators. Table 3.5 indicates the marginal effects for this dimension.

Table 3.5: Marginal effects of earthquake and tsunami on “Housing”.

	Short-Term				Long-Term			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Art	0.090***	0.077***	0.089***	0.076***	0.093***	0.079***	0.091***	0.078***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
$ShockE$	0.012***	0.026***			0.009***	0.030***		
	(0.002)	(0.002)			(0.002)	(0.002)		
$Art\times ShockE$	-0.030	-0.038			-0.045*	-0.053**		
	(0.040)	(0.040)			(0.025)	(0.025)		
$ShockT$			0.094***	0.086***			0.051***	0.042***
			(0.005)	(0.005)			(0.003)	(0.003)
$Art\times ShockT$			-0.105*	-0.088			-0.092***	-0.080**
			(0.057)	(0.057)			(0.035)	(0.035)
N	1200509	1200509	1200509	1200509	1200509	1200509	1200509	1200509
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes
Region FEs		yes		yes		yes		yes

Note: The dependent variable is the dimension Housing. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The findings show that both disasters, the earthquake ($ShockE$) and the tsunami ($ShockT$) had a positive significant effect on the housing dimension in the short and long term, which means that households impacted by the shock are more likely to have a lack in terms of this dimension, but also on the artisanal households (Art), whether or not region is controlled. Interestingly, the interaction between shocks and being artisanal shows a significant negative effect. For the long term, the data reports that being artisanal and receiving the impact of the earthquake ($Art\times ShockE$) reduces the likelihood of having a lack in terms of housing conditions by around 4.5% and by 5.3% controlling for region fixed effects. Moreover, being artisanal and receiving the impact of the tsunami ($Art\times ShockT$) reduces the probability of being poor in the housing dimension from 9.2% to 8.0% after controlling for region fixed effects.

Moreover, being artisanal and affected by the earthquake ($Art\times ShockE$) is not significant. However, accounting for the tsunami,($Art\times ShockT$), the probability decreases by around 10% controlling by time fixed effects. The results show that having a lack in terms of material housing conditions is less likely for those working in the artisanal sector and even lower for those impacted by the tsunami. The difference between the short and long-term shows that recovery from the shock is faster for fishermen compared to the rest of the population.

Health dimension

The health dimension is measured by malnutrition, healthcare security and health system access indicators. Table 3.6 indicates the marginal effects for this dimension.

Table 3.6: Marginal effects of earthquake and tsunami on “Health”.

	Short-Term				Long-Term			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Art	0.012**	0.010*	0.011**	0.009	0.011**	0.011*	0.012**	0.009
	(0.005)	(0.006)	(0.005)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)
ShockE	-0.022***	0.010***			-0.026***	0.006***		
	(0.002)	(0.002)			(0.001)	(0.002)		
Art×ShockE	-0.138***	-0.125***			-0.063***	-0.048**		
	(0.042)	(0.042)			(0.023)	(0.023)		
ShockT			-0.044***	-0.011**			-0.042***	-0.008***
			(0.005)	(0.005)			(0.003)	(0.003)
Art×ShockT			-0.115*	-0.121**			-0.031	-0.028
			(0.061)	(0.062)			(0.032)	(0.032)
N	1200507	1200507	1200507	1200507	1200507	1200507	1200507	1200507
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes
Region FEs		yes		yes		yes		yes

Note: The dependent variable is the dimension Health. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The findings reveal that the earthquake (*ShockE*) had a negative significant effect on the health dimension; therefore it is less likely having lack on the dimension after received the shock. However, the effect turns positive when region is used as a fixed effect. The tsunami (*ShockT*) had a negative significant effect on the overall population, whether or not region fixed effects are controlled. Moreover, having lack a in terms of health is more likely for an artisanal household (*Art*); similar results are shown for both disasters whether or not region fixed effects are controlled. Those results are consistent for both the short and long-term periods.

Moreover, the interaction between earthquake and artisanal (*Art×ShockE*) is significant and negative whether or not the region is used as a fixed effect, for both periods of time. Similarly to the housing dimension, being artisanal and receiving the impact of the earthquake reduces the likelihood of being poor in the health dimension. In the case of the tsunami, the interaction between being artisanal and receiving the shock (*Art×ShockT*) is significant and negative in the short-term. Conversely, that relation is not significant when tsunami is examined as a long-term shock.

Education dimension

The education dimension is measured by attendance, backwardness and schooling indicators. Table 3.7 indicates the marginal effects for this dimension.

Table 3.7: Marginal effects of earthquake and tsunami on "Education".

	Short-Term				Long-Term			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Art	0.176***	0.140***	0.172***	0.139***	0.178***	0.140***	0.172***	0.139***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.008)	(0.007)	(0.007)	(0.007)
ShockE	0.049***	0.013***			0.038***	0.007***		
	(0.002)	(0.003)			(0.002)	(0.002)		
Art× *ShockE*	-0.033	-0.029			-0.017	-0.013		
	(0.044)	(0.043)			(0.027)	(0.026)		
ShockT			0.073***	0.026***			0.047***	0.002
			(0.005)	(0.005)			(0.003)	(0.004)
Art× *ShockT*			-0.034	-0.003			-0.023	0.002
			(0.063)	(0.062)			(0.037)	(0.037)
N	1200511	1200511	1200511	1200511	1200511	1200511	1200511	1200511
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes
Region FEs		yes		yes		yes		yes

Note: The dependent variable is the dimension Education. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The results indicate that the educational dimension is positively and significantly affected by the earthquake accounting for the overall population (*ShockE*), in the short and long-term. A similar effect was found for the tsunami, when region is not accounted for as a fixed effect (*ShockT*). Having a lack in terms of the educational dimension is more likely when people are working in the artisanal sector (*Art*) for both, the earthquake and the tsunami. In contrast to the previous dimensions, not significant effects are found for the interaction between being artisanal and the earthquake (*Art*× *ShockE*) or being artisanal and the tsunami (*Art*× *ShockT*).

3.6 Robustness and sensitivity Analysis

The robustness checks of the multidimensional poverty estimations are done in two ways. Firstly, I use sub-samples of the reports to ascertain that the significant effect for the interaction between being artisanal and the shock is not caused by the heterogeneity of the control group. Secondly, the variable shock is redefined in terms of its length and intensity, is in order to investigate possible differences in the shock impact between the populations and the dimensions of poverty.

Sub-sample

The sample is restricted to households located in localities (comunas) with direct access to the sea, and fishermen's households.

Tables 3.8 to 3.11 show the results from these estimations. The first four columns of each table show the households located in coastal localities, whereas the following columns (from fifth to eight) indicate those households economically related to fishery activities.[6]

Table 3.8: Marginal effects of earthquake and tsunami on "Work and Social Security".

	Coastal Localities				Households related to Fishery			
	Short-Term		Long-Term		Short-Term		Long-Term	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Art	0.260***	0.261***	0.249***	0.256***	0.183***	0.187***	0.175***	0.184***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.009)	(0.009)	(0.010)	(0.009)
ShockE	0.003		-0.004		-0.141***		-0.051	
	(0.004)		(0.004)		(0.044)		(0.034)	
Art×*ShockE*	0.191***		0.263***		0.169***		0.198***	
	(0.060)		(0.039)		(0.060)		(0.040)	
ShockT		0.002		-0.004		0.009		-0.051
		(0.006)		(0.004)		(0.075)		(0.050)
Art×*ShockT*		0.221***		0.242***		0.069		0.148**
		(0.082)		(0.049)		(0.102)		(0.063)
N	365850	365850	365850	365850	8621	8621	8621	8621
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes
Region FEs	yes	yes	yes	yes	yes	yes	yes	yes

Note: The dependent variable is Work and Social Security. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

For all of the estimations in table 3.8, the marginal coefficient of the variable *Art* is significant and positive, showing a value of around 0.2. The lack represents that being an artisanal fisherman increases by around 20% the lack in the "work and social security" dimension. That value is similar to the baseline estimations, which are around a 24%. The interaction between *Art* and *ShockE* is significant for most

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[6] The CASEN survey uses the international occupation classification known as CIUO-88. Fishery activity includes all people who work as artisanal fishermen, or in aquaculture or industry fishery or who declare that they are part of their communities.

of the columns; the earthquake values are slightly higher than the tsunami in both of the restricted samples.

Table 3.9: Marginal effects of earthquake and tsunami on "Housing".

	Coastal Localities				Households related to Fishery			
	Short-Term		Long-term		Short-Term		Long-term	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Art	0.080***	0.080***	0.083***	0.082***	0.026**	0.023**	0.025**	0.022**
	(0.007)	(0.007)	(0.007)	(0.007)	(0.011)	(0.011)	(0.011)	(0.011)
ShockE	0.014***		0.023***		0.077		0.006	
	(0.004)		(0.003)		(0.049)		(0.038)	
Art×*ShockE*	-0.034		-0.060**		-0.070		-0.014	
	(0.041)		(0.026)		(0.062)		(0.043)	
ShockT		0.094***		0.048***		-0.014		-0.079
		(0.006)		(0.004)		(0.083)		(0.059)
Art×*ShockT*		-0.099*		-0.086**		0.022		0.062
		(0.056)		(0.034)		(0.100)		(0.067)
N	365850	365850	365850	365850	8621	8621	8621	8621
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes
Region FEs	yes	yes	yes	yes	yes	yes	yes	yes

Note:The dependent variable is Housing. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.9 shows that the key variables $Art\times ShockE$ and $Art\times ShockT$ are negative for the case of costal localities. This effect is similar to the results shown in table 3.5. That means that being a fisherman and receiving the shock is less likely to lead to a lack in the housing dimension. However, those interactions are not significant for the estimations using the restricted sample for households with at least one member related to artisanal fishery.

Table 3.10: Marginal effects of earthquake and tsunami on “Health”.

	Coastal Localities				Households related to Fishery			
	Short-Term		Long-term		Short-Term		Long-term	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Art	0.011*	0.010*	0.011*	0.010*	0.027***	0.024***	0.025***	0.023***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.009)	(0.009)	(0.009)	(0.009)
$ShockE$	0.023***		0.012***		0.094**		0.008	
	(0.003)		(0.003)		(0.039)		(0.032)	
$Art\times ShockE$	-0.120***		-0.048**		-0.184***		-0.042	
	(0.044)		(0.024)		(0.055)		(0.037)	
$ShockT$		0.004		-0.001		0.130**		0.007
		(0.005)		(0.003)		(0.062)		(0.049)
$Art\times ShockT$		-0.114*		-0.028		-0.233***		-0.033
		(0.061)		(0.031)		(0.086)		(0.056)
N	365850	365850	365850	365850	8621	8621	8621	8621
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes
Region FEs	yes	yes	yes	yes	yes	yes	yes	yes

Note: The dependent variable is Health. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.10 shows the robustness checks for the “health” dimension. The key variable $Art\times ShockE$ is significant and negative in the first and second column, with a value of around 0.05. That is similar to the values and trend observed in table 3.6, when the estimations are accounting for the earthquake. However, the variable $Art\times ShockT$ is not significant for any estimation accounting for the tsunami. These results are in the same line as the baseline estimations for health, in which the interaction variable is just significant for the earthquake.

Table 3.11: Marginal effects of earthquake and tsunami on “Education”.

	Coastal Localities				Households related to Fishery			
	Short Term		Long term		Short Term		Long term	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Art	0.148***	0.148***	0.146***	0.148***	0.063***	0.064***	0.061***	0.064***
	(0.007)	(0.007)	(0.008)	(0.008)	(0.011)	(0.011)	(0.011)	(0.011)
$ShockE$	0.004		-0.010***		-0.100**		-0.078**	
	(0.004)		(0.003)		(0.048)		(0.037)	
$Art \times ShockE$	0.006		0.023		0.084		0.065	
	(0.045)		(0.028)		(0.060)		(0.041)	
$ShockT$		0.056***		0.031***		-0.117		-0.064
		(0.006)		(0.004)		(0.080)		(0.054)
$Art \times ShockT$		-0.021		-0.012		0.135		0.060
		(0.061)		(0.036)		(0.098)		(0.062)
N	365850	365850	365850	365850	8621	8621	8621	8621
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes
Region FEs		yes		yes		yes		yes

Note: The dependent variable is Education. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3.11 shows the robustness checks for the “education” dimension. The key variables $Art \times ShockE$ and $Art \times ShockT$ are not significant for any of the estimations. This is similar to the results showed in table 3.7, where these variables are also not significant.

Overall, the patterns represented in tables 3.8 to 3.11 are consistent with the baseline estimates shown in tables 3.4 to 3.7, in which the variable interaction between being artisanal and receiving the shock shows a positive impact on the “work and social security” dimension, a negative impact on “housing” and “health” and a not significant interaction for the “educational” dimension.

Re-definition of shock

The shock used in the baseline estimation is defined for the years 2011 and 2013 to the short and long-term respectively. In terms of the length of the shock a new definition is used: $ShockE_L$ which includes up to five-years after the earthquake impact (from 2010 to 2015). Analogously, the variable $ShockT_L$ is defined for the tsunami. Those results are shown in tables 3.12.

Table 3.12: Marginal effects for MPI dimensions, using five-years shock.

Dep. Var:	Work and SS		Housing		Health		Education	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Art	0.241***	0.244***	0.095***	0.081***	0.011*	0.010**	0.179***	0.138***
	(0.008)	(0.008)	(0.007)	(0.007)	(0.006)	(0.006)	(0.008)	(0.007)
$ShockE_L$	0.017***		-0.004***		-0.026***		0.026***	
	(0.001)		(0.001)		(0.001)		(0.001)	
$Art\times ShockE_L$	0.178***		-0.067***		-0.059***		-0.009	
	(0.026)		(0.021)		(0.018)		(0.022)	
$ShockT_L$		0.007***		0.006**		-0.014***		0.003***
		(0.003)		(0.003)		(0.002)		(0.003)
$Art\times ShockT_L$		0.245***		-0.091***		-0.036		0.015
		(0.038)		(0.028)		(0.025)		(0.029)
N	1200511	1200511	1200509	1200509	1200507	1200507	1200511	1200511
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes
Region FEs		yes		yes		yes		yes

Note: Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The findings above are similar to the baseline estimations for all of the dimensions analysed, using both kinds of shocks. The interactions between earthquake/tsunami and artisanal are positive and significant for the dimension “work and social security”, whereas they are significant, but negative for the “housing” and “health” dimensions. Finally, the interactions are not significant for the “education” dimension.

Tables 3.13 and 3.14 show the marginal effects for the MPI dimensions, using intensities for the variable shock. Firstly, for the earthquake a seismic intensity value is used, which represents the grade of damage assigned using the description given by Medvedev and Sponheuer (Astroza et al., 2012). Secondly, using information from Contreras and Winckler (2013), the tsunami’s intensity is defined according to the number of square metres (m^2) flooded divided by the total square kilometres (km^2) of the respective locality.

Table 3.13: Marginal effects for “Work and Social Security” and “Housing”, using a shock by intensities.

	Work and Social Security				Housing			
	Short-Term		Long-term		Short-Term		Long-term	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Art	0.252***	0.252***	0.245***	0.247***	0.076***	0.089***	0.079***	0.078***
	(0.008)	(0.008)	(0.008)	(0.008)	(0.007)	(0.007)	(0.007)	(0.007)
$ShockE$	-0.001**		-0.001***		0.004***		0.004***	
	(0.000)		(0.000)		(0.000)		(0.000)	
$Art\times ShockE$	0.124**		0.150***		-0.034		-0.049***	
	(0.052)		(0.032)		(0.040)		(0.025)	
$ShockT$		-0.173		-0.254***		0.327***		0.164***
		(0.115)		(0.068)		(0.106)		(0.063)
$Art\times ShockT$		0.204**		0.239***		-0.027		-0.051
		(0.101)		(0.058)		(0.073)		(0.042)
N	1200511	1196947	1200511	1192065	1200509	1196945	1200509	1192063
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes
Region FEs	yes	yes	yes	yes	yes	yes	yes	yes

Note: Standard errors in parentheses. Time fixed effects is used in all the estimations.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

In the first four columns of table 3.13 for the “work and social security” dimension, the interaction between artisanal and the shock ($Art\times ShockE$ and $Art\times ShockT$) shows a positive and significant marginal effect for the short and long-term. These results are similar to the baseline estimations in the dimension “work and social security” shown in table 3.4. In the case of the dimension “housing” (columns six to eigh), the coefficient of the interaction is negative as in the baseline estimation (table 3.5), but they are not significant, with the exception of the long-term estimations accounting for the earthquake. The coefficients for the variable *Shock* are positive and significant, as with the baseline for the earthquake and tsunami.

Table 3.14: Marginal effects for “Health” and “Education” dimensions, using a shock by intensities.

	Health				Education			
	Short Term		Long term		Short Term		Long term	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Art	0.013**	0.009	0.014**	0.012**	0.140***	0.172***	0.140***	0.171***
	(0.005)	(0.005)	(0.006)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)
ShockE	-0.002***		-0.002***		0.002***		0.001***	
	(0.000)		(0.000)		(0.000)		(0.000)	
Art× *ShockE*	-0.147***		-0.074***		-0.027		-0.012	
	(0.042)		(0.023)		(0.043)		(0.026)	
ShockT		0.150		-0.254***		0.117**		-0.415***
		(0.093)		(0.054)		(0.114)		(0.067)
Art× *ShockT*		-0.180**		-0.090**		0.040		0.038
		(0.090)		(0.040)		(0.080)		(0.045)
N	1200507	1196943	1200507	1192061	1200511	1196947	1200511	1192065
Time FEs	yes	yes	yes	yes	yes	yes	yes	yes
Region FEs	yes	yes	yes	yes	yes	yes	yes	yes

Note: Standard errors in parentheses. Time fixed effects is used in all the estimations.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3.14 shows the dimensions of “health” and “education”. For the first to the fourth columns, the estimations show a negative and significant coefficient for the interactions between *Artisanal* and *Shock*, which have a similar trend, but stronger effect than the baseline estimations in table 3.6. Finally, for the fifth to the eighth columns (“education” dimension), the interaction variables are not significant, as with the baseline estimation shown in table 3.7.[7]

3.7 Discussion and Conclusions

I estimated the short and long-term effects of the 2010 earthquake and the later tsunami on households' multidimensional poverty in Chile. Through a difference in-difference strategy, I compared the impact of both disasters on fishermen and no-fishermen households' multidimensional poverty. The main findings of this study are the following: First, whereas the overall population shows significant effects of both shocks on its MPI in the short and long-term, there are not significant effects for fishermen even when controlling for territorial and time effects when only the

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[7] As an extension of the previous estimation an heterogeneous treatment effects model is run. These details are available in the appendix B.4.

aggregated poverty index is estimated. Second, an analysis by poverty dimension reveals that fishermen are hit harder than the rest of the population in regard to "work and social security" after both disasters in the short and long-term, but especially as an effect of the tsunami. In contrast to the above, fishermen are less likely to be poor in terms of "housing" than the overall population in the long-term after the earthquake and in the short and long-term after the tsunami. Third, after both disasters fishermen and no-fishermen population decrease their likelihood of being poor in in terms of "health" in the short and long-term, controlling for territorial and time effects, whereas only the overall population show to be more likely to fall into educational poverty after both disasters in the short and long-term. Finally, being part of the fishermen group increases the likelihood of being poor in the short and long-term for each of the four dimensions involved in the MPI.

Taking into consideration the findings above, some guidelines for policy purposes might be suggested. Because no differences between fishermen and non-fishermen were observed in the overall MPI estimations, it is highly recommended that poverty is measured using not only aggregated indices or single indicators. Indeed, MPI is not significantly influenced by the earthquake and tsunami in the short or long-term for the fishermen population; however significant effects are visible in the analysis by dimension. As I expected, fishermen show a higher lack in the dimension "work and social security" compared with the rest of the Chileans after both disasters in the short and long-term. I also found that artisanal households were especially affected by the tsunami. This differentiated effect by shock was not observed in the other three poverty dimensions, suggesting that the tsunami had a greater negative impact on fishermen's labour capital. Official statistics reinforce this evidence because the tsunami was particularly destructive for the artisanal small-scale fishery sector who lost their vessels and basic equipment and therefore, their opportunities to go back to work (SERNAPESCA, 2010, 2009).

The results also indicate that "work and social security" is the only dimension in which fishermen do not show successful recovery after the shocks. An explanation might be associated with the lower governmental investment focused on recovering the physical capital losses suffered by fishermen. Chilean social policy after both disasters mainly focused on the reconstruction of houses, basic services and infrastructure, instead of implementing programmes to cope with the problems of specific groups such as the artisanal communities (Sehnbruch et al., 2017). In fact, the most important initiative for recovering fishermen's labour capital was mainly funded by the private sector, rather tan governmental sources, through the programme "Back to Sea". This finding supports the need for well-targeted natural emergency planning because fishermen's work capacity is seriously affected after these kinds of disasters. Further actions might include the use of insurance to protect fishermen's labour capital or searching for strategies for fishing and harvesting in different ways especially in those communities where a greater social capital and trust in regional federations and regional fisheries authorities has been found (Marín et al., 2015; Rosas et al., 2014).

Beyond the "work and social security" dimension, the findings show that fishermen had a faster recovery in terms of the "housing" aspect compared with the non-fishermen population after both shocks. According to the post-earthquake survey (EPT) done in 2010, one of the most dramatic consequences of both disasters was the damage caused to, and the destruction of housings. In the three regions most affected by the earthquake, Libertador Bernardo OHiggins, Maule and Bio-Bio, the percentage of people affected was around 17.3% (Lawner, 2010). Further studies concluded that 17,000 houses which is 8.5% of the total in the Coastal zones were destroyed by the tsunami rather than the earthquake (Contreras and Winckler, 2013; Marín et al., 2010).

Accounting for the fact that most of the artisanal fishermen live in the coastal areas, a greater impact of both shocks was expected and especially due to the tsunami, on the "housing" dimension. However, our results indicate that fishermen experienced less impact in this dimension compared with the rest of the population. A Chilean policy focused especially on the reconstruction of households, basic services and urban infrastructure in the zones most affected by both disasters could explain this finding. Indeed, the reconstruction plan after both disasters was focused on building new houses in the most affected zones, remodeling damaged housing and restoring basic services such as health, education and road services (Gobierno de Chile, 2010). People living in the coastal zones who experienced partial or total loss of their houses were a critical target group for the emergency policy, receiving temporary houses first and then, new houses. Therefore, a quicker response in terms of housing solutions for those living in high risk zones might explain why the fishermen decreased their likelihood of being poor in the housing dimension compared with the non-fishermen population (Sehnbruch et al., 2017; Contreras and Winckler, 2013).

The findings also indicated that the fishermen and non-fishermen populations decreased their likelihood of being poor in the health dimension after both disasters in the short-term. This result might be explained by the emergency response, which was focused on quickly restoring access to healthcare services and re-building damaged health centres (Gobierno de Chile, 2010). The results are also similar in regard to how the overall population were affected by both disasters in the long-term and how the fishermen were impacted by the earthquake in the long-term. Although these results show a positive balance in the health dimension, the inclusion of psychosocial variables might show new insights and trends within the Chilean population. For example, the international literature finds a strong relationship between natural disasters and post-traumatic stress (Bromet et al., 2017; Platt et al., 2016); however mental health indicators are not included in the MPI index.

Regarding the education dimension I found no significant effects of the earthquake or tsunami on fishermen people and a higher likelihood of being poor in the short and long-term for the overall population. Such a difference within the Chilean population needs further investigation. I hypothesise that having educational attainments as a means of staying out of poverty is less relevant for the fishermen than the non-fishermen population. Some evidence shows that fishermen people have both less years of schooling than non-fishermen people and a higher school drop-out rate as result of earlier incorporation into the labour sector (Baquedano and Rosas, 2012; Chávez et al., 2010). Otherwise, considering the negative effects on the overall population, further studies might evaluate the long-term effects of natural disasters on other aspects such as students' academic performance, quality of teaching and learning and schools' strategies for coping with the lack of essential educative resources among others.

Moreover, although fishermen showed a faster recovery after the shock in terms of work and social security and housing dimension compared with non-fishermen, the results highlight that being an artisanal household consistently increases the likelihood of being poor in the four MPI dimensions beyond the occurrence of the shocks. This result is similarly to other studies that provide evidence of high social vulnerability for people working in the artisanal sector in Chile (Baquedano and Rosas, 2012; Chávez et al., 2010). I also conclude that fishermen are in a more precarious condition in terms of successfully facing unexpected natural shocks compared with the rest of the population. That evidence is in line with a negative relationship found between faster post-disaster recovery and poverty in the international literature (Sawada and Takasaki, 2017; Jha and Stanton-Geddes, 2013; Fothergill and Peek, 2004). Poor people are more likely to experience shocks as risky, die, suffer injuries, psychological trauma, having higher material losses and face more obstacles during the phases of immediate response, recovery and reconstruction.

Some explanations might be the lower living standards of poor people before the shocks' occurrence, such as living in remote and isolated areas, having houses in poor material condition, and lacking insurances, savings or personal resources to tackle the post-disaster consequences. In the light of the evidence that being artisanal increases the likelihood of being poor for all the dimensions, specific actions from governmental services should be taken to prepare them against a potential natural disaster as well as post-emergence responses and recovery because of their higher vulnerability.

Finally, some limitations in this paper are related to the lack of information available on relevant control variables such as the type and amount of public and private investments for aftershocks in specific territorial areas. Further research might collect disaggregated information in order to enhance our knowledge about the effectiveness of the post-disaster response and recovery strategies in the long-term.

Policy Guidelines

Taking into account my results, I propose some general guidelines for policies focused on the artisanal fishery sector in Chile. Beyond the occurrence of a natural disaster I found that being an artisanal fisherman increases the likelihood of being poor compared with the rest of the population. That is true for both the overall multidimensional poverty index and for each dimension involved. Due to such socio-economic vulnerability, it is expected that after a shock, fishermen people will be even more affected; therefore special attention should be paid to this group.

Some actions should also include promoting higher labour capital recovery. As shown, the most affected dimension was "work and social security" for both disasters in the short and long-term. Some actions applied in the international context include the implementation of insurances and more involvement by the artisanal organisations in the recovery policy design (Jia et al., 2018; Marín et al., 2010). The latter point would invoke higher social capital and cultural resilience in the fisheries communities, which in turn would activate their networks and skills in terms of coping with post-disaster effects (Eriksson et al., 2017; Yoshino et al., 2017). In the Chilean case the evidence shows that fishermen people are able to change their usual harvesting practices accounting for a reduced labour capital after a natural disaster (Marín et al., 2010). Policy makers should involve the fishermen people in the emergency and recovery planning, following a participative strategy in which key actors and organisations are included. Moreover, quicker economic activation in the artisanal sector might be reinforced by the existence of an exclusive governmental fund for acquiring basic materials and equipment to enable them to go back to sea.

Due to the fishermen people usually living in high risk zones, a well-established emergency response plan is needed. People must recognise safe areas, and have a good communication system that is connected despite the distance and isolation. Moreover, the preventive plan must consider a way to provide basic goods such as water, food, electricity and temporary houses, such as tents.

The recovery planning in the long-term should think about how the fisheries communities can benefit from the public and private investments and improvements made after the shock. For example, investments in labour capital might provide the opportunity for modernisation, affecting the future harvesting capacity and target species. Housing quality and connectivity could also be improved, applying more strict building parameters and re-thinking the nexus between risky zones and the urban centres nearby.

Appendices

B.1 Chilean Map

Figure 3: Chilean map by regions

Note: Regions most affected by the 2010 earthquake were between VI to VIII.

B.2 Additional Descriptive Statics

Table 15: Summary statistics by year for fishing families, dimensions and indicators.

	(1) Observations	(2) 2006	(3) 2009	(4) 2011	(5) 2013	(6) 2015
Education dimension	8,621	0.709	0.670	0.580	0.580	0.546
		(0.453)	(0.470)	(0.493)	(0.493)	(0.498)
Attendance	8,621	0.154	0.129	0.072	0.062	0.042
		(0.361)	(0.336)	(0.259)	(0.242)	(0.201)
Backwardness	8,621	0.053	0.054	0.043	0.041	0.040
		(0.224)	(0.227)	(0.203)	(0.199)	(0.197)
Schooling	8,617	0.667	0.635	0.548	0.545	0.523
		(0.471)	(0.481)	(0.497)	(0.498)	(0.499)
Health dimension	8,621	0.203	0.214	0.179	0.180	0.143
		(0.402)	(0.410)	(0.384)	(0.384)	(0.351)
Malnutrition	8,543	0.056	0.080	0.075	0.080	0.070
		(0.230)	(0.272)	(0.264)	(0.272)	(0.255)
Healthcare Security	8,585	0.146	0.094	0.078	0.086	0.054
		(0.353)	(0.292)	(0.268)	(0.281)	(0.227)
Health System Access	8,597	0.012	0.051	0.033	0.026	0.029
		(0.111)	(0.220)	(0.179)	(0.160)	(0.168)
Work and Social Security dimension	8,621	0.535	0.760	0.618	0.674	0.636
		(0.498)	(0.426)	(0.485)	(0.468)	(0.481)
Occupation	8,621	0.044	0.109	0.067	0.045	0.058
		(0.206)	(0.312)	(0.251)	(0.208)	(0.235)
Pension system	8,496	0.443	0.726	0.563	0.631	0.589
		(0.496)	(0.446)	(0.496)	(0.482)	(0.492)
Retirement	8,621	0.155	0.097	0.083	0.091	0.065
		(0.362)	(0.296)	(0.276)	(0.288)	(0.246)
Housing dimension	8,621	0.487	0.491	0.449	0.363	0.332
		(0.499)	(0.500)	(0.497)	(0.481)	(0.471)
Overcrowding	8,610	0.171	0.165	0.160	0.119	0.096
		(0.376)	(0.371)	(0.367)	(0.324)	(0.295)
Material Conditions	8,608	0.193	0.221	0.195	0.171	0.160
		(0.394)	(0.415)	(0.396)	(0.377)	(0.366)
Basic Supplies	8,615	0.298	0.281	0.229	0.187	0.189
		(0.457)	(0.449)	(0.420)	(0.390)	(0.391)

Note: Columns (2) to (6) show the mean for the respective year and standard errors are in parentheses.

Table 16: Summary statistics by year for non fishing families, dimensions and indicators.

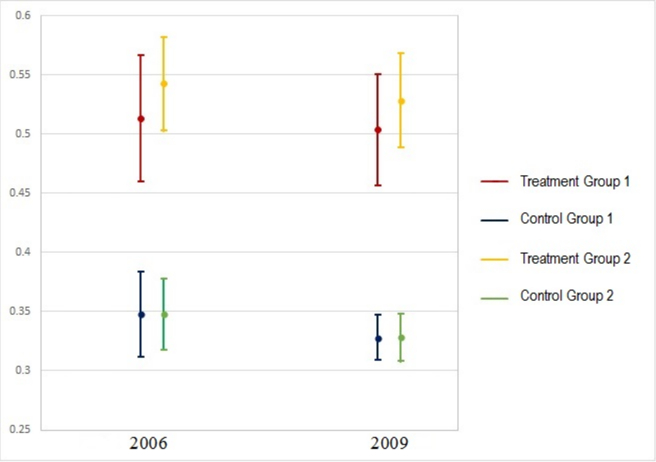
	(1) Observations	(2) 2006	(3) 2009	(4) 2011	(5) 2013	(6) 2015
Education dimension	1,191,890	0.578	0.537	0.437	0.415	0.397
		(0.493)	(0.498)	(0.496)	(0.492)	(0.489)
Attendance	1,191,890	0.103	0.081	0.055	0.046	0.037
		(0.305)	(0.272)	(0.229)	(0.209)	(0.189)
Backwardness	1,191,791	0.045	0.045	0.040	0.038	0.035
		(0.209)	(0.207)	(0.197)	(0.193)	(0.185)
Schooling	1,190,891	0.542	0.499	0.403	0.384	0.371
		(0.498)	(0.500)	(0.490)	(0.486)	(0.483)
Health dimension	1,191,886	0.185	0.195	0.190	0.176	0.176
		(0.388)	(0.396)	(0.392)	(0.381)	(0.381)
Malnutrition	1,180,404	0.053	0.064	0.074	0.073	0.072
		(0.225)	(0.246)	(0.263)	(0.260)	(0.258)
Healthcare Security	1,188,537	0.120	0.074	0.071	0.071	0.067
		(0.325)	(0.263)	(0.258)	(0.257)	(0.251)
Health System Access	1,188,711	0.022	0.073	0.057	0.046	0.049
		(0.146)	(0.260)	(0.232)	(0.209)	(0.216)
Work and Social Security dimension	1,191,890	0.464	0.544	0.493	0.471	0.487
		(0.498)	(0.498)	(0.499)	(0.499)	(0.499)
Occupation	1,191,890	0.099	0.142	0.105	0.107	0.110
		(0.299)	(0.349)	(0.307)	(0.310)	(0.314)
Pension system	1,174,040	0.272	0.405	0.360	0.338	0.362
		(0.445)	(0.490)	(0.480)	(0.473)	(0.480)
Retirement	1,191,890	0.190	0.115	0.114	0.108	0.098
		(0.392)	(0.319)	(0.317)	(0.310)	(0.298)
Housing dimension	1,191,888	0.433	0.396	0.352	0.283	0.254
		(0.495)	(0.489)	(0.477)	(0.450)	(0.435)
Overcrowding	1,191,888	0.190	0.170	0.150	0.131	0.104
		(0.392)	(0.376)	(0.357)	(0.338)	(0.306)
Material Conditions	1,191,066	0.213	0.217	0.191	0.144	0.143
		(0.409)	(0.412)	(0.393)	(0.351)	(0.350)
Basic Supplies	1,191,607	0.213	0.152	0.109	0.074	0.060
		(0.410)	(0.359)	(0.312)	(0.262)	(0.239)

Note: Columns (2) to (6) show the mean for the respective year and standard errors are in parentheses.

B.3 Difference-in-Difference

Figure B.1 shows the trends for both groups analysed, for earthquake and tsunami between the years 2006 to and 2009. They are also tested by a t-test considering a decision rule at the 5% significance level. Then, the null hypothesis that those differences are statistically different from zero is rejected, and the alternative hypothesis is accepted, i.e. that those differences are different from zero.

Figure B.1: Treatment and control group trends before shocks.



Note: MPI based CASEN 2006 and 2009. Earthquake and Tsunami 2010 are considered as an external shocks. There are two treatment groups: the first is composed by fishermen households located in the areas affected by the earthquake with at least one member working in the artisanal sector; second is composed by fishermen households located in the areas affected by the tsunami with at least one member working in the artisanal sector. Control groups include the rest of the population for each case.

Fixed effects are also added to the regressions, in the sense to control some possible deviation trends.

B.4 Heterogeneous treatment effects

A heterogeneous treatment effects is estimated according to the following equation:

$$P(Y_{ijt} = 1|x) = \beta_0 + \beta_1 Art_{ijt} + \beta_2 \widetilde{Shock}^{Y}_{jt} + \beta_3 Art_{ijt} \times \widetilde{Shock}^{Y}_{ijt}, \tag{3}$$

where,

$$\begin{aligned}\widetilde{Shock}^{Y}_{jt} &= \{ShockE^{Y}_{jt},\, ShockT^{Y}_{jt}\}\\ Y &= \{2011, 2013, 2015\}\end{aligned}$$

Table B.1 illustrates the results for the heterogeneous treatment effects using a probit model and controlling for time and region fixed effects.

Table B.1: Heterogeneous treatment effects, using different lengths for Shock.

	Earthquake		Tsunami	
	(1)	(2)	(3)	(4)
Art	0.154***	0.154***	0.152***	0.138***
	(0.006)	(0.006)	(0.006)	(0.006)
$\widetilde{Shock}^{2011}$	0.019***	0.019***	0.056***	0.056***
	(0.003)	(0.003)	(0.007)	(0.007)
$\widetilde{Shock}^{2013}$	0.013***	0.013***	0.004	0.005
	(0.003)	(0.003)	(0.006)	(0.006)
$\widetilde{Shock}^{2015}$	-0.017***	-0.017***	-0.021***	-0.030***
	(0.002)	(0.002)	(0.004)	(0.004)
$Art \times \widetilde{Shock}^{2011}$	0.026	0.026	0.054	0.061
	(0.046)	(0.046)	(0.066)	(0.066)
$Art \times \widetilde{Shock}^{2013}$	-0.015	-0.015	-0.005	-0.010
	(0.041)	(0.041)	(0.056)	(0.055)
$Art \times \widetilde{Shock}^{2015}$	-0.021	-0.021	-0.001	0.013
	(0.030)	(0.030)	(0.039)	(0.038)
N	116192	116192	116192	116192
Time FEs	yes	yes	yes	yes
Region FEs		yes		yes

Note: MPI is used as dependent variable. Standard errors in parentheses. Time fixed effects is used in all the estimations. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B.1 shows that being part of an artisanal household male someone around 15% more likely to fall into multidimensional poverty. The variable shock also has similar behaviour and is significant to the baseline estimation (table 3.3) for the years 2011 and 2013. That supports a positive and significant impact on MPI for the earthquake and tsunami shocks in 2011 and just for the earthquake in 2013. Those results are consistent with the baseline estimations. However, the interaction between the shock and belonging to a fisherman's household is not significant for any of the three variables estimated.

Chapter 4

Monitoring in Artisanal Fisheries working under the TURFs system, a theoretical approach.

4.1 Introduction

Faced with the overexploitation of fishery resources as a result of the open-access regime before the 1980s, the Chilean government has implemented some new management strategies in the search for sustainable artisanal fishery activity. In the 1980s, individual transferable quotas (ITQs) were established, giving individual rights for catching based on specific species and offering uniform regulations over large maritime areas. Later, as an alternative system to the ITQs, the territorial use rights for fisheries (TURFs) marked a shift from an individual system to an organisational regime, giving rights to manage a single, or a subset of resources in a specific marine area.

One of the main reasons for the TURFs implementation in Chile was that it had been widely shown through international experiences that TURFs systems improve the sustainability of the resources and the economic performance of those organisations working under such a regime (González et al., 2006; Cancino, 2007). Indeed, years after the TURFs implementation in Chile, there is a certain consensus about its biological and economic benefits; nevertheless other actions, such as poaching resources and illegal catching have turned out to be problematic for achieving more successful management (González et al., 2006; Gelcich et al., 2008).

Some evidence in regard to the Chilean case highlights that high levels of poaching of resources and illegal catching are putting at risk the sustainability of the resources due to overcatching (Bandin and Quinones, 2014; Gelcich et al., 2008; González et al., 2006). Therefore, the TURFs regime has lost credibility as an efficient common rights management system due to those negative actions violating the rights of those who legally extract the resources (SERNAPESCA, 2015). In fact, illegal fishery has been considered an extremely serious matter by fishing members of TURFs (Gelcich et al., 2009; Chávez et al., 2010). In some cases, organisations might be overwhelmed by the requirement to control poaching and illegal catching. Nevertheless, there is international evidence showing that promoting enforcement and compliance is highly costly for regulators in developing countries and they are not usually able to play that role effectively (Sutinen and Andersen, 1985).

On the other hand, studies focused on promoting enforcement and compliance behaviours under the TURFs system have found positive biological benefits such as greater abundance and size of resources as well as a higher diversity (Quynh et al., 2017; Gelcich et al., 2012; Samoilys et al., 2007; Jennings and Polunin, 1996). Another expected benefit is a lower monitoring cost because catching rights rest on organisational decisions instead of individual behaviours, and therefore collective action and monitoring problems are solved in a reinforcing manner (Ostrorn, 2000).

Using a theoretical approach, this paper contributes in the latter line, examining a set of scenarios to aim first, to maximise enforcement and fishermen's compliance behaviours, and second, to minimise their burden for sanctions. Evaluating the interaction of key actors in the monitoring of artisanal fishery can provide useful information for policy purposes in the sector. To do that, I examine three monitoring models involving three main actors: first, artisanal organisations who have rights to manage an assigned maritime area; second, a regulator who is a governmental institution responsible for assigning harvesting quotas to each artisanal organisation, monitoring organisations' compliance and applying sanctions; and third, fishermen who are active members of the artisanal organisation.

I evaluate three different models identify the minimum fine to induce compliance with the assigned quota among organisations and fishermen. The first model considers an exogenous monitoring model based on a static version, whereas the second is an exogenous monitoring model, but a dynamic version. The third model accounts for an endogenous monitoring model in a static version. These three models examine three scenarios: fishermen working in the artisanal organisation without a regulator; fishermen controlled by the regulator; and fishermen controlled by the organisation and the regulator. All of these models aim to define the optimum fine that should be set by the regulators to incentivize fishermen to catch the assigned quota. Testing a wide range of models, I expect to obtain more precise guidelines for monitoring decisions in the artisanal sector.

Due to the lack of knowledge about enforcement and compliance under the TURFs system in Chile, I expect to contribute novel information that can aid further policy decision making by multiple actors. The use of a theoretical approach allows me to examine several sceneries without being limited by the availability and reliability of illegal catching and poaching resources data. Nevertheless, some further empirical research is suggested as a possible extension of my work.

The results show that the extraction efforts are higher when fishermen work only with the artisanal organisation. Moreover, the regulator's fine is lower and the organisation's fine is higher when fishermen are working together with the organisation and the regulator. The case with both agents is better compared to the others because it generates higher welfare and also concerns the sustainability of the resources.

The rest of the paper is organised as follows: section 4.2 gives a literature review of theoretical studies focused on enforcement and compliance behaviours, section 4.3 explains the models developed, section 4.4 details an exogenous monitoring, section 4.5 shows cases based on exogenous monitoring extended to a dynamic version, section 4.6 covers cases based on endogenous monitoring, and in section 4.7, I compare all of the models. Finally, section 4.8 provides conclusions and some possible extensions of the work.

4.2 Literature Review

There is a certain consensus that regimes based on property rights such as individual quota (IQ), individual transferable quotas (ITQ), and territorial user rights (TURFs) provide a positive framework to deal with overcatching problems and stock collapsing (Isaksen and Richter, 2019; Costello et al., 2016; Coase, 1960). Nevertheless, it is also true that the lack of compliance behaviours and optimum normative actions for promoting enforcement are relevant matters in fisheries under those kinds of regimes (Dietz et al., 2003; Hauck, 2008). My research provides new evidence that can help tackle enforcement decisions under the TURFs system.

A review of the most relevant theoretical studies examining non-compliance and enforcement reveals that most of them are focused on fishing in general, and less are based on specific systems such as the ITQs and TURFs. In the first case, I found pioneer studies focused on the effects of illegal fishery on the catching quota defined by regulators. For example, Sutinen and Andersen (1985) developed a model under an open access system in order to contribute a more accurate quota assignation for regulators, thereby reducing enforcement costs and promoting compliance. Similar attempts were made by (Milliman, 1986) who proposed a model with legal and illegal markets to examine how the illegal catching impacts on the quota assigned by the regulators. Anderson and Lee (1986) observed how firms react to possible penalties from the regulator. Anderson (1989) compared fisheries regulations and their importance in the policy application and, finally, Charles et al. (1999) studied the responses of individual fishermen to the regulations.

All of the studies mentioned above discuss the need for balancing normative enforcement actions and fishermen's compliance behaviours. However, there are some limitations that I will address in this chapter. First, instead of a governmental authority as the unique regulator, I also evaluate the presence of artisanal organisations as fishermen's regulators. Second, whereas in the studies above the regulators define an individual quota for fishermen, I estimate a quota for the whole fishery. Such a decision makes the estimations based on just one quota easier as well as minimising enforcement costs. Third, I propose a set of models that together lead to a more efficient enforcement system because the controls are not only applied by a governmental authority, but also by the organisations for each fisherman and among fishermen. Finally, the cost function in the studies mentioned above does not account for the externalities generated by other fishermen, while my research does.

Other recent studies have highlighted the importance of accurate enforcement models for policy guidelines. For example, Kotchen and Segerson (2019) and Zhou and Segerson (2016) analysed group performance through the application of non-point source pollution problem, which was generalised to different contexts. Among these, the closest one to my paper is given by the proportional tax with an allowable group limit, where the main analysis is based on 2 agents imposing externalities outside of the group. This research builds on earlier work by Segerson (1988) on the non-point pollution problem, where the individual pollution is not observed for the regulator. In contrast to those studies, I consider that the agents impose externalities outside of the group but also on each other.

On the other hand, there are some studies based on ITQs that examine the impact of different tax systems on the assigned quota in fisheries with illegal catching (Salgado and Chávez, 2016; Costello et al., 2008; Chávez and Salgado, 2005). They search for the best tax solution to increase enforcement and reduce quota violations. However, there are some limitations due to the static vision of the violations, whereby there is no consideration that catching in the second period is impacted by the decisions taken in the first (Chávez and Salgado, 2005); or because they are based on developed countries in which the authorities properly enforce compliance (Costello et al., 2008); or because they are focused on individual decisions instead of collective ones (Chávez and Salgado, 2005).

Overcoming such limitations, my research considers a dynamic model that allows fishermen, organisations and regulators to increase their profit accounting for information from different periods of time. Moreover, I involve a richer set of options with sanctions from the regulator and organisations working simultaneously or individually, instead of only considering taxes imposed by the regulator.

Finally, only one study was found that focused on the TURFs regime and used a theoretical approach. Villena and Chávez (2005) formed a static game of norm compliance involving monitoring and penalty strategies under a regime of common property resource exploitation. They examined whether fishing communities with no tradition in co-operative management were able to achieve an appropriate level of compliance using a simultaneous game in which no regulator was included. On the contrary, I propose the inclusion of both a governmental authority and artisanal organisations as key regulator actors, whereby their decisions are sequential.

Additionally, some research, such as Casas et al. (2017) and Inoue et al. (2008), among others, explores the issue of who is monitoring the monitors. Although, those studies are applied in other contexts, they highlight the importance of monitoring the regulators due to the presence of bias favouring their own preferences. Such a point is especially relevant in accounting for the artisanal organisations as a key monitor under the TURFs system. It might be not recommended to delegate to the organisations the whole responsibility for keeping their catching below or equal to their quota assigned by the governmental authority. In this sense, I evaluate the effect of the presence of the organisation and the regulator in the compliance with the quota, by alternating between the regulator, the organisation and both of them in the structure of the game.

In the next section, I explain in detail the models developed to promote enforcement and compliance in the TURFs management.

4.3 Model

A static version of the exogenous monitoring model is analysed in the first instance. Then, it is compared with its dynamic and endogenous monitoring versions. Exploring the reasons why the regulator and organisation are necessary in the game, all of the previous models are analysed in three different scenarios. The first scenario considers the artisanal organisation setting quotas and fines for exceeding the quotas to the individual fishermen. The second scenario considers a regulator setting a quota and a fine for the whole fishery. Finally, the third scenario includes both agents, the regulator setting a quota and fine for the artisanal organisation, and the organisation setting quotas and fines for individual fishermen.

These models aim to reconcile the normative (regulator) and positive (organisation/fisherman) analysis through the right fines. Basically, the models solve the problem of poaching in the fishery with the right fines.

All cases are solved considering two fishermen i and j; and an initial stock of resources is considered as given and defined by S.

The two fishermen are identical in terms of the harvest and cost functions. The extraction for each fisherman is given by Se_i and Se_j, where S shows the level of stock (S), the extraction effort level for fishermen are presented by e_i and e_j and the total effort is given by $E = e_i + e_j$. The cost of fishing, following Espínola-Arredondo and Muñoz-Garcia (2013), is defined as:

$$c_f = c_e \frac{e_i(e_i + e_j)}{2}$$

where $c_e > 0$ is an effort cost parameter and the fraction represents the product of individual effort with the total effort. This cost function is increasing in fisherman i's own effort and in his rival's extraction effort, it can be understood as a negative externalities: when a fisherman appropriates one more unit of fish, this unit is not available to other fishermen, which increases their appropriation costs if they seek to maintain their appropriation level unaltered. Intuitively, the stock abundance decreases as fishing increases, making it harder to catch an additional unit of fish.

The fisherman without regulation faces the following maximisation problem:

$$\max_{e_i} \pi_{i,nr} = Se_i - c_e \frac{e_i(e_i + e_j)}{2} \tag{4.1}$$

Where the first term represents the revenue with the price of fish normalized to one and the second one shows the fishing cost. Therefore, differentiating with respect to

e_i, we obtain:

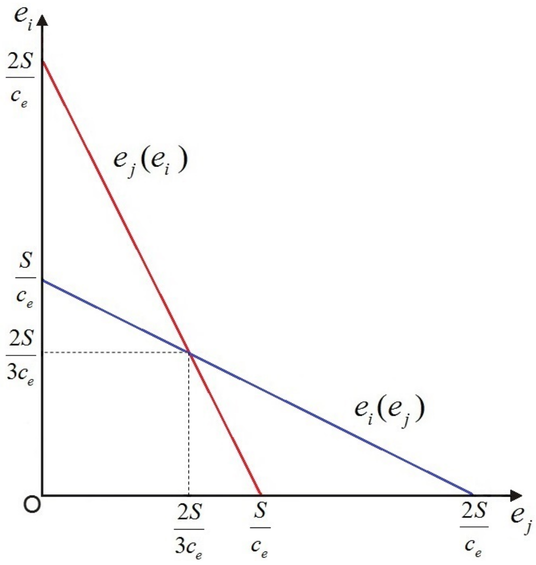
$$S - \frac{c_e}{2}(2e_i + e_j) = 0$$

From this, the reaction curve for fisherman i without regulation is:

$$e_i(e_j) = \frac{S}{c_e} - \frac{1}{2}e_j$$

In this context, the equilibrium can be depicted as the point where the two fishermen's reaction curves cross each other; as illustrated in figure 4.1.

Figure 4.1: Equilibrium effort in the case without regulation



Then, the optimal total effort without regulation is:

$$\bar{E} = \bar{e}_i + \bar{e}_j = \frac{4S}{3c_e} \tag{4.2}$$

Substituting (4.2) into (4.1), the profit in equilibrium for the fisherman without regulation is:

$$\pi^*_{i,nr} = \frac{2S^2}{9c_e} \tag{4.3}$$

In order to obtain an interior solution $E < 1$ for all of the scenarios analysed, it is assumed that the cost of effort is higher than 4/3 times the stock:

$$c_e > \frac{4S}{3} \tag{4.4}$$

The organisation and the regulator can penalise a fisherman or an organisation respectively, if they are detected extracting more than their assigned quota. In Sections 4.4 and 4.5, the probabilities of detection are given exogenously by β for the regulator and α for the organisation. Depending on the level of over-extraction detected, there are two rates of penalisation: the first one, F, is given by the regulator if the total extraction of the fishery is above the quota defined by the regulator; second, a fine f, is imposed by the organisation if a fisherman's extraction is higher than the quota defined for him. As we shall see, with exogenous monitoring the organisation and the regulator can implement their preferred level of extraction with different combinations of quotas and fines. I shall assume that they would choose the combination that minimises the burden on the fishermen.

4.4 Exogenous Monitoring, static version.

The first case analysed considers fishermen working with the artisanal organisation, with exogenous monitoring. The next case considers only the regulator and the last case includes both, the regulator and the organisation.

4.4.1 Case 1: Only organisation.

A scenario with only the organisation and fishermen is analysed, where the stages of the model are as follows:

In the first stage, the organisation decides an extraction quota for each fisherman Se_q, and fines for exceeding the quota, proportional to the violation at rate f. When the fine is imposed on one fisherman, the revenue is given to the other player.

In the second stage, each member (fisherman) chooses his own level of appropriation (Se_i and Se_j).

The model is solved by backward induction.

Second stage, Fisherman i.

Fisherman i maximises his benefits by choosing e_i according to the following equation:

$$\max_{e_i} \pi_i = Se_i - c_e \frac{e_i(e_i + e_j)}{2} - \alpha I_i f(Se_i - Se_q) + \alpha I_j f(Se_j - Se_q) \tag{4.5}$$

Where the first term represents the revenue of selling the catch Se_i (the price is normalized to 1). The second term shows the total extraction cost. The third term represents the sanction imposed if he is caught extracting more than his quota and the last term represents the sanction imposed on player j if he is caught extracting over the quota, which is given to the player i; and

$$I_i = \begin{cases} 1, \text{if } e_i > e_q \\ 0, \text{Otherwise.} \end{cases}$$

Differentiating the equation (4.5) with respect to e_i for the condition $e_i \neq e_q$, we obtain

$$c_e e_i = S - \frac{1}{2} c_e e_j - S\alpha I_i f \tag{4.6}$$

The expression above shows that the marginal cost of fishing (left hand side) is equal to the marginal benefits (right hand side).

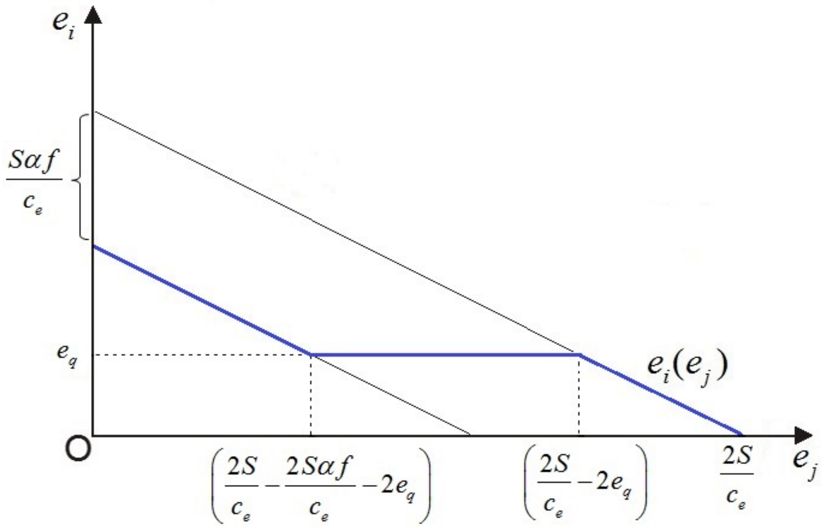
When $e_i = e_q$, the first order conditions are:

$$\underbrace{S - \frac{1}{2} c_e e_j - \alpha S f}_{MB_{I_i=1}} \leq \underbrace{c_e e_i}_{MC} \leq \underbrace{S - \frac{1}{2} c_e e_j}_{MB_{I_i=0}} \tag{4.7}$$

Where the left hand side shows the marginal benefits when the quota is exceeded; the marginal costs are given by the expression in the middle; and the right hand side shows the marginal benefits when the extraction is below the quota.

Figure 4.2 shows the reaction curve for fisherman i, when the organisation defines a quota, e_q.

Figure 4.2: Reaction curve for e_i.



In the graph above, if the extraction effort of fisherman i is below the quota e_q, he keeps the original reaction curve $e_i(e_j) = \frac{S}{c_e} - \frac{1}{2}e_j$, but when the effort is over the quota, the curve $e_i(e_j) = \frac{S}{c_e} - \frac{1}{2}e_j - \frac{\alpha S f}{c_e}$ moves down and $S\alpha f / c_e$ represents the expected fine from the organisation. In the interval $[0, \frac{2S}{c_e} - \frac{2S\alpha f}{c_e} - 2e_q)$ fisherman j's effort is low and fisherman i prefers to exceed the quota and pays the fine, $e_q < e_i \leq \frac{S - S\alpha f}{c_e}$. Then, the horizontal blue line represents when fisherman i catches exactly level of the quota, $e_i = e_q$. In the last interval $(\frac{2s}{c_e} - 2e_q, \frac{2S}{c_e}]$ fisherman j's effort is big and fisherman i's effort is below the quota, $0 \leq e_i < e_q$.

First stage, Organisation.

In stage one, the organisation induces the level of appropriation that maximises joint profits; this should be at the individual effort.

$$\max_{e_i, e_j} \pi_o = \left(Se_i - c_e \frac{e_i\,(e_i + e_j)}{2}\right) + \left(Se_j - c_e \frac{e_j\,(e_i + e_j)}{2}\right) \tag{4.8}$$

Deriving the first order conditions for the optimal e_i and e_j, which I call e_{io} and e_{jo}, representing the organisation's preferred level of effort.

$$S - c_e(e_{io} + e_{jo}) = 0 \tag{4.9}$$

The result above shows that the joint profits are determined by the joint effort, regardless of how it is distributed between the two fishermen. The first order conditions define the sum of the efforts, $E_o = e_{io} + e_{jo}$, given by:

$$E_o = \frac{S}{c_e} \tag{4.10}$$

Equation (4.10) represents the total effort preferred by the organisation, which is lower than the effort selected by the fisherman without regulation, equation (4.2), which is why the organisation needs to impose quotas.

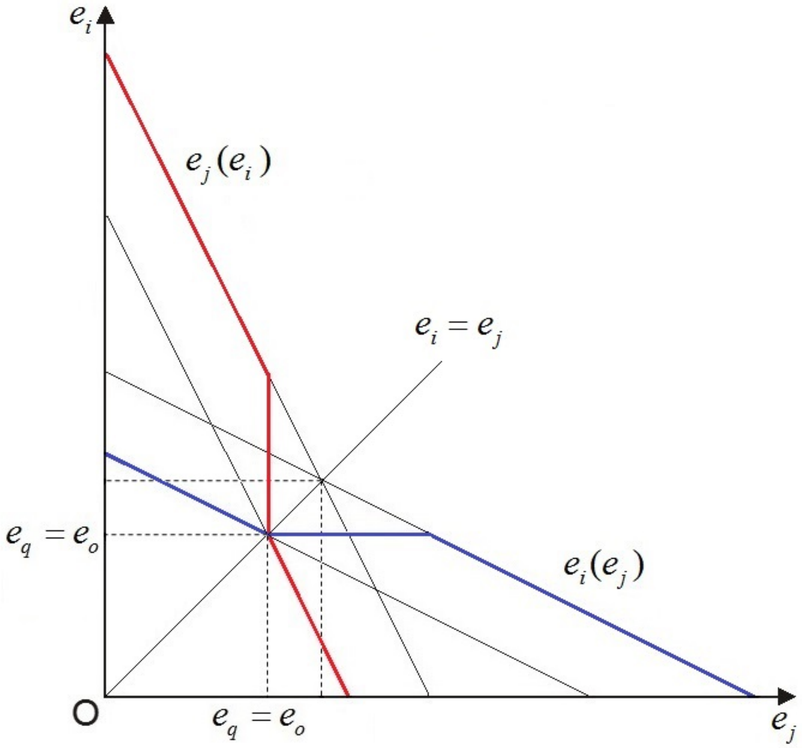
The organisation has to impose the same quota Se_q and the same fine f on each fisherman. This means that the quota has to be on the $e_i = e_j$ line in Figures 4.3 and 4.4. The organisation's preferred effort level per fisherman is then $e_o = E_o/2$, as also shown in Figures 4.3 and 4.4. There are many combinations of f and e_q that lead to the organisation's preferred effort level of $e_o = E_o/2$. However, as noted in section 4.3, the organisation can implement its preferred level of extraction with different combinations of quotas and fines, as shown in Figure 4.4. Then the organisation will minimise the burden on the fishermen, setting $e_q = e_o$ and f at the lowest level that satisfies that relationship, as shown Figure 4.3. Therefore, solving the first equation in (4.7) with equality, setting $e_j = e_i = E_o/2$, with E_o given by (4.10), yields the equilibrium fines:

$$f = \frac{1}{4\alpha} \tag{4.11}$$

The optimal fines induce each fisherman to select the optimal extraction, e_o. In addition, the fines are decreasing in the probability α that fisherman i is monitored.

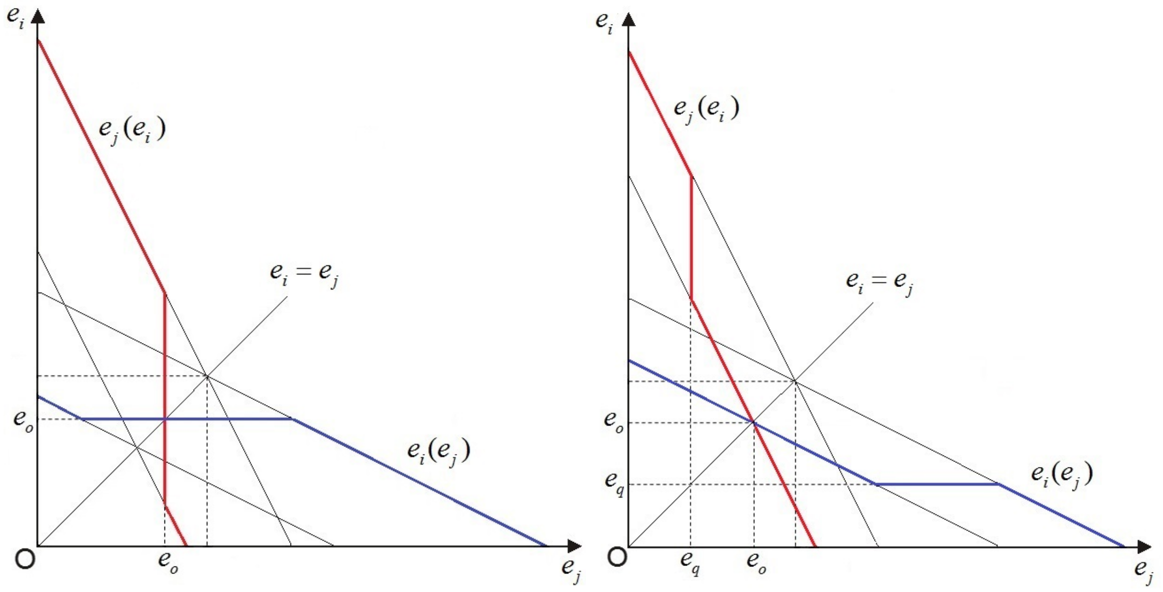
Figure 4.3 shows the reaction curves for fisherman i (blue line) and fisherman j (red line) in equilibrium.

Figure 4.3: Reaction curves for e_i and e_j in equilibrium.



In order to illustrate that there are different ways to get the quota, figure 4.4 shows the reaction curves for fisherman i (blue line) and fisherman j (red line), when the fine is higher, graph (a) and when the quota is lower, graph (b). In graph (a), the quota is still at the preferred extraction level, ($e_q = e_o$), but at a higher fine (f). The reaction curve decreases in the fine when the fisherman's effort is over the quota. In graph (b), reducing the quota from e_o to e_q the reaction curves intercept at e_o, which is higher than the quota; therefore the fisherman prefers to exceed the quota and pay the fine.

Figure 4.4: Reaction curves for fishermen i and j.



(a) For a higher fine.

(b) For a lower quota.

The analysis above is applied for all of the scenarios studied in the paper when the organisation is presented in the game. Since each fisherman's catch equals his quota and their efforts add up to the organisation's preferred total effort level (4.11), their equilibrium effort levels in Case 1 are:

$$e_i = e_j = e_q = E_o/2 = \frac{S}{2c_e} \equiv e^*_{i,1} \tag{4.12}$$

Substituting this into (4.5) and (4.8) gives the equilibrium payoffs for fishermen and organisation respectively:

$$\pi^*_{i,1} = \frac{S^2}{4c_e} \tag{4.13}$$

$$\pi^*_{o,1} = \frac{S^2}{2c_e} \tag{4.14}$$

The above results show that the equilibrium for those variables only depends on the stock, S and the cost of effort, c_e. The equilibrium for effort and profits increases in S, but decreases in c_e. This is intuitive as fishermen and organisation increase their extraction or quota as the resource becomes more abundant (higher S), but decrease them as their cost of extractions becomes higher.

4.4.2 Case 2: Only a regulator.

Case 2 analyses a scenario with only a regulator, and the stages of the model are outlined as follows:

In the first stage, the regulator sets up the quota SE_q , for the whole fishery, and a fine for exceeding the quota, proportional to the violation at rate F. If there is a fine, each fisherman needs to pay half of the fine.

In the second stage, each member (fisherman) chooses his own level of appropriation (Se_i and Se_j), which could be higher than the quota proposed by the regulator.

The model is solved by backward induction.

Second stage, Fisherman i.

Fisherman-i maximises his benefits by choosing e_i according to the following equation:

$$\max_{e_i} \pi_i = Se_i - c_e \frac{e_i(e_i + e_j)}{2} - \beta I_o \frac{F}{2} S(e_i + e_j - E_q) \tag{4.15}$$

Where the first term represents the revenue from selling the catch Se_i; the second term shows the total extraction cost; the third term represents the sanction received if the organisation is caught extracting more than its quota; and

$$I_o = \begin{cases} 1, \text{if } e_i + e_j > E_q \\ 0, \text{Otherwise.} \end{cases}$$

Differentiating the equation (4.15) with respect to e_i for the condition $e_i + e_j \neq E_q$, we obtain:

$$c_e e_i = S - \frac{1}{2} c_e e_j - \beta \frac{F}{2} S I_o$$

Where the left hand side shows the marginal cost of fishing, which is equal to the marginal benefits on the right hand side.

Then, differentiating (4.15) with respect to e_i for the condition $e_i + e_j = E_q$:

$$\underbrace{S - \frac{1}{2}c_e e_j - \beta\frac{F}{2}S}_{MB_{I_i=1}} \leq \underbrace{c_e e_i}_{MC} \leq \underbrace{S - \frac{1}{2}c_e e_j}_{MB_{I_i=0}}$$

The expression above shows the marginal benefits when the quota is exceeded on the left hand side; the marginal costs are given by the expression in the middle; and the right hand side shows the marginal benefits when the extraction is below the quota.

Figure 4.5: Reaction curves for e_i.

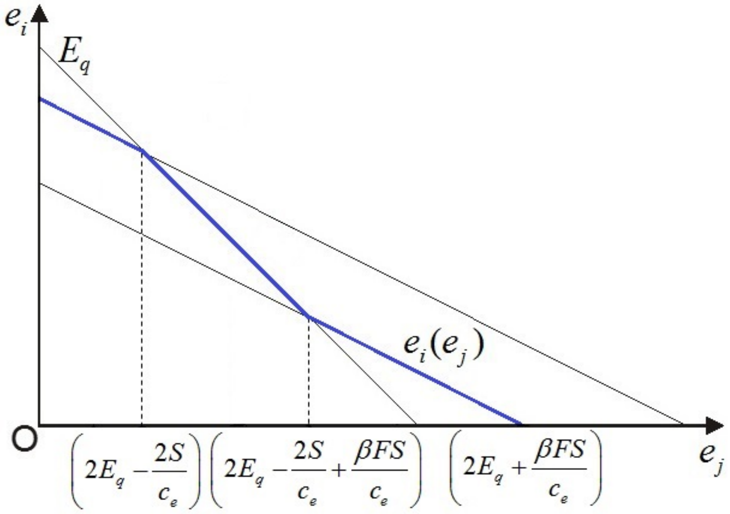


Figure 4.5 shows the reaction curves for fisherman i (blue line), when the regulator defines a quota for the whole fishery, E_q. In this case, the constraint of the quota is given by the total effort, $e_i + e_j \leq E_q$. It is a decreasing line with a slope equal to -1; therefore, all of the points in this line represent the same amount of total effort for the two fishermen. In the first interval $[0,\ 2E_q - \frac{2S}{c_e})$, the effort of fisherman j is low and fisherman i's effort is below the quota. In the second interval $[2E_q - \frac{2S}{c_e},\ 2E_q - \frac{2S}{c_e} + \frac{\beta FS}{c_e}]$, fisherman i stick to the quota. In the last interval $(2E_q - \frac{2S}{c_e} + \frac{\beta FS}{c_e},\ 2E_q + \frac{\beta FS}{c_e}]$, when fisherman j's effort is high, fisherman i prefers to exceed the quota and pays the fine.

First stage, Regulator.

Similar to case 1, the regulator seeks to induce the level of appropriation that maximises the social welfare in terms of fishery profits, gross of any fine. The regulator sees the fine as a transfer from the fishermen to the rest of society, both of whom receive equal weight in its social welfare function. Furthermore, the regulator is also concerned about future profits through the stock at the end of the period; based on Perman et al. (2011) page 566, the fish-stock growth is defined as the biological growth (Sg) less the quantity harvested (SE).

$$\max_{E} W = (SE - c_e\frac{E^2}{2}) + d[S(1+g-E)] \tag{4.16}$$

Where $d < 1$ represents the concern about future profits. I denote with E_r the regulator's preferred level of E. Thus, differentiating and solving for E_r, we obtain:

$$E_r = \frac{S(1-d)}{c_e} \tag{4.17}$$

If the above effort is compared with those found in case 1, equation (4.12), and the case without regulation, equation (4.2), it is less than them. Thus, the regulator wants to limit fishermen's efforts. In particular, the effort becomes lower when the concern about future profits increases.

Similar to case 1, the regulator will choose the combination of quota and fine that minimises the burden on the fishermen. This means that the quota has to be on the $e_i+e_j = E_r$ black line in Figure 4.6. The regulator's preferred effort level per fisherman is then $e_r = E_r/2$, as also shown in Figures 4.6 and 4.7. Therefore, the regulator sets up $E_r/2 = e_i = e_j$, which follows from the fishermen's first order conditions in equation (4.17). Thus, the fine F, which archives the regulator's preferred level of extraction, is:

$$F = \frac{1+3d}{2\beta} \tag{4.18}$$

The regulator's fine increases in d, but it decreases in β, indicating that the fine increases as the concern about future profits increases. On the other hand, the regulator's fine decreases as the probability of catching overfishing increases.

Figure 4.6 shows the reaction curves for fishermen i and j in equilibrium. The regulator sets the quota at their preferred level, $E_q = E_r$, the equilibrium quota is given at that level, $e_i = e_j = e_r$ and the fine is selected at the lower level. For the interval $[0, e_r]$ in the horizontal axes, fisherman j exceeds the quota and fisherman i sticks to the quota. In the following interval ($e_j > e_r$), fisherman i exceeds the quota and fisherman j sticks to the quota.

Figure 4.6: Reaction curves in equilibrium.

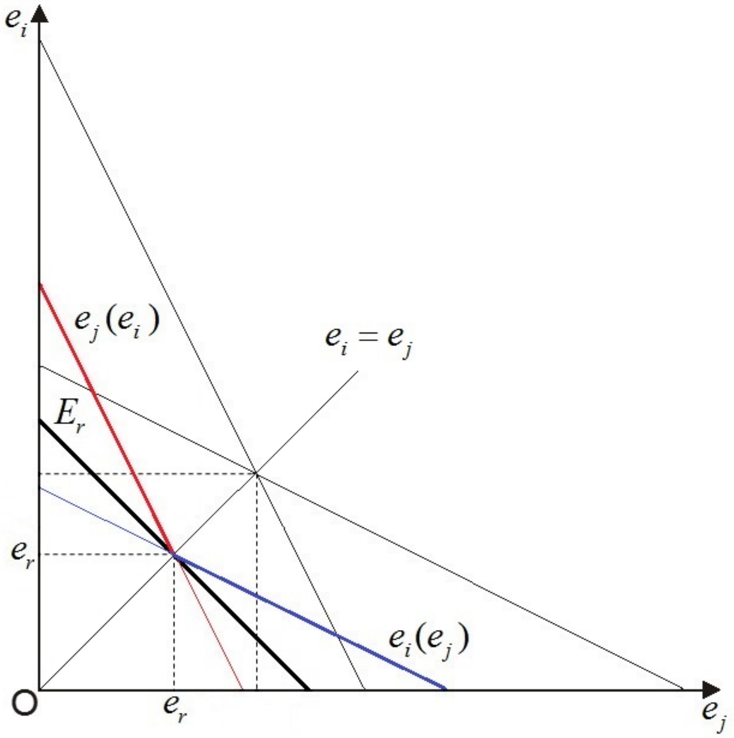
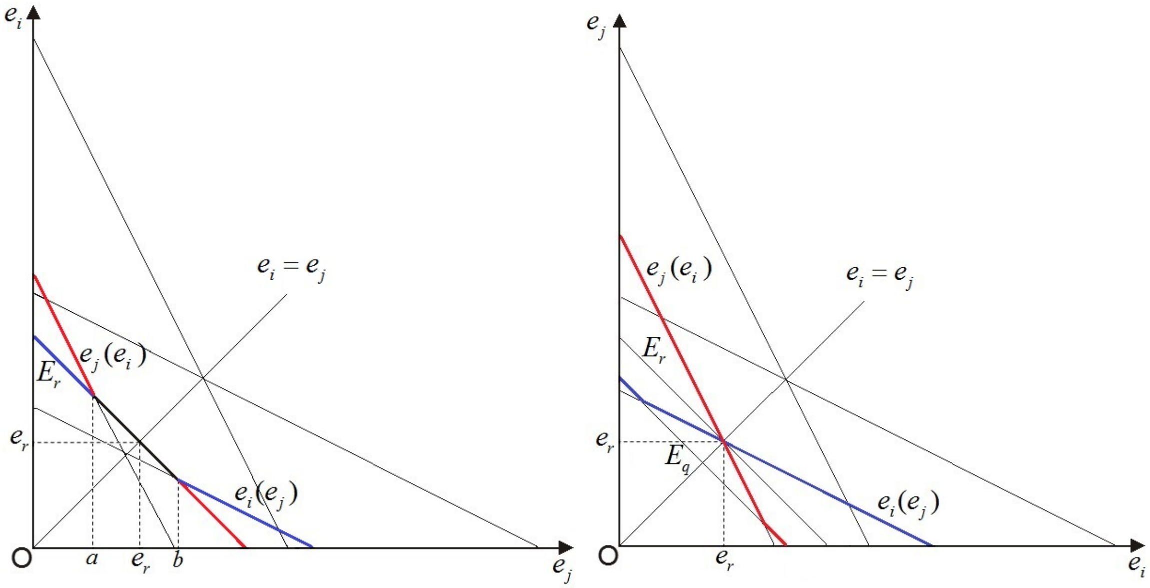


Figure 4.7 shows the reaction curves for fisherman i (blue line) and fisherman j (red line) for a higher fine, graph (a), and for a lower quota, graph (b). In graph (a), the quota is still E_r but the fine is higher, therefore, the reaction curves for fishermen i and j shift to the left. There is an overlap equilibrium region in the interval $[a, b]$. However, from the point of view of the regulator, they do not care how the effort is distributed.

In graph (b), the regulator reduces the quota from his preferred level E_r to E_q. In equilibrium both exceed the quota, but they reaches the level of effort preferred by the regulator, E_r.

Figure 4.7: Reaction curves for fishermen i and j.



(a) For a higher fine.

(b) For a lower quota.

Since the fishermen's total catch equals the regulator's quota and their total efforts add up to the regulator's preferred total effort level (4.17), their equilibrium effort levels in Case 2 are:

$$e_i = e_j = E_q/2 = E_r/2 = \frac{S(1-d)}{2c_e} \equiv e^*_{i,2} \tag{4.19}$$

Substituting this into (4.15) and (4.21) gives the equilibrium payoffs for fishermen and regulator respectively:

$$\pi^*_{i,2} = \frac{S^2(1-d^2)}{4c_e} \tag{4.20}$$

$$W^*_2 = \frac{S^2(1-d^2)}{2c_e} + d(1+g)S \tag{4.21}$$

4.4.3 Case 3: Organisation and Regulator.

This case analyses a scenario with the organisation and the regulator, where the stages of the model are as follows:

In the first stage, the regulator sets up an extraction quota SE_q, for the artisanal organisation, and a fine at rate F.

In the second stage, the organisation decides the extraction quota Se_q for each fisherman, and the fines for exceeding the quota at rate f. When a fine is imposed on one fisherman, the revenue goes to the other fisherman.

In the third stage, each member (fisherman) chooses his own level of appropriation (Se_i and Se_j).

The model is solved by backward induction.

Third stage, Fisherman i.

Fisherman-i maximises his benefits by choosing e_i according to the following equation:

$$\max_{e_i} \pi_i = Se_i - c_e \frac{e_i(e_i + e_j)}{2} - \alpha I_i f S(e_i - e_q) + \alpha I_j f S(e_j - e_q) - \phi \tag{4.22}$$

Where the first term represents the revenue from selling catch Se_i; the second term shows the total extraction cost; the third term represents the sanction received by fisherman i if he is caught extracting more than his quota; the fourth term represents the fine imposed on player j if he is caught extracting over the quota, which is given to player i; and the last term shows fisherman i's payment to the organisation to cover the expected fine that the organisation has to pay to the regulator. Fisherman i sees this payment as exogenous and independent of his effort; and

$$I_i = \begin{cases} 1, \text{if } e_i > e_q \\ 0, \text{Otherwise.} \end{cases}$$

Differentiating (4.22) with respect to e_i for the conditions $e_i \neq e_q$:

$$c_e e_i = S - \frac{1}{2} c_e e_j - \alpha I_i f S \tag{4.23}$$

Differentiating (4.22) with respect to e_i for the conditions $e_i = e_q$:

$$S - \frac{1}{2}c_e e_j - \alpha f S \leq c_e e_i \leq S - \frac{1}{2}c_e e_j \tag{4.24}$$

Note that the above first order conditions are the same as we saw in equations (4.6) and (4.7) in Case 1.

Second stage, Organisation.

The organisation induces the level of appropriation that maximises the joint profits,

$$\max_{E} \pi_o = S(E) - \frac{c_e}{2}(E)^2 - \beta I_o F S\,(E - E_q) \tag{4.25}$$

Where,

$$I_o = \begin{cases} 1, & \text{if } E > E_q \\ 0, & \text{Otherwise.} \end{cases}$$

Differentiating the equation (4.25) with respect to e_i for the condition $E \neq E_q$, we obtain:

$$c_e E = S - \beta I_o F S \tag{4.26}$$

Where the left hand side shows the marginal cost of fishing, which is equal to the marginal benefits on the right hand side. Note that for $E < Eq$, this is the same as (4.9), in Case 1. Thus, even if the regulator's quota is not binding, the organisation will want to restrict the fishermen's efforts.

Figure 4.8: Organisation's marginal costs (MC) and marginal benefits (MB), $E \neq E_q$.

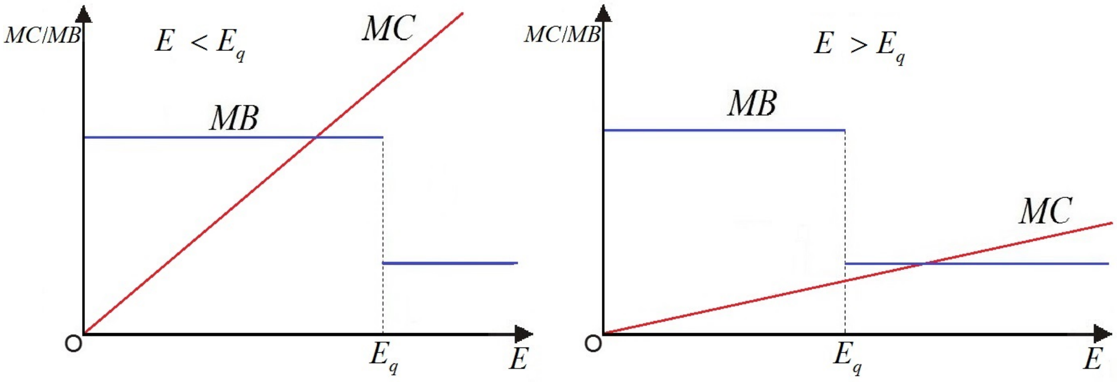


Figure 4.8 represents the scenarios of $E \neq E_q$. There are two possible options: first, $E < E_q$ (left hand side of graph), which represents an interior solution when the fisherman's effort is lower than the effort defined by the organisation; and second, $E > E_q$ (right hand side of graph), which shows a solution where the fisherman's effort is above the extraction effort defined by the organisation. The marginal benefit function has a discontinuity at E_q, due to the probability of receiving a sanction from the organisation.

Then, differentiating (4.25) with respect to e_i for the condition $E = E_q$:

$$\underbrace{S - \beta F S}_{MB_{I_o=1}} \leq \underbrace{c_e E}_{MC} \leq \underbrace{S}_{MB_{I_o=0}} \tag{4.27}$$

The expression above shows the marginal benefits when the quota is exceeded on the left hand side; the marginal costs are given by the expression in the middle; and the right hand side shows the marginal benefits when the extraction is below the quota.

Figure 4.9: Organisation's marginal costs (MC) and marginal benefits (MB), $E = E_q$.

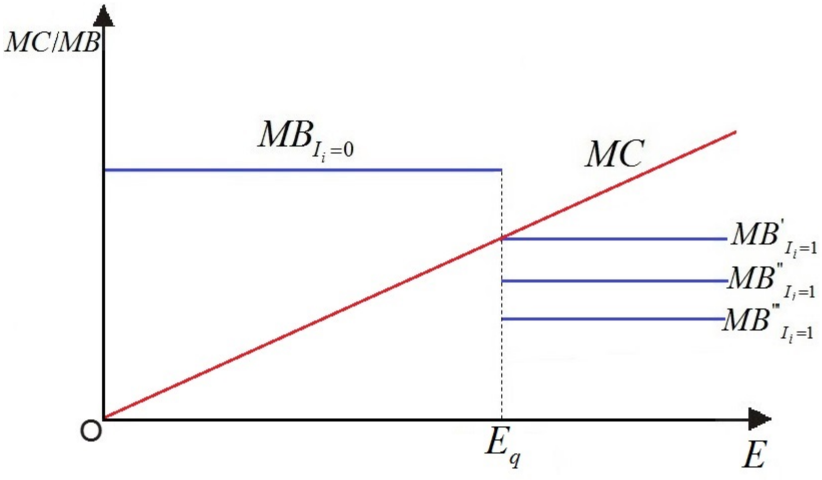


Figure 4.9 shows the curves for the marginal benefits and marginal costs according to the relation (4.7). The marginal benefits have a discontinuity as they depend on the fine (f) and the quota. Therefore, there are many combinations of f and E_q that can be selected by the organisation that lead to the same level of E, those combinations modify the level of marginal benefits when the extraction is over the quota. They are represented by the $MB_{I_i=1}$ lines on the graph.

As in Case 1, we can only solve (4.26) and (4.27) for the sum of efforts E_{oq}, that the organisation prefers. Also as in Case 1, the organisation will implement the E_{oq} by setting the quotas and the fines to minimise the burden on the fishermen. The organisation will thus set $e_q = E_{oq}/2$. Substituting $e_i = e_j = E_{oq}/2$ into the first equation of (4.27) with equality yields the fine:

$$f(E_{oq}) = \frac{1}{\alpha}\left(1 - \frac{3c_e E_{oq}}{4S}\right) \tag{4.28}$$

First stage, Regulator.

The regulator maximises social welfare through the maximisation of the joint profits and concern about future profits.

$$\max_{E_{oq}} W = (SE_{oq} - c_e \frac{E_{oq}^2}{2}) + d[S(1 + g - E_{oq})] \tag{4.29}$$

The maximisation problem above takes into account that the fishermen stick to the quotas $Se_i = Se_j = SE_{oq}/2$ set by the organisation. Then, differentiating with respect to E_{oq} and solving for the regulator's preferred joint effort level E_r:

$$E_r = \frac{S}{c_e} - \frac{dS}{c_e} \tag{4.30}$$

Note that this is the same as E_r in (4.17). The regulator's preferred effort level does not depend on whether or not there is an artisanal organisation, because the artisanal organisation can get the fishermen to select its own preferred effort level. The regulator wants the organisation to select the quota at the level they prefer, E_r, but with a combination of quota and fine that minimises the burden on the organisation. Therefore, the regulator sets $E = E_q = E_r$ in (4.30) and the first equation of (4.27) with equality to get fine F.

$$F = \frac{d}{\beta} \tag{4.31}$$

Substituting $E_{oq} = E_r$ from (4.30) into (4.28) yields the fine that the organisation imposes on the fishermen in Case 3:

$$f_3^* = \frac{1}{4\alpha} + \frac{3d}{4\alpha} \tag{4.32}$$

The regulator's fine increases in the concern about future profits and decreases in the probability of being monitored, β. In addition, this fine is lower than in Case 2, equation (4.18), this is because the fine in equation (4.31) to the organisation only has to correct for the fact that the organisation ignores future profits. Furthermore, the fine in equation (4.28) that the organisation imposes on the fishermen corrects for the externalities that they inflict upon each other. In Case 2, the regulator's fine in equation (4.18) to the fishermen has to correct for both.

Since the catches per fisherman equal their respective quotas from the organisation which add up to the regulator's quota, and the fishermen's total efforts add up to the regulator's preferred total effort level (4.30), their equilibrium effort levels in Case 3 are:

$$e_i = e_j = e_q = E_{oq}/2 = E_q/2 = E_r/2 = \frac{S(1-d)}{2c_e} \equiv e^*_{i,3} \tag{4.33}$$

Substituting this into (4.22), (4.25) and (4.29) gives the equilibrium payoffs for fishermen, organisation and regulator respectively:

$$\begin{aligned} \pi^*_{i,3} &= \pi^*_{i,2} = \frac{S^2(1-d^2)}{4c_e} && (4.34) \\ \pi^*_{o,3} &= \frac{S^2(1-d^2)}{2c_e} && (4.35) \\ W^*_3 &= W^*_2 = \frac{S^2(1-d^2)}{2c_e} + d(1+g)S && (4.36) \end{aligned}$$

4.5 Exogenous Monitoring, a dynamic version.

This section analyses the exogenous monitoring in a dynamic version context, considering two periods.

The following variables are defined: first, $X = x_i + x_j$ represents the total effort, and x_i and x_j show the fisherman's effort for the first period; second, δ_f is the fisherman discount factor and δ_r is the regulator discount factor; third, s represents the initial stock; fourth, t and T show the organisation's and the regulator's fines in period-1; and finally, the stock in the second period is represented by S, which is represented in the same way as in cases 2 and 3, which means that the fish stock growth is a function of the biological growth less the quantity harvested. That is,

$$S = s + sg - s(x_i + x_j) \tag{4.37}$$

Note that while the regulator's concern for the future was modelled by setting $d > 0$ in (4.16), in this case it will be modeled by giving the regulator a larger discount factor than the organisation and the fishermen: $0 < \delta_f < \delta_r < 1$. Thus, the results from Section 4.4 represent the solution for period two, but with $d = 0$.

I assume the following relationships to hold for the second order conditions to be satisfied:

$$c_e^2 - \delta_r s^2 > 0 \tag{4.38}$$

In order to evaluate $X = x_i + x_j > 0$ to hold, we look at the strictest case (Case 2') where the relevant condition is:

$$(1+g)\delta_r < \frac{c_e}{s} \tag{4.39}$$

On the other hand, for the first period, fisherman i internalises (4.3), which represents the solution for the second period, and maximises its profits according to the following equation:

$$\max_{x_i} \pi = s x_i - c_e \frac{x_i(x_i + x_j)}{2} + \delta_f \left[\frac{2S^2}{9c_e}\right] \tag{4.40}$$

Substituting (4.37) and differentiating (4.40) with respect to x_i, we obtain:

$$s - \frac{c_e}{2}(2x_i + x_j) - \delta_f \left[\frac{4s^2(1+g-x_i-x_j)}{9c_e}\right]$$

Then, solving simultaneously for both fishermen, we find:[1]

$$X = \frac{4s(9c_e - 4(1+g)s\delta_f)}{27c_e^2 - 16s^2\delta_f} \tag{4.41}$$

Which represents the total fishermen's effort for the case without regulation.

Therefore, to examine the conditions for the existence of an interior solution in the total fishermen's effort $X = x_i + x_j < 1$, we look at the most lenient case (without regulation), equation (4.41), which holds if

$$\delta_f > \frac{9c_e(4s - 3c_e)}{16gs^2} \tag{4.42}$$

As we saw in section 4.3, fishermen without regulation maximise the problem (4.1), which represents the second period in the dynamic version. Therefore, substituting

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[1] Note that the denominator on the RHS is positive by (4.38). The same is true for the expressions for x_i and X in (4.46), (4.49), (4.55) and (4.64).

(4.37) into (4.4), the condition for $E < 1$ is:

$$X > 1 + g - \frac{3c_e}{4s}$$

Substituting (4.41) and solving for δ_f yields:

$$\delta_f < \frac{3(4s - 3c_e)^2}{16s^2} + \frac{9}{4s} c_e \left(1 - g\right)$$

Condition (4.38) implies $c_e^2 - \delta_f s^2 > 0$. Combining this with (4.42) yields:

$$\frac{9c_e(4s - 3c_e)}{16gs^2} < \delta_f < \frac{c_e^2}{s^2}$$

A necessary condition for both inequalities to hold simultaneously is:

$$\frac{9c_e(4s - 3c_e)}{16gs^2} < \frac{c_e^2}{s^2}$$

which can be rewritten as:

$$c_e(27 + 16g) - 36s > 0 \tag{4.43}$$

4.5.1 Case 1': Only organisation.

This case follows the same game structure as case 1, but it extends to two periods.

Second stage, Fisherman i.

Fisherman i internalises the second period profits from equation (4.13) and maximises his profits accounting for two periods according to the following equation:

$$\max_{x_i} \pi_i = sx_i - c_e \frac{x_i(x_i + x_j)}{2} - \alpha I_i ts(x_i - x_q) + \alpha I_j ts(x_j - x_q) + \delta_f \left[\frac{S^2}{4c_e}\right] \tag{4.44}$$

and,

$$I_i = \begin{cases} 1, \text{ if } x_i > x_q \\ 0, \text{ Otherwise.} \end{cases}$$

Therefore, differentiating (4.44) with respect to x_i for the condition $x_i \neq x_q$, we obtain:

$$c_e x_i - \delta_f \frac{s^2 x_i}{2c_e} = s - \frac{1}{2} c_e x_j - \alpha I_i ts - \delta_f \left[\frac{s^2 (1 + g - x_j)}{2c_e} \right] \tag{4.45}$$

Similar to (4.6) in case 1, the above equation shows that the cost is equal to the marginal benefits of fishing for the first period. Moreover, equation (4.45) also includes the effect of the effort on the second-period profit, which is given on the LHS by the second term and is a function of fisherman i's effort. On the RHS, the effect is given by the last term and depends on fisherman j's effort.

The second order condition of (4.45) is given by:

$$\frac{\partial^2(\pi_i)}{\partial x_i^2} = -c_e + \delta_f \frac{s^2}{2c_e} < 0$$

The inequality above holds by (4.38). Therefore, solving (4.45) for $x_i = x_j$, accounting for $I_i = 0$, i.e. without regulation in period one, but with regulation in period two, total effort in period one is:

$$X^{0'} = \frac{2s\,(2c_e - (g+1)s\delta_f)}{3c_e^2 - 2s^2\delta_f} \tag{4.46}$$

On the one hand, the total fishermen's effort is higher than zero ($X^{0'} > 0$) if $\delta_f < \frac{2c_e}{(1+g)s}$, which holds from (4.39) since $\delta_f < \delta_r$. On the other hand, the total fishermen's effort is less than one ($X^{0'} < 1$) if $\delta_f > \frac{c_e(3c_e - 4s)}{2s^2 g}$, which holds by (4.42).

Differentiating (4.44) with respect to x_i for the condition $x_i = x_q$, we find:

$$s - \frac{1}{2} c_e x_j - \alpha ts - \delta_f \left[\frac{s^2 (1 + g - x_j)}{2c_e} \right] \leq c_e x_i - \delta_f \frac{s^2 x_i}{2c_e} \leq s - \frac{1}{2} c_e x_j - \delta_f \left[\frac{s^2 (1 + g - x_j)}{2c_e} \right] \tag{4.47}$$

The expression above shows the marginal benefits when the quota is exceeded on the left hand side; the marginal costs are given by the expression in the middle; and the right hand side shows the marginal benefits when the extraction is below the quota.

First stage, Organisation.

The organisation selects the level of appropriation that maximises the joint profits for both periods. The second period profit is according to $\pi^*_{o,1}$, equation (4.13), from case 1. Furthermore, the organisation takes the same discount factor as the fishermen in terms of the future profits.

$$\max_X \pi_o = sX - c_e \frac{X^2}{2} + \delta_f \left[\frac{S^2}{2c_e} \right] \tag{4.48}$$

Substituting the stock, (4.37), and differentiating (4.48) with respect to X, we obtain:

$$s - c_e X - \delta_f \left[\frac{s^2 (1 + g - X)}{c_e} \right] = 0$$

and, the second order condition is given by:

$$-c_e + \delta_f \frac{s^2}{c_e} < 0$$

Which holds by the inequality (4.38) and $\delta_f < \delta_r$. Then, the organisation's preferred total effort level in period one is:

$$X_o = \frac{s(c_e - s(g+1)\delta_f)}{c_e^2 - s^2 \delta_f} \tag{4.49}$$

$X_o > 0$ by (4.39) and $\delta_f < \delta_r$. We shall now see that this is lower than what fishermen do by themselves in total from (4.46), $X_o < X^{0'}$. Suppose, on the contrary, that $X_o > X^{0'}$ for some δ_f values. It is easily seen that $X_o < X^{0'}$ for $\delta_f = 0$. But can $X_o > X^{0'}$ for high enough δ_f?

Solving for δ_f from $X^{0'} = X_o$ in (4.46) and (4.49) yields:

$$\delta_f = \frac{c_e^2}{s\left[2s - (1+g)c_e\right]} \tag{4.50}$$

In order for $X_o > X^{0'}$ for some δ_f values, the RHS of (4.50) would have to be positive, which requires:

$$2s - (1+g)c_e > 0 \tag{4.51}$$

However, substituting (4.50) into (4.46) and (4.49) yields:

$$X^{0'} = X_o = \frac{2s}{c_e} > 1$$

The inequality follows from (4.51).

We conclude that $X_o < X^{0'}$ for all $X^{0'} < 1$.

As we saw before, the organisation will set the quotas equal to its preferred level and the fines as low as possible. This means, solving for the first equation of (4.47) with equality, and setting $x_i = x_j = x_q = X_o/2$:

$$s - \frac{1}{2}c_e x_j - \alpha f s - \delta_f \left[\frac{s^2(1+g-x_j)}{2c_e}\right] = c_e x_i - \delta_f \frac{s^2 x_i}{2c_e}$$

The solution is:

$$t = \frac{1}{4\alpha}\left[1 + \frac{\delta_f s\left[c_e(1+g) - s\right]}{c_e^2 - s^2\delta_f}\right] > \frac{1}{4\alpha} \tag{4.52}$$

The inequality follows from (4.41) and (4.43).

4.5.2 Case 2’: Only regulator.

This case follows the same game structure as case 2 with $d = 0$, but it extends to two periods.

Second stage, Fisherman i.

Fisherman i internalises the second period profit, equation (4.15) with $d = 0$, into his maximisation problem for the two periods, according to the following equation:

$$\max_{x_i} \pi_i = s x_i - c_e \frac{x_i(x_i+x_j)}{2} - \beta I_o \frac{T}{2} s(x_i + x_j - X_q) + \delta_f \left[\frac{S^2}{4c_e}\right] \tag{4.53}$$

and,

$$I_o = \begin{cases} 1, & \text{if } x_i + x_j > X_q \\ 0, & \text{Otherwise.} \end{cases}$$

Where δ_f represents the discount factor for fishermen and X_q shows the total effort imposed by the regulator and S is given by (4.37).

Differentiating the maximisation problem (4.53) with respect to x_i for the condition $x_i \neq x_q$, we obtain:

$$c_e x_i - \delta_f \frac{s^2 x_i}{2c_e} = s - \frac{1}{2} c_x x_j - \beta \frac{T}{2} s I_o - \delta_f \left[\frac{s^2 (1 + g - x_j)}{2c_e} \right]$$

Where the left hand side shows the marginal cost of fishing for period one, which is equal to the marginal benefits on the right hand side.

Then, differentiating (4.53) with respect to x_i for the condition $x_i = x_q$:

$$\begin{aligned} s - \frac{1}{2} c_e x_j - \beta \frac{T}{2} s - \delta_f \left[\frac{s^2 (1 + g - x_j)}{2c_e} \right] &\leq c_e x_i - \delta_f \frac{s^2 x_i}{2c_e} \\ &\leq s - \frac{1}{2} c_e x_j - \delta_f \left[\frac{s^2 (1 + g - x_j)}{2c_e} \right] \end{aligned} \tag{4.54}$$

Where the first expression shows the marginal benefits when the quota is exceeded; the expression in the middle shows the marginal costs; and the third expression represents the marginal benefits when the extraction is below the quota.

First stage, Regulator.

The regulator seeks to induce the level of appropriation that maximises the social welfare in terms of joint profits for both periods. Substituting the second period welfare (4.21) from case 2 with $d = 0$, the maximisation problem can be written as:

$$\max_X W = (sX - c_e \frac{X^2}{2}) + \delta_r \left[\frac{S^2}{2c_e} \right]$$

Substituting (4.37) and differentiating with respect to X:

$$s - c_e X - \delta_r \left[\frac{s^2(1+g-X)}{c_e} \right] = 0$$

and, the second order condition is given by:

$$-c_e + \delta_r \frac{s^2}{c_e} < 0$$

which holds by (4.38). Then, the regulator's preferred total effort is:

$$X_r = \frac{s\left(c_e - (g+1)s\delta_r\right)}{c_e^2 - s^2\delta_r} \tag{4.55}$$

Which is higher than zero by (4.39), $X_r > 0$, and; it is less than the organisation's preferred effort, (4.49), because $X_r = X_o$ for $\delta_r = \delta_f$ and X_r is decreasing in δ_r by (4.43).

In order to determine the fine, the regulator selects $X_r/2 = x_i$, which archives the regulator's preferred level of extraction and minimises the burden on the fisherman:

$$T = \frac{1}{2\beta}\left[1 + \frac{s(3\delta_r - 2\delta_f)(c_e(1+g) - s)}{c_e^2 - s^2\delta_r}\right] > \frac{1}{2\beta} \tag{4.56}$$

The inequality holds by (4.38), (4.43) and $\delta_f < \delta_r$.

4.5.3 Case 3': Organisation and regulator

This case is a two periods game, where the first part is given by the case 3 and the second period follows the same structure that games with organisation and regulator involved. A detail of the structure can be found in 4.4.3.

Third stage, Fisherman i.

Fisherman i internalises the second period profits from equation (4.34) with $d = 0$, and maximises his profits accounting for two periods according to the following equation:

$$\max_{x_i} \pi_i = sx_i - c_e \frac{x_i(x_i + x_j)}{2} - \alpha I_i ts(x_i - x_q) + \alpha I_j ts(x_j - x_q) - \psi + \delta_f \left[\frac{S^2}{4c_e}\right] \tag{4.57}$$

and

$$I_i = \begin{cases} 1, & \text{if } x_i > x_q \\ 0, & \text{Otherwise.} \end{cases}$$

Where x_i and x_j represent the fishermen's effort, s is the stock at period one and ψ represents fisherman i's payment to the organisation to cover the expected fine that the organisation has to pay to the regulator.

Therefore, substituting the stock for the second period, equation (4.37), and differentiating (4.57) with respect to x_i for the condition $x_i \neq x_q$, we obtain:

$$c_e x_i - \delta_f \frac{s^2 x_i}{2c_e} = s - \frac{1}{2} c_e x_j - \alpha t I_i s - \delta_f \left[\frac{s^2(1 + g - x_j)}{2c_e}\right]$$

Then, differentiating (4.57) with respect to x_i for the condition $x_i = x_q$, we find:

$$s - \frac{c_e x_j}{2} - \alpha ts - \delta_f \left[\frac{s^2(1 + g - x_j)}{2c_e}\right] \leq c_e x_e - \delta_f \frac{s^2 x_i}{2c_e} \leq s - \frac{c_e x_j}{2} - \delta_f \left[\frac{s^2(1 + g - x_j)}{2c_e}\right] \tag{4.58}$$

Note that the above first order conditions are the same as those in equations (4.45) and (4.47) in case 1'.

Second stage, Organisation.

The organisation induces the level of appropriation that maximises joint profits with period-2 joint profits given by (4.35) with $d = 0$.

$$\max_X \pi_o = sX - c_e \frac{X^2}{2} - \beta T s I_o \left(X - X_q\right) + \delta_f \left[\frac{S^2}{2c_e}\right] \tag{4.59}$$

and,

$$I_i = \begin{cases} 1, & \text{if } X > X_q \\ 0, & \text{Otherwise.} \end{cases}$$

Substituting the stock for the second period, equation (4.37), and differentiating (4.59) with respect to X for the condition $X \neq X_q$, we obtain:

$$c_e X - \delta_f \frac{s^2}{2c_e} X = s - \beta T s I_o - \delta_f \left[\frac{s^2\left(1+g\right)}{2c_e}\right] \tag{4.60}$$

Which represents the marginal cost equals to the marginal benefits. Then, differentiating (4.59) with respect to X for the condition $X = X_q$:

$$s - \beta T s - \delta_f \left[\frac{s^2(1+g)}{c_e}\right] \leq c_e X - \delta_f \frac{s^2}{2c_e} X \leq s - \delta_f \left[\frac{s^2(1+g)}{c_e}\right] \tag{4.61}$$

The expression above shows the marginal benefits when the quota is exceeded on the left hand side; the marginal costs are given by the expression in the middle; and the right hand side shows the marginal benefits when the extraction is below the quota.

As in case 1', we can only solve for the sum of efforts X_{oq} that the organisation prefers. The organisation will implement this X_{oq} by setting the quotas and the fines to minimize the burden on the fishermen. It will thus set $x_q = X_{oq}/2$. Substituting $x_i = x_j = X_{oq}/2$ into the first equation of (4.58) with equality yields the fine:

$$t(X_{oq}) = \frac{4c_e s - 3c_e^2 X_{oq} - 2\delta_f s^2(1+g-X_{oq})}{4c_e s\alpha} \tag{4.62}$$

First stage, Regulator.

The regulator internalises the profit for the second period from equation (4.35) with $d = 0$, and maximises the social welfare for two periods.

$$\max_{X} W = (sX - c_e \frac{X^2}{2}) + \delta_r \left[\frac{S^2}{2c_e} \right] \tag{4.63}$$

X_r denotes the regulator's preferred level of X. Thus, differentiating (4.63) and solving for X_r, we obtain:

$$X_r = \frac{s\left(c_e - (g+1)s\delta_r\right)}{c_e^2 - s^2\delta_r} \tag{4.64}$$

Then, regulator will choose the combination of quota and fine that minimises the burden to the fishermen, that is setting $X_q = X_r$. Therefore, the fine T which achieves the regulator's preferred level of extraction is:

$$T = \frac{s\left((g+1)c_e - s\right)\left(\delta_r - \delta_f\right)}{\beta\left(c_e^2 - s^2\delta_r\right)} \tag{4.65}$$

Which is positive by (4.38), (4.39) and $\delta_r > \delta_f$. Then, substituting $X_{oq} = X_r$ from (4.64) into (4.62), we find:

$$t = \frac{c_e^2 + 2s^2\left(\delta_f - 2\delta_r\right) - (g+1)sc_e\left(2\delta_f + 3\delta_r\right)}{4\alpha\left(c_e^2 - s^2\delta_r\right)} \tag{4.66}$$

Which shows the organisation's fine in equilibrium.

4.6 Endogenous Monitoring

In this section, I analyse a model with endogenous monitoring, which means that the monitoring for the artisanal organisation is carried out by its fishing members, who set their monitoring levels non-cooperatively. Monitoring by the regulator is still exogenous, with a detection probability β. Fisherman i's cost of monitoring is $c_m m_i^2$, and the probability that fisherman i detects fisherman j's violation is a function of fisherman i's monitoring effort, $P_i = m_i$.

It is assumed that the fine rate $f > 0$ for exceeding the quota is exogenous. This is because the organisation's payoff is increasing monotonically in f: the higher the fine, the less monitoring fisherman i has to do to obtain a given effort level from fisherman j.

4.6.1 Case 1": Only organisation.

This section sets out a two stage model.

In the first stage, the artisanal organisation decides an extraction quota Se_q for each fisherman.

In the second stage, each member (fisherman) chooses his own level of appropriation, Se_i and Se_j and monitoring level m_i and m_j.

Second stage, Fisherman i

Fisherman i chooses simultaneously his preferred effort and monitoring according to the following equation

$$\max_{e_i, m_i} \pi_i = Se_i - c_e \frac{e_i(e_i + e_j)}{2} + m_i I_j f S(e_j - e_q) - c_m m_i^2 - m_j I_i f S(e_i - e_q) \quad (4.67)$$

and,

$$I_i = \begin{cases} 1, & \text{if } e_i > e_q \\ 0, & \text{Otherwise.} \end{cases}$$

Similar to before, the first two terms of equation (4.67) represent the net revenues from extraction, the third term is the cost of monitoring and the last two terms indicate that if fisherman i monitors and finds fisherman j extracting above the quota then he receives the fine imposed on fisherman j; however, if fisherman i is found extracting over the quota, he needs to pay a fine.

Differentiating (4.67) with respect to m_i, we obtain:

$$c_m m_i = \frac{I_j f S \left(e_j - e_q\right)}{2} \tag{4.68}$$

Which shows that the marginal cost of monitoring is equal to the marginal benefits of monitoring. Monitoring is equal to zero, $m_i = 0$, when $I_j = 0$, this means that fisherman i does not monitor when fisherman j's extraction is below its quota. Moreover, the fisherman i's monitoring is positive if fisherman j's extraction exceeds its quota, $e_j > e_q$.

Differentiating (4.67) with respect to e_i, for $e_i \neq e_q$, we obtain:

$$c_e e_i = S - \frac{1}{2} c_e e_j - I_i f S m_j \tag{4.69}$$

Equation (4.69) shows that the marginal cost of extraction is equal to the marginal benefits of fishing.

Differentiating (4.67) with respect to e_i for the condition $e_i = e_q$, we find:

$$S - \frac{1}{2} c_e e_j - f S m_j \leq c_e e_i \leq s - \frac{1}{2} c_e e_j \tag{4.70}$$

The expression (4.70) shows the marginal benefits when the quota is exceeded on the left hand side; the marginal costs are given by the expression in the middle; and the right hand side shows the marginal benefits when the extraction is below the quota.

For a given quota e_q, there are two types of equilibria: on the one hand, if the quota is larger than the extraction without the regulation found in equation (4.2) $e_q \geq 2S/3c_e$, then the monitoring is zero $m_i = m_j = 0$ and the effort is given by $e_i = e_j = 2S/3c_e$; on the other hand, if $e_q < 2S/3c_e$, the equilibrium is given by solving (4.68) and (4.69) with $I_i = 1$ for fisherman's effort and monitoring:

$$e_i = \frac{S\left(2c_m + f^2 S e_q\right)}{3c_e c_m + f^2 S^2} \tag{4.71}$$

$$m_i = \frac{f S \left(2S - 3c_e e_q\right)}{6c_e c_m + 2f^2 S^2} \tag{4.72}$$

Fisherman's effort and monitoring depend on the e_q quota effort, which will be determined in the next stage. However, in order to examine whether $e_i > e_q$: firstly, equation (4.71) is evaluated at $e_q = 2S/3c_e$ giving $e_i = e_q$, and; secondly, the derivative of e_i with respect to e_q is calculated:

$$\frac{\partial e_i}{\partial e_q} = \frac{f^2 S^2}{3c_e c_m + f^2 S^2} < 1 \tag{4.73}$$

This implies that $e_i > e_q$ for $e_q < 2S/3c_e$. Moreover, from equation (4.72), monitoring is decreasing in e_q:

$$\frac{\partial m_i}{\partial e_q} = -\frac{3fSc_e}{6c_e c_m + 2f^2 S^2} < 0 \tag{4.74}$$

and m_i is equal to zero at $e_q = 2S/3c_e$, which implies that the monitoring effort is positive for $e_q < 2S/3c_e$.

First stage, Organisation.

In this stage, the organisation defines a quota effort e_q. If $e_q \geq 2S/3c_e$, then $m_i = m_j = 0$ and $e_i = e_j = 2S/3c_e$. On the other hand, if $e_q < 2S/3c_e$, the organisation internalises $E = e_i + e_j$, m_i and m_j given by (4.71) and (4.72) into the maximisation problem, and maximises the joint profits:

$$\max_{e_q} \pi_o = SE(e_q) - c_e \frac{E(e_q)^2}{2} - c_m(m_i(e_q)^2 + m_j(e_q)^2) \tag{4.75}$$

Since $E = e_i(e_q) + e_j(e_q)$, differentiating (4.75) with respect to e_q, the FOC is:

$$(S - c_e E)\frac{\partial E}{\partial e_q} - 2c_m\left(m_i \frac{\partial m_i}{\partial e_q} + m_j \frac{\partial m_j}{\partial e_q}\right) = 0 \tag{4.76}$$

Substituting (4.73) and (4.74) into (4.76), the effort quota can be written as:

$$e_q = \frac{2S}{3c_e}\left(\frac{6c_e c_m + 3f^2 S^2}{9c_e c_m + 4f^2 S^2}\right) \tag{4.77}$$

Which represents the quota set up by the organisation for the fisherman. It is below $2S/3c_e$, since that value is multiplied by an expression smaller than one (the denominator of the fraction is greater than the numerator) as shown in (4.77).

The Second Order Condition of (4.75) with respect to e_q is:

$$-\frac{f^2S^2c_e\left(9c_ec_m+4f^2S^2\right)}{\left(3c_ec_m+f^2S^2\right)^2}<0 \tag{4.78}$$

Showing that (4.77) is a maximum. Therefore, substituting (4.77) into (4.71) and (4.72) to obtain equilibrium effort and monitoring.

$$e_i = \frac{6Sc_ec_m+2f^2S^3}{4f^2S^2c_e+9c_e^2c_m} \tag{4.79}$$

$$m_i = \frac{fS^2}{9c_ec_m+4f^2S^2} \tag{4.80}$$

Due to the second order condition is negative (equation 4.78) and e_i (equation 4.71) is positive when it is evaluated at e_q (equation 4.77), the fishermen will exceed the quota in equilibrium. This is because the monitoring between the fishermen only works when the extraction exceeds the quota. Otherwise, the quota preferred by the organisation can only be imposed when the fine tends to infinity. That is:

$$\lim_{f\to\infty} e_i = e_q = \frac{S}{2c_e}$$

In this case, the monitoring is equal to zero and the fisherman's effort is equal to the organisation's quota. This extraction effort is the same as with exogenous monitoring (Case 1). Moreover, from equation (4.77), e_q is less than $\frac{2S}{3c_e}$, which holds for any positive parameters, meaning that the organisation prefers to set a quota effort lower than the fisherman's effort without regulation.

4.6.2 Case 2": Only regulator.

This case is the same as 4.4.2 (case 2) with exogenous monitoring, where in the absence of an organisation, fishermen are monitored and sanctioned just by the regulator. Therefore, endogenous monitoring is not applied to this case, because there is not an organisation that can generate an interaction between the monitoring and sanctioning of fishermen.

4.6.3 Case 3”: Organisation and Regulator.

This section sets up a three stage model.

In the first stage, a social planner sets up the extraction, SE_q, for the artisanal organisation, and a fine at rate F.

In the second stage, the artisanal organisation decides an extraction quota, Se_q, for each fisherman.

In the third stage, each member (fisherman) chooses his own level of appropriation, Se_i, and his own monitoring level, m_i.

Third stage, Fisherman i.

Fisherman i chooses simultaneously his preferred effort and monitoring according to the following equation

$$\max_{e_i,m_i} \pi_i = Se_i - c_e\frac{e_i(e_i+e_j)}{2} + m_i I_j fS(e_j - e_q) - c_m m_i^2 - m_j I_i fS(e_i - e_q) - \phi \tag{4.81}$$

and,

$$I_i = \begin{cases} 1, & \text{if } e_i > e_q \\ 0, & \text{Otherwise.} \end{cases}$$

Differentiating (4.81) with respect to m_i, we obtain:

$$c_m m_i = \frac{I_j fS\left(e_j - e_q\right)}{2} \tag{4.82}$$

Which shows the marginal cost of monitoring is equal to the marginal benefits of monitoring. Similar to case 1”, the monitoring is zero, $m_i = 0$, when $I_j = 0$. That means that the fisherman i does not monitor when the fisherman’s extraction j is below its quota.

Differentiating (4.81) with respect to e_i, for $e_i \neq e_q$, we obtain:

$$c_e e_i = S - \frac{1}{2} c_e e_j - I_i f S m_j$$

The equation above shows the marginal cost of extraction equals to the marginal benefits of fishing.

Then, differentiating (4.81) with respect to e_i for the condition $e_i = e_q$, we find:

$$S - \frac{1}{2} c_e e_j - f S m_j \leq c_e e_i \leq S - \frac{1}{2} c_e e_j \tag{4.83}$$

Similar to case 1", the expression above shows the relationships between marginal cost and marginal benefits when the quota is exceeded and when it does not.

The equilibrium depends on the size of the quota e_q, there are two types of equilibriums: First, if the quota is larger than the extraction without regulation $e_q \geq 2S/3c_e$, then the monitoring are zero $m_i = m_j = 0$ and the effort is given by $e_i = e_j = 2S/3c_e$; Second, if $e_q < 2S/3c_e$, the equilibrium is given by (4.71) and (4.72).

Second stage, Organisation.

The organisation internalises the extraction effort and endogenous monitoring according to equations (4.71) and (4.72) and seeks the level of appropriation that maximises joint profits.

$$\max_{e_q} \pi_o = SE - c_e \frac{E^2}{2} - c_m(m_i^2 + m_j^2) - \beta I_o F S (E - E_q) \tag{4.84}$$

and,

$$I_o = \begin{cases} 1, & \text{if } E > E_q \\ 0, & \text{Otherwise.} \end{cases}$$

Differentiating the equation (4.84) with respect to e_q for the condition $E \neq E_q$, we obtain:

$$c_e E = \frac{4S \left(c_e c_m \left(2 - 3\beta F I_o \right) + f^2 S^2 \left(1 - \beta F I_o \right) \right)}{9 c_e c_m + 4 f^2 S^2}$$

Where the left hand side shows the marginal cost of fishing, which is equals to marginal benefits on the right hand side. Thus, the relation can be rearranged to:

$$E = \frac{4S}{3c_e}\left(\frac{3f^2S^2\left(1-\beta FI_o\right)+3c_ec_m\left(2-3\beta FI_o\right)}{4f^2S^2+9c_ec_m}\right) \tag{4.85}$$

Which shows the total quota preferred by the organization for the condition $E \neq E_q$ and it is below $4S/3c_e$, since the fraction is multiplied by an expression smaller than one; even with $I_o = 0$, which is represented by (4.77). So the organisation wants to impose a quota even if the regulator's quota is not binding. Then, differentiating (4.84) with respect to e_q for the condition $E = E_q$:

$$\frac{4S\left(c_ec_m\left(2-3\beta F\right)+f^2S^2\left(1-\beta F\right)\right)}{9c_ec_m+4f^2S^2} \leq c_eE \leq \frac{4S\left(2c_ec_m+f^2S^2\right)}{9c_ec_m+4f^2S^2} \tag{4.86}$$

The expression above shows the marginal benefits when the quota is exceeded on the left hand side; the marginal costs are given by the expression in the middle; and the right hand side shows the marginal benefits when the extraction is below the quota.

Then, solving as an equality the left hand side of inequality (4.86), we find:

$$e_q = \frac{2S\left(c_ec_m(2-3\beta F)+f^2S^2(1-\beta F)\right)}{c_e\left(9c_ec_m+4f^2S^2\right)} \tag{4.87}$$

Substituting (4.87) into (4.71):

$$e_i = \frac{6Sc_ec_m+2f^2S^3(1-\beta F)}{c_e\left(9c_ec_m+4f^2S^2\right)} \tag{4.88}$$

which represents the extraction effort of fisherman i and it can be rearranged as follows:

$$e_i = e_q + \frac{2Sc_ec_m(1-3\beta F)}{c_e(9c_ec_m+4f^2S^2)} \tag{4.89}$$

Where e_i depends of F, which is determined in the following stage. Also, the fisherman i will stick to the quota when the organisation fine f tends to infinity.

First stage, Regulator.

In this stage, the regulator defines a quota E_q and a positive fine. The regulator internalises the monitoring effort, m_j and m_i, and maximises its objective function according to the following equation:

$$\max_{e_q} W = SE - c_e\frac{E^2}{2} - c_m(m_i^2 + m_j^2) + d(S + Sg - SE)$$

Differentiating and solving for e_q:

$$e_q = \frac{2(2-3d)Sc_ec_m + 2(1-d)f^2S^3}{c_e\left(9c_ec_m + 4f^2S^2\right)} \tag{4.90}$$

Thus, solving $E_r = e_i + e_j$ from (4.71), we find:

$$E_r = \frac{12Sc_ec_m + 4(1-d)f^2S^3}{c_e\left(9c_ec_m + 4f^2S^2\right)} \tag{4.91}$$

Which is the total effort extraction preferred by the regulator. Monitoring of the organisation by the regulator is still exogenous. So we have the same result as in Case 3 that there are many combinations of quota and fine that result in the regulator's desired level of total effort. The regulator will choose the combination that minimises the burden to the organisation setting $E_q = E_r$ and F to solve the first equation of (4.86) with equality for $E = E_q = E_r$:

$$F = \frac{df^2S^2 - c_ec_m}{3\beta c_ec_m + \beta f^2S^2} \tag{4.92}$$

This fine is lower than the exogenous monitoring in the case 3, equation (4.31).

Finally, from (4.92), we obtain:

$$e^*_{i,3''} = \frac{E_r}{2} = \frac{6Sc_ec_m + 2(1-d)f^2S^3}{c_e\left(9c_ec_m + 4f^2S^2\right)} \tag{4.93}$$

Which gives equilibrium expression for individual effort defined by the regulator.

4.7 A comparative analysis.

This section shows a comparative analysis between the models and the first best for each scenario (exogenous monitoring-static, exogenous monitoring dynamic and endogenous monitoring). The key variables analysed are: total extraction effort, organisation's fine, regulator's fine and profits.

In order to obtain a graphic representation of the solutions shown in the previous sections, the following parameters are used: $c_e = 10$, $g = 0.7$, $d = 0.5$, $\delta_f = 0.3$, $\delta_r = 0.7$, $c_m = 8$.

4.7.1 Total Extraction Effort.

In the case of the extraction effort, the variables in equilibrium that are used come from the following equations: (4.12), (4.19), (4.33), (4.49), (4.55) (4.64), (4.77) and (4.91). Figure 4.10 shows these graphs. For the endogenous monitoring cases 1" and 3", we set the exogenous fine f equal to the respective optimal to the first best on cases 1 and 3.

Figure 4.10: Extraction effort in equilibrium

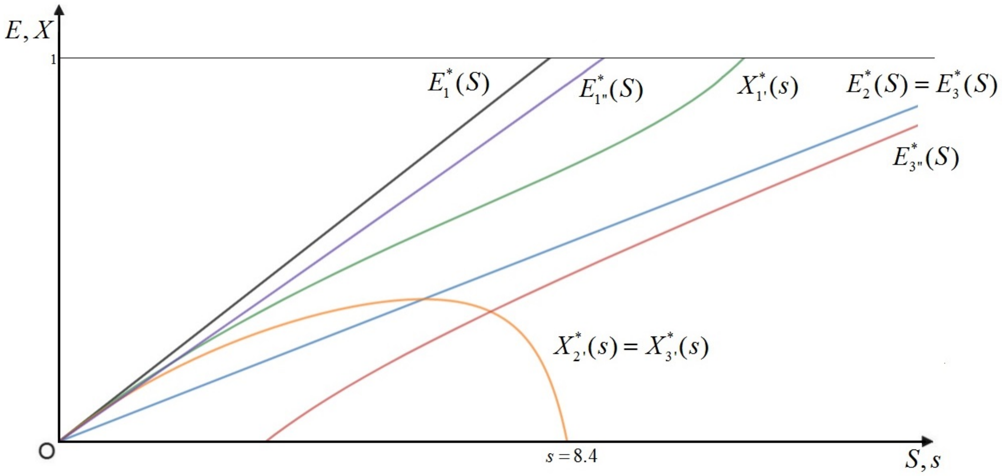


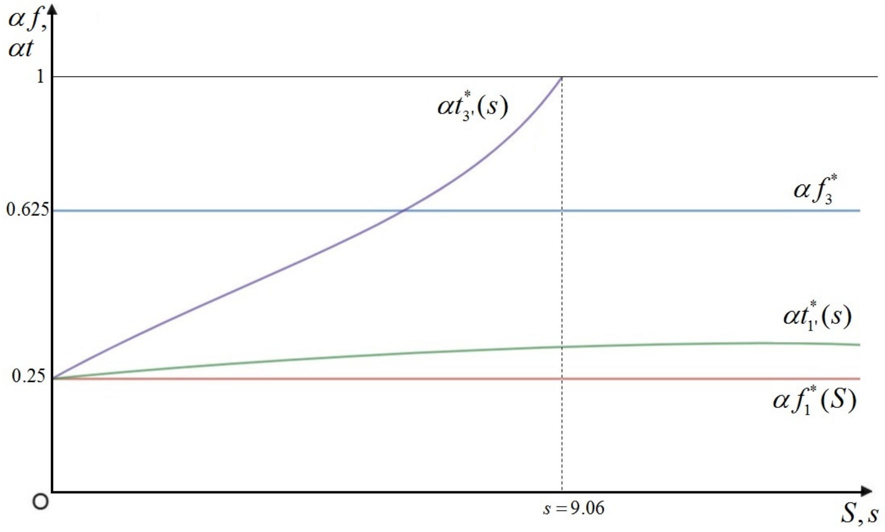
Figure 4.10 shows that the highest extraction level is given by case 1, where the fishermen interact only with the organisation. Also, when the fishermen interact only with the organisation there is a higher level of extraction in all of the models

estimated, which is shown in the graph with the following curves per model: for the first best in the exogenous monitoring case, $E^*_1(S) > E^*_2(S) = E^*_3(S)$; for the dynamic case $X^*_{1'}(s) > X^*_{2'}(s) = X^*_{3'}(s)$; and for the endogenous case $E^*_{1''}(S) > E^*_{3''}(S)$. The figure also shows that the total fishermen's effort with only the regulator (case 2 and case 2') and with the exogenous monitoring by the regulator and organisation (case 3 and case 3') are the same.

4.7.2 Organisation's fine

Another key variable is the organisation's expected fines αf and αt, which in equilibrium are given for the following equations: (4.11), (4.32), (4.52) and (4.66). Figure 4.11 shows the organisation's fines for the four cases.

Figure 4.11: Organisation's expected fines in equilibrium

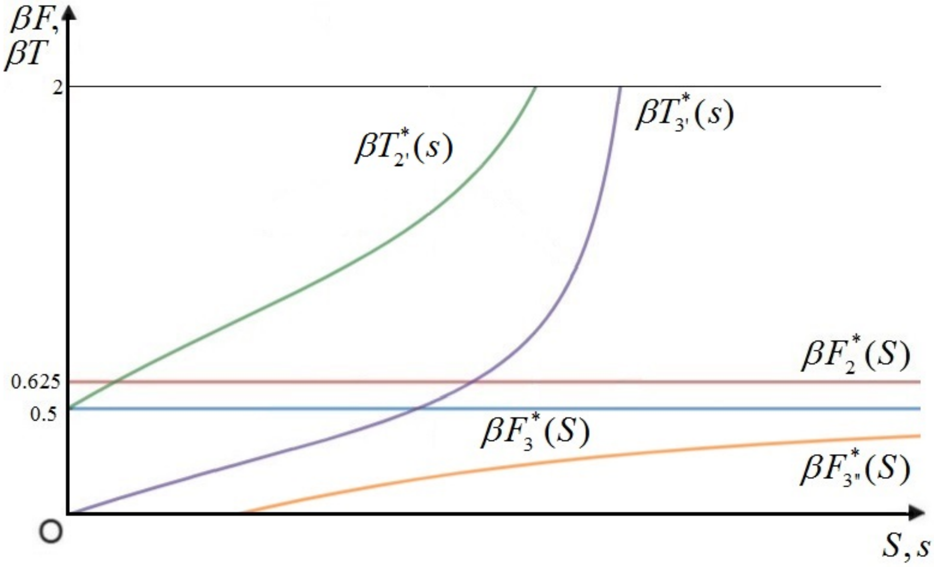


The organisation's fines are lower when the fishermen interact only with the organisation (case 1 and case 1') compared to the fisherman interacting with the organisation and the regulator (case 3 and case 3') for exogenous monitoring. Furthermore, it is interesting to note that the organisation's fine in the dynamic version is higher in period 1 than in period 2, $\alpha t^*_{1'} > \alpha f^*_1$. Nevertheless, the fine decreases when the fisherman interact with the organisation and the regulator, $\alpha f^*_3 > \alpha t^*_{3'}$, when the stock is relatively low, but this inequality is the other way around for higher levels of stock.

4.7.3 Regulator's fine

The regulator's expected fines βF and βT are given by the equations (4.18), (4.31), (4.56), (4.65) and (4.92). Figure 4.12 shows a graphical representation of those fines.

Figure 4.12: Regulator's fines in equilibrium



The cases in which the fishermen interact only with the regulator have a higher fine than the cases when the fishermen interact with the organisation and the regulator. That could be observed in the exogenous model $\beta F_2^* > \beta F_3^*$ and in the dynamic model $\beta T_{2'}^*(S) > \beta T_{3'}^*(S)$. This relationship also holds for the endogenous monitoring, where $\beta F_{2''}^* = \beta F_2^* > \beta F_{3''}^*$. In the case of the fishermen and regulator interacting, the fine is higher in the dynamic case compared to the static one, $\beta T_{2'}^* > \beta F_2^*$.

It is interesting to highlight that in the endogenous monitoring case 3", the fine $\beta F_{3''}^*$ is equal to zero for low stock level, but it tends to be constant and equal to case 3 for a high level of stock.

4.7.4 Profits

Regarding the profits in equilibrium, there are general results that hold for a combination of parameters, i.e. profits are increasing in the stock and decreasing in the cost of extraction.

In relation to the fisherman, the higher profit is given for cases 1, gives by (4.13), when they interact only with the organisation, rather than cases 2 and 3, equations (4.20) and (4.34).

4.8 Discussion and Conclusions

This paper examines how the territorial use rights for fishing might archive effective control of fishery resources. I first examine a static model in which monitoring is exogenous. Then, I extent it to a dynamic setting where fishermen interact during two periods and a context with endogenous monitoring. Finally in order to study the role of the artisanal organisation and the regulator, I examine three different cases in which fishermen interact: (1) only with the artisanal organisation, (2) only with the regulator, and (3) with both agents, the artisanal organisation and the regulator.

The findings show that normative and positive exercises can be reconciled through fines. As long as the fines are set appropriately for each case, they can reconcile normative and positive exercises, reaching the first best. However, in the case of endogenous monitoring, the equilibrium works when the extraction effort exceeds the quota, otherwise the fine to induce compliance will tend to infinity. I also found that such reconciliation solves the problem of over-catching, because the fines disincentivise catching over the quotas.

The results show that the organisation and the social planner can reach the first best effort levels by setting fines f/t and F/T respectively, which are a ratio of the exceeded quota. Therefore, there are many combinations for both agents, the organisation and the regulator, in terms of fines and quotas that lead to their preferred efforts, as it appears on graphs 4.8 and 4.9. Subsequently, organisations and regulator will minimise the burden on the fishermen by choosing fines at the lowest level that satisfies the relationship for the quota preferred.

The reaction curves indicate that the extraction effort of fisherman i and j are strategic substitutes, indicating that if fisherman j increases his captures, then the effort of fisherman i will be lower. In addition, an abundant resource increases fisherman i's effort, but a high extraction cost c_e reduces it.

Regarding the extraction effort, the higher level is given by the extraction without regulation. That level is higher than the level preferred by the regulator and the organisation. This is the classical common pool problem (Hardin, 1968; Ostrorn, 2000). Moreover, the extraction effort is lower in the cases where the regulator is involved because the regulator cares about future profits and therefore define a more strict quota. On the other hand, the extraction effort is the same for the cases in which the fishermen are only with the regulator or with the regulator and the organisation. That might be because the final extraction effort (final stage) is defined by the regulator in both scenarios.

Otherwise, the organisation's fine f/t is lower when the fishermen interact with both agents (case 3 and case 3'), because in case 2 and case 2", the organisation only has to correct for the fact that they ignore future profits, whereas in cases 3 and 3", the organisation corrects for ignoring future profits and also for the externalities that fishermen inflict upon each other.

The findings also indicate that the regulator's fine (F/T) is larger in the cases when the fishermen interact with only the regulator, because the regulator has to correct for all of externalities by itself, whereas when the organisation is involved, the cost of correcting the externalities is distributed between both sanctions.

It is interesting to note that when the fishermen interact only with the regulator (case 2) is similar to the non-point source pollution (Segerson, 1988). The results show that it is feasible to regulate non-point source effort extraction in an efficient way, although no information about individual's level of effort is available.

The original design of the TURFs system considered that the organisation could manage all of the issues related to the area, including quotas and fines, among others. This is an ideal scenario for the regulator, because enforcement is costly. However, in practice organisations share the management with the regulator in terms of an environmentally friendly quota (sustainable) and the regulator enforcement the whole fishery instead by each fisherman. Therefore, faced with the question of what is the preferable role for the artisan organization and the regulator, the results suggest that the organisation should choose a quota and fine that are optimal for them (joint profits), but the regulator should also plays a prominent role in the sustainability of resources. Therefore, the presence of the regulator and the organisation makes it easier to reach the first best.

Extensions

It would be interesting to complement the conceptual analysis of this paper with empirical work. While it is difficult to obtain empirical data, experimental economics can be a useful tool for studying human behaviour in a controlled laboratory setting or in the field. This methodology could test the theoretical models developed in this paper.

The only non-compliance behaviour explored here is when the quota is exceeded by the organisation's members. However, another important enforcement problem in the artisanal fisheries is the poaching of resources from non-members of the organisation. In that sense, it might be interesting to analyse the case in which artisanal organisations can apply sanctions to members the other organisations when they are caught stealing resources.

Time constraint, endogenous monitoring is analysed as a costly action in terms of income, but it could also be costly in terms of time. Therefore, with this new constraint, fishermen have to distribute their time between fishing and monitoring activities.

Asymmetric information: The artisanal organisation probably knows more about local conditions and fishermen (e.g. their cost of effort) than the regulator. This gives the artisanal organisation an advantage, which can be balanced against its more short-run and localized outlook.

Finally, endogensing the organisation's discount rate. Putting the organisation in charge biases the outlook toward the short term, because the organisation might lose its licence in the future. However, the regulator needs to keep this threat to discipline the organisation.

Chapter 5

Conclusions

This thesis is composed of three research chapters, all of which focused on the artisanal fishery sector in Chile. I paid special attention to the TURFs regime, a management system that grants territorial common rights to artisanal organisations to harvest in a maritime area. More specifically I covered two relevant matters in the TURFs management. On the one hand, I estimated optimal harvesting decisions accounting for a dynamic context instead of the current static approach used by experts and policy makers in Chile. On the other hand, to tackle the high level of poaching and illegal harvesting under the TURFs regime, I proposed a theoretical model that looks at better monitoring. Moreover and beyond the TURFs management, I reviewed the link between multidimensional poverty and natural disasters. I examined the differences between the fishermen and non-fishermen populations due to greater socioeconomic vulnerability, as reported in previous studies for the first group. A summary of each chapter emphasising the main results and further research lines follows.

Chapter 2 examined the determinants of the harvesting decisions made by artisanal organisations working under the territorial use rights fishery (TURFs) in Chile. I firstly proposed a theoretical model through which the organisations decide their harvesting periods and quotas. I worked under the assumption that fishermen harvest less than the official approved quota, in order to have higher stocks and quotas in the future. I also presumed that organisations make harvesting decisions, accounting for information from different periods of time, with a view to maximising their pay-offs. I contributed with a dynamic model instead of the current one-period approach used for estimating the assigned quotas. In a second time , the four predictions supported by the theoretical model were empirically examined.

The findings show that three out of the four predictions were supported by the data. First, the organisations' harvesting is positively impacted by a higher governmental approved quota. In fact, this is the strongest effect supported across all of the estimations, suggesting that organisations successfully manage their harvest up to the maximum assigned quota. Second, increases in the resource stock have a positive effect on harvesting. In this sense, organisations might choose an interior solution of harvesting lesser than the quota, in order to increase their stock in the next period and, therefore, the harvest. As a result, they maximise their revenues in future harvest periods, assuming that the stock will increase. Similarly, the third prediction examining a positive impact of a higher catchability on harvest was also empirically supported. Finally and contrary to the expected, increases in the loco's price showed a negative impact on harvest, even controlling for competition grade. Further research to clarify the negative impact of the loco's price on harvest should examine how local prices are impacted by some organisations' practices, such as cooperation among fishermen's collectives and previous agreements with buyers.

This chapter's strength is the use of a theoretical model empirically tested, however, some limitations need to be addressed in further research. On one hand, the theoretical model does not account that those harvesting decisions made by one organisation are influenced by others, such us similar organisations, buyers and regulators. Future studies might estimate changes in the organisational harvesting decisions into a wider context. For another hand, the empirical estimations of the theoretical model assume that the approved quota affects the harvest in the quota was assumed to affect the harvest in the same way at any level of harvest. However, the data analysed shows that the quota often constrains the harvest. Further research could include a methodology to estimate the unconstrained harvest. Then, if the harvest exceeds the quota, the harvest needs to be reduced to (just below) the quota.

The results also highlight the importance of examining harvesting decisions involving multiple variables related to the TURFs management. There are several aspects related to the organisational structure which are not involved in this chapter. For example, harvesting decisions might be influenced by the leadership styles (authoritative, democratic, strategic, bureaucratic, etc.) and personal backgrounds (sex, age, educational attainments, etc.). Later studies should introduce such control variables. Moreover, there is evidence supporting a strong importance of the social capital in common rights contexts. Future studies might evaluate the relationship between harvesting decisions monitoring and social capital. For instance, including the cooperation with other similar artisanal organisations and networks between artisanal organisations and strategic actors such as buyers, trading companies, industrial fishery's companies, governmental regulators and non-governmental institutions. Accounting for the context in which the TURFs operate, some geographical and socio-economic characteristics should be included in next studies. For example, territorial settings such as connectivity with greater urban areas, fishery infrastructure, transport services and communication systems might impact on the harvesting decisions made.

In Chapter 3 I estimated the impact of the earthquake that occurred in Chile on 27th February 2010 and the later tsunami on households' multidimensional poverty, emphasising short and long-term differences between the overall population and those working in artisanal fishery. I proposed a difference-in-difference methodology to estimate the effect of the earthquake and the tsunami on multidimensional poverty for two population groups: fishermen-households located in the areas affected by the shocks with at least one member working in the artisanal sector, and the rest of the population. The hypotheses examined through this chapter were: First, both the fishermen and non-fishermen populations increased their likelihood of falling into multidimensional poverty after both shocks, but fishermen were hit harder because of the tsunami. Second, fishermen were mostly affected in terms of the housing and work and social security dimensions as an effect of the tsunami rather than the earthquake. Third, the overall population as well as the fishermen group were more likely to be poorer a year after the disasters compared with three years later. Finally, fishermen were more likely to be poor in terms of work and social security and housing in the short-term and lower but significant to the long-term . As expected, fishermen were hit harder than the rest of the population in terms of the work and social security dimension after both disasters, but especially as a result of the tsunami; nevertheless their of being poor in terms of housing in the short and long-term decreased. Interestingly, no significant effects linking MPI and natural disasters for fishermen were found, which reinforces the relevance of going beyond aggregated analysis.

The findings show that the dimension of fishermen's lives that was most affected after both shocks was work and social security; therefore emergency and recovery planning should be strongly focused on this dimension in order to face future disasters more successfully. In addition, faster recovery in the housing dimension in the short and long-term compared with the non-fishermen population suggests a well-targeted policy for those localities most affected. The findings also show that after both disasters fishermen and no-fishermen population decrease their likelihood of being poor in "health" in the short and long-term, controlling for territorial and time effects, whereas only the overall population show to be more likely to fall into educational poverty after both disasters in the short and long-term.

Taking into consideration those results, some limitations of this chapter should be addressed in further research. First, even though the estimations are controlled by territorial and time effects, other controls are necessaries for more precise insights involving socio-economic and demographic territorial settings such as localities' poverty rate, access to healthcare and educational services, population density and urbanisation among others.

Moreover, further research should analyse the impact of those public and private investments made after post-disasters in the short and long-term. Therefore the effectiveness of the post-disasters responses and recovery strategies might be evaluated and improved in case of future shocks. In the Chilean case such information is disaggregated and no systematic, then additional efforts are required for preparing data. Research in this line certainly contribute for thinking on better strategies for coping with future shocks in the short term, but also promote the development of localities based on a long-term recovery programme.

Another limitation is the absence of a fifth poverty dimension called "networks and social cohesion" which was added to the Chilean MPI from 2015 onwards. Such dimension introduces the importance of social support networks, social participation, equity and security as key aspects for understanding poverty. Unfortunately, such relevant could not be added to the present research due to the lack of information for measuring that dimension in the target periods. It is highly recommended that future studies include capital social into poverty studies, especially when small communities and organisations based on common rights systems are involved.

Finally, the findings for the dimensions "health" and "education" support some new lines of research. I found a positive balance for the health dimension, however, the inclusion of psychosocial variables could show new insights and trends within the Chilean population. Such thing is especially relevant in the relationship natural disasters and post-traumatic stress or financial strain feelings which might negatively impact on people's health. For another hand, I found no significant effects of the earthquake or tsunami on fishermen people and a higher likelihood of being poor in the short and long-term for the overall population. Such a difference within the Chilean population needs further investigation. Future studies might detect socio-cultural differences explaining why the educational attainments are less valued as means of staying out of poverty by fishermen compared with the rest of the population.

Chapter 4 examined several scenarios in which normative actions by regulators and positive behaviours by fishermen can be reconciled through fines to deal with the overcatching problem in the TURFs management. Using a theoretical approach, I proposed three monitoring models to maximise enforcement and positive harvesting behaviours, but minimise organisations' burden in terms of sanctions. The first exogenous and static model considers fishermen working in the artisanal organisation without the regulator. The second exogenous and dynamic model involves fishermen controlled by the regulator and fishermen, and the third endogenous and static model accounts for the organisation and the regulator.

The findings show that the extraction efforts are higher when fishermen work only with the artisanal organisation. Moreover, the regulator's fine is lower and the organisation's fine is higher when fishermen are working together with the organisation and the regulator. The case with both agents is better compared to the others because it generates higher welfare and also deals with concerns about the sustainability of the resources.

Contrasting with the first chapter, this study is entirely theoretical. The main limitation for addressing an empirical estimation is the lack of information about poaching resources and illegal harvesting. Coping with such limitation, the experimental economics appears as a useful tool for studying human behaviour in a controlled laboratory setting or in the field. Further studies could evaluate other sceneries in which artisanal organisations apply sanctions to non- members when they are caught stealing resources or the existence of higher sanctions for non-compliance supported for organisations politically representative to fishermen.

Other studies might also evaluate other constraints such as the time assigned for monitoring and harvesting as well as asymmetric information between relevant actors in the fishery context.

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