The Dynamic Preferences and Incentives of Natural Resource Users

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Preface

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Introduction

Managing the world's natural resources in a sustainable manner is one of humanities major challenges going forward (Duarte et al., 2020). Many natural resources are currently overexploited (FAO, 2020; Butchart et al., 2010) and climate change has the potential to fundamentally change resource systems (Folke et al., 2004). Not only are natural resources profoundly influenced by human activity, the individuals and communities dependent on them are in many ways shaped by the natural resource they harvest. So much so, that natural resources are often considered components of a social-ecological system (SES), that encompass the resource, the governance system and the resource users.[1]

Ideally, the governance system designings and implements enforceable polices that balance social, economic and environmental objectives. This is a complex task and due to the immense heterogeneity of natural resources and resource users, resource managers are not able to rely on one-size-fits-all solutions (Ostrom et al., 2007). Nevertheless, a guiding concept for harvesting policies is that aligning the incentives of the resource users with sustainable harvesting behaviour can improve economic and environmental outcomes (Costello et al., 2010; Isaksen and Richter, 2019). In order to design policies that align incentives with sustainable behaviour we need to know what the incentives and preferences are of the affected resource users.[2]

The underlying theme of this dissertation is that the preferences and incentives that underlay the behaviour of the resource users are dynamic and will change based on the other components of the social-ecological system. The first two papers in this dissertation deal with incentives and how these change based on the characteristics of the resource, such as its natural variability, and the manner in which the resource is governed. The third and fourth paper are concerned with the underlying economic preferences of the resource users, and how these can change over time and are perhaps shaped by the natural resource.

The majority of the projects in this dissertation build on data gathered through a series of 6 field surveys conducted with small-scale fishers in Chile, Norway and Tanzania. This set of countries features fisheries in all stages of development, ranging from artisinal open-access

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[1] Social-ecological system is a widely used term with several related definitions (Colding and Barthel, 2019). This dissertation mostly follows the framework as described in Ostrom (2009).

[2] The standard assumption in economics is that when making a decision individuals try to maximize their utility based on (dis)incentives, preferences and constraints. Here, incentives are all consequences that add positive utility to an action, and therefore motive someone to act this way. An incentive can be material gain, but the well-being of others or an increase in social status can also be incentives to act. Conversely, disincentives add negative utility and are a reason not to act a certain way, take for example, the chance of receiving a fine for speeding. The same incentive can have a different value to two people, due to them differing in their by preferences. Preferences are an internal characteristic of an individual that evaluate a particular incentive; some individuals are more averse to risk, and some particularly value the well-being of others. Therefore, individuals that are asked to make the same choice, with options offering the same incentives, can still make a different decision based on their preferences.

fisheries, to industrialized fisheries with well defined property rights. During the field surveys, incentivized lab-in-the-field experiments are used to measure the economic preferences of the fishers. Aside from standard measures for risk preference and social preference, a relatively recent development in experimental economics is used to measure prudence for one of the first times outside of a university lab. Prudence is a higher-order risk preference, which is related to the motive for precautionary savings and implies an aversion to down-side risk.[3] A further methodological contribution is that the data from the field surveys is supplemented with analysis of official fisheries landings data. This analysis is used to estimate the participants' exposure to natural resource variability and to what extent their harvest is limited by restrictive regulations. This allows us to differentiate between groups of fishers and determine how these characteristic influence preferences and incentives.

The importance of incentives has long been recognized in natural resource economics in the form of the 'Tragedy of the Commons' (Hardin, 1968). The premise of which is that a rational resource user will attempt to maximize his own gain, but doing so will be at the detriment of others and the commons.[4] To take fisheries as an example, an individual fisher has an incentive to harvest more, as each harvested fish increases his marginal earnings by the worth of one fish. However, the fish that is removed from the water will no longer grow and reproduce, meaning that in future the resource stock will be smaller. The incurred cost on the fisher will only be a fraction of the worth of one fish. However, all other fishers also incur the cost, but receive none of the gain. Therefore, each individual fisher has an incentive to harvest more than what is socially optimal and in time the resource will be overexploited at the detriment of all fishers.

In order to protect the natural resource from overexploitation it is often necessary to implement restrictions on harvesting. The restrictions however can create unintended incentives that are damaging to the resource users or the resource itself. Take for example, total allowable catch quotas (TAC) in fisheries. TACs are generally introduced with the intention of limiting overexploitation by putting an upper bound on the collective amount of fish that can be harvested in a fishing season. Under a TAC, fishers are prohibit from landing fish after the quota has been filled. Therefore fishers have an incentive to land as much as possible before the quota is filled by others and claim a larger share of the overall quota for themselves. In particular for high value species, a TAC can create a competition between fishers to land fish as quickly as possible. This 'race to fish' can compress the fishing season to several days or even hours in extreme cases (IPCH, 1991). This unintended incentive to harvest quickly can create health risks (Pfeiffer and Gratz, 2016), economic inefficiencies (Birkenbach et al., 2017) and environmental damages (Grafton et al., 2005).

An increasingly used tool in resource management, catch shares, utilizes the concept of aligning incentives with sustainable behaviour by granting fishers or groups exclusive rights to a share of the total quota.[5] Because fishers are guaranteed their share of the quota the incentive to harvest quickly is reduced (Birkenbach et al., 2017) and fishers are incentivized to fill

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[3] Precautionary savings is the term for savings motivated by uncertainty about future income. (Lugilde et al., 2018)

[4] The commons refers to shared resources that are neither privatized nor subject to government regulation.

[5] Here catch shares is used as a broad term which encompasses both tradeable and non-tradeable, individual fishing quotas and collective catch shares.

their share efficiently.[6] The exclusive rights also strengthen the fishers' incentive for protecting the long term health of the resource stock, as they are guaranteed to benefit from it. Whilst catch shares are a promising tool that can align incentives with sustainable behaviour, they are not always suitable or available. Catch shares require the ability to enforce property rights and the administrative burden is relatively high, which can be a barrier to implementation in developing countries (Jardine and Sanchirico, 2012; Copeland and Taylor, 2009). Regardless, aligning resource users incentives with sustainable behaviour is a valuable concept for harvesting policies.

Hardin (1968) predicted that without privatization or formal regulation the commons are doomed, however this view is now considered to be too narrow, and only accurate under a specific set of assumption (Ostrom, 2009). Resource users have incentives aside from short-term income maximization, which can motivate them to voluntarily restrict harvesting rates. For example resource users might restrain their harvesting rates because they value the well-being of other resource users or the stable income which can be derived from harvesting the resource in a sustainable manner. There exists a host of examples of common-pool resources which are successfully regulated by communities of resource users in the absence of formal regulations.[7] In these cases of community governance, the resource users have created a structure of rules and norms to regulate a shared resource. Communities can enforce their rules through several mechanisms, such as peer punishment (Sethi and Somanathan, 1996; Rustagi et al., 2010), conditional cooperation (Vollan and Ostrom, 2010; Richter and Grasman, 2013) and ostracism of non-compliers (Tavoni et al., 2012). An important contribution factor to the success of these community governance structures is that the rules are tailored to the preferences and needs of the resource users instead of being imposed by an external regulator (Cox et al., 2010).

Community governance systems are particularly valuable when formal harvesting regulations are infeasible. However these systems can be fragile when individuals are in a position to exploit the cooperative efforts of others (Richter et al., 2013; Berkes et al., 2006) and when the incentives to overexploit the resource are particularly strong (Schaap and Richter, 2019). A key determinant for both these threats is the harvesting capacity of the resource users (Hilborn et al., 2003). Simply put, when defecting from the rules means harvesting only slightly more, the incentive to do so is relatively small. However, when defecting means harvesting substantially more the incentive is larger. Therefore, the question arises to what extent community governance systems can control the harvesting capacity of resource users.

This speaks to a particularly important development in fisheries; the increasing technical efficiency of fishing vessels. The efficiency of vessels continuously increases between 2% and 4% per year due to a combination of major developments in gears and small improvements in the skill of skippers (Palomares and Pauly, 2019). If a resource is unregulated or regulations are not properly enforced, these increases in efficiency will gradually increase the pressure on the resource stock (Eigaard et al., 2014). In the case of community governance, improvements in efficiency increase the ability of individual harvesters to free-ride on the cooperative efforts

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[6] This can lead to other destructive behaviours. As to maximize the value of the quota share, fishers can be incentivized to high-grade (Batsleer et al., 2015), or harvest fish at sizes smaller than socially optimal (Diekert, 2012).

[7] Successful community governance structures can be found for shared irrigation systems (Ostrom, 2014), fisheries (Cox et al., 2010) and forestry resources (Gautam and Shivakoti, 2005).

of others (Sethi and Somanathan, 1996). The first paper of this dissertation develops a bioeconomic model in which endogenous technological developments are allowed for. It studies how the incentives of individuals change when technological improvements are possible and analyses whether community governance structures can protect cooperative resource exploitation by influencing the incentives for potential non-compliers (Schaap and Richter, 2019).

The compliance of resource users with regulation, either formal or community based, can be dependent on whether the regulation is coherent with the livelihood strategies of the resource users (Ostrom, 1990; Cox et al., 2010). For example, poorer households in forested areas in Uganda are more likely to gather forest resources after experiencing a negative income shock (Debela et al., 2011). In particular in developing countries, gathering natural resources can be an insurance for shocks (Coomes et al., 2010) or even a 'livelihood of last resort' (Hannesson et al., 2010). Individuals that gather resources to attain a subsistence level of income have different incentives compared to those harvesting purely for income maximization. When regulations do not consider these uses, this can cause welfare losses and be detrimental to compliance (Gautam and Shivakoti, 2005). Because either individuals have strong incentives for non-compliance or the regulation can be seen as lacking legitimacy (Viteri and Chávez, 2007).

Alleviating poverty and the pressure to earn a living wage are strong incentives for fishers to turn to unsustainable fishing practices (Hannesson, 2002; Cinner et al., 2009). The second paper deals with this issue by studying the consequence that restrictive harvesting regulations have on the ability of fishers to smooth their consumption when dealing with negative shocks. In the short term, restrictive harvesting regulations limit the ability of individuals to gather the resource as an insurance to shocks (Schaap et al., 2020). However, in the long term harvesting regulations are beneficial as these stabilize the resource, reducing the income shocks experienced by the natural resource users (Isaksen and Richter, 2019). With a combination of surveys and analysis of official fisheries data, the paper shows that if harvesting regulation shut down this method for smoothing consumption, fishers will have to rely more on other methods such as precautionary savings.[8] Resource managers should therefore be cognisant, that insufficient access to alternative consumption smoothing mechanisms can induce welfare losses and potentially create destructive incentives when harvesting regulations are introduced.[9]

Resource users do not all behave identically when faced with the decision to either overharvest or adhere to regulations (either social normal based or formal). Similarly people will accumulate different amounts of precautionary savings when faced with the same level of risk. These difference are based on their individual preferences. For example, breaking from a social norm can negatively impact others, a fisher with strong social preferences might therefore be less inclined to do so compared to one with weaker social preferences. There is also an element of risk associated with breaking rules; will I get caught? In this case, the fishers' risk preference could influence his decision. Whilst for precautionary savings, prudence is the relevant preference.

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[8] The cost of accumulating and holding precautionary savings can be substantial in developing countries, due to transaction costs.

[9] Axbard (2016) show a further example of destructive behaviour motivated through poverty in the form of piracy.

The third and fourth paper are concerned with the economic preferences of resource users. The three previously mentioned preferences are addressed, namely prudence in the third paper and in the fourth paper, risk- and social preference. Each of which will be defined and discussed below. The central question in both papers, is whether economic preferences change over time and whether resource users preferences are perhaps shaped by the natural resource. In the fourth paper, this is done by comparing the preferences of fishers based on the characteristics of their fishery. Is the level of risk exposure (stable/risky) in a fishery indicative of the fishers' risk preferences, and does the type of social organisation (individualistic/collectivistic) matter for social preferences? Furthermore the paper attempts to disentangle the potential mechanisms that can cause such a change, and whether these changes happen exclusively on the group level, or also within the individual.

Consider the lobster as a simplified example of how preferences can change within individuals and in groups. It might be surprising to know that in the early 1800s the American lobster (*Homarus americanus*) was consider food for the lower class. The status of lobster was substantially low that it was considered cruel to feed prisoners lobster more than once a week. It is clear that since then societies attitude towards eating lobster has changed substantially and is developing further both on the individual and group level. Individuals still frequently change their mind on how they feel about eating lobster. One of the reasons is simply exposure, as someone previously indifferent might become enthusiastic about lobster after tasting it (we posit that a similar process happens for risk and social preferences). It is also true that groups form that are either exposed to lobster frequently (seafood enthusiasts) or never (for example, groups that value the ethical treatment of animals). Individuals join or leave these groups based on their preference or aversion for eating lobster, similar to how high risk occupations such as fishing can deter individuals that are averse to risk.

As mentioned previously, economic preferences allow individuals to evaluate incentives and in turn will partly determine their behaviour. Hence, it can benefit regulators to know what the preferences of the resources users are, so they can better predict how they will react to incentives. In particular, risk preference and prudence play a fundamental role when evaluating options with uncertain outcomes. Under expected utility the degree of an individual's risk preference is determined by the second derivative of their utility function. An individual is considered risk averse when the second derivative of their utility function is negative and therefore their utility function concave ($U''(.) < 0$) (Rothschild and Stiglitz, 1970). This characteristic implies that, everything else equal, the individual would prefer outcomes that have a lower variance. Risk preferences underlay many of the fundamental decisions in fishing, as it captures the mean-variance trade-off which is prevalent in many short-term (such as when and where to fish) and long-term decisions (investments in gears and vessels).

Prudence, is a higher-order risk preference and has important implications when evaluating the skewness of distributions and when preparing for uncertainty (Noussair et al., 2014). In the everyday use of the term, prudence means being cautious or well prepared when facing risks. In economics an individual is considered to be prudent when the third derivative of their utility function is positive ($U'''(.) > 0$), which means that the marginal utility function is convex (Kimball, 1990). Whilst this definition is more technical, the behaviours associated with this characteristic of the utility function mostly fit the everyday meaning of the word. Namely, a positive third derivative of the utility function is a necessary condition for precautionary savings (Leland, 1968). Prudence is also associated with an aversion to downside risk, a distaste for negative skewness in distributions (Deck and Schlesinger, 2010) and precautionary effort (Lee, 2019).[10]

Lastly, for social preference there is no generally accepted definition in the economic literature. However, the Global Preferences Survey, considers social preferences a combination of reciprocity, altruism and trust (Falk et al., 2018). All of which have important ramifications when it comes to functioning in a social environment and when choosing to comply with social norms.

Knowledge about the current preferences of resource allows for more precise predictions regarding the effects of harvesting policies and how the created incentives will be valued by the resource users. Knowing how preferences are formed allows for moving from models where preferences are considered a fixed input, to models where preferences are endogenous variables. Such a development could increase the long term accuracy of models and identify possible feedback loops between preferences and resource outcomes. However, to inform these models it is first necessary to map the relevant processes that alter preferences and the constraints on their malleability.

The literature largely acknowledges that preferences are to some extent malleable (Schildberg-Hörisch, 2018). On the individual level, the Global Preferences Survey (Falk et al., 2018) has demonstrated that risk and social preferences vary systematically with age, confirming that preferences change over the life cycle.[11] Early childhood educational interventions can also have a long-term causal impact on the social preferences of children (Cappelen et al., 2020). For groups it has been established that selection can alter the composition of preferences, for example, by individuals who are more prudent and averse to risk selecting into low risk jobs (Fuchs-Schündeln and Schündeln, 2005). These findings show that preferences within individuals and groups change, at times in predictable ways. A developing literature now studies to what extent economic preferences are shaped by the social environment and the natural environment.

This literature features evidence from country level data that the natural environment and the associated modes of production can shape the economic preferences of populations over generations (Buggle, 2020; Galor and Özak, 2016). Also there exists case-study evidence showing that, within the life-cycle, riskier and more social environments lead to stronger risk- and social preferences respectively (Gneezy et al., 2016; Nguyen, 2011). The fourth paper, combines the merits of a detailed case study analysis with that of a global scope, and aims to bridge the gap between the long term country level analysis and the short term case-studies. It does so by testing whether the level of risk exposure and the type of social organisation in a fishery influences risk and social preferences respectively. This analysis is repeated with fishers in Chile, Norway and Tanzania. Additionally, using repeated observations, the paper makes a first pass at disentangling the different mechanisms.

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[10] Precautionary effort reduces the probability of bad outcomes occurring. For example, installing safety equipment on a vessel can reduce the probability of a catastrophic outcome after an accident.

[11] They show that age has an inverted-U-shaped relationship with social preferences and a decreasing one with risk preferences.

Synopsis

The four papers in this dissertation are placed in the chronological order in which they have been written. The first paper which was developed out of my master thesis has been published as (Schaap and Richter, 2019). The other three papers are manuscripts in preparation for submission.

The first paper, *"Overcapitalization and social norms of cooperation in a small-scale fishery"*, co-authored by Andries Richter, develops a bioeconomic model and analyses whether social norms of cooperation can regulate investment in fishing capacity. The model starts with the canonical Gordon-Schaefer model (Clark, 1990) in which a technology variable is introduced. The technology variable positively influences the catch per unit effort and increases with the capital that the agent has accumulated. The model is centred around the standard social dilemma; the socially optimal levels of resource extraction and capital accumulation are lower than the levels which would maximize the income of the individual agent.

In order to solve the social dilemma and improve the collective outcome, the community can set a norm for target levels of capital and resource extraction. The model uses the evolutionary game theoretic framework developed by Sethi and Somanathan (1996) to analyse if a social norm can be successful in regulating investments. In this framework, the community is comprised of three types of agents, cooperators, defectors and enforcers. Cooperators adhere to the norm set by the community, they limit their investments and harvest the socially optimal level. Defectors act selfishly and try to maximize their income by overharvesting, and enforcers behave like cooperators but additionally punish the defectors. Agents continuously evaluate the strategies and adopt the most successful one.

Analysis of the model shows that there are two interacting (dis)incentives which control whether the system will converge to a cooperator or defector equilibrium. The first is quite obvious, which is the punishment defectors receive from the enforcers (enforcement power). If a defector is punished substantially for overinvesting, they have a strong incentive to conform to the social norm and become a cooperator. The second, counteracting, incentive is the marginal return defectors receive from their overinvestments. The gains from overinvesting and subsequently overharvesting increase relatively to the size of the resource stock, meaning that more enforcement power is needed to deter agents from becoming defectors at greater levels of resource abundance. Finally, the decision to defect and overinvest is based on whether the expected return from the investments is sufficient to compensate for the received punishment.

When the regulator (in this case the community), lacks the power to enforce the first best levels of resource extraction and capital accumulation, they can prevent agents from defecting by lowering the incentive to do so. This is achieved by increasing the extraction rate of cooperators and lowering the equilibrium level of resource abundance. Reducing the incentive to defect by depleting the resource stock is not socially optimal, but it can prevent a collapse to an open-access situation when enforcement power is insufficient. This result speaks to the idea by Copeland and Taylor (2009) that when enforcement power is insufficient to prevent agents from overharvesting by punishment, it can be compensated for by reducing the incentive to defect.

The second paper *"Risk, restrictive quotas and income smoothing"*, co-authored by Florian Diekert, Exequiel Gonzalez-Poblete and Karin Loreto Silva Aedo, features a different dilemma related to resource management. Namely, to what extent restrictive harvesting regulations limit the ability of resource users to smooth their consumption when faced with income shocks. In the absence of harvesting regulations fishers have control over how many fishing trips to make and how long these trips last (Hammarlund, 2018). If extra income is needed due to an unexpected expense, this can to some extent be compensated for with extra fishing trips. When harvesting regulation restrict the amount of fish that can be caught, or the hours spend at sea, this channel for smoothing consumption is effectively shut down.

The study is based on an economic survey and experiment with Chilean small-scale fishers. The survey assess the fishers' need for precautionary savings and their income variability, whilst the experiment elicits if the participant has prudent preferences. Analysis of official fisheries landing data determines to what extent fishers' harvesting opportunities are restricted. The need for precautionary savings and the income variability are then compared between restricted fishers and unrestricted fishers.

The results can be summarized as follows. The first result is that the unrestricted fishers consider their income from harvesting less variable compared to the restricted fishers. The fact that unrestricted fishers report lower income variability can either be a sign that restrictive regulations have been successful in reducing income variability, or it can reflect that harvesting income is endogenous for the unrestricted group, and contains responses to fluctuations in expenses. Second, fishers that are unrestricted in their harvesting require significantly less savings, compared to fishers that are exposed to restrictive harvesting regulations. Third, the need for savings increases with income variability, but only for the restricted fishers. The fact that the need for savings does not increases with variability for unrestricted fishers could reflect that the income from harvesting (and therefore part of the income variability) in this group is endogenous.

We run three robustness checks that address potential concerns about the internal validity of the results. First we control for selection, by showing that the results are robust for fishers which could not have selected into (un)restrictive fisheries, as they started fishing before the restrictive regulations were introduced and thus the regulations were exogenously assigned to them. Second, we address the concern that the need for savings is influenced by an omitted variable confounding with the degree to which participants are restricted by quotas, such as the method of production. For this we exploit a part of the sample that uses the same gears, but has a different balance in their landings of restricted and unrestricted species. Lastly we control for the underlying economic preferences, prudence and risk aversion. The results remain consistent for all robustness checks.

In the second paper it is necessary to control for prudence because an unobserved difference between the restricted and unrestricted group would have the potential to bias the results. If these groups differ in their underlying preferences, it is possible that any found effect, with regard to precautionary savings, is due to the difference in preferences and not a difference in the treatment variable. The sole-authored third paper,*"Prudence and self-selection: Do fishers have a distaste for self-insurance?"*, presents in greater detail the results of the measurement of prudence. Measurements of prudence using experimental methods are relatively new within economics and have so far scarcely been done outside of university labs with students (Trautmann and van de Kuilen, 2018). However, prudence does have economic significance outside the lab and in particular for high risk groups such as fishers.

Since 2006 a new method has been available to measure prudence, which uses relatively simple choices over lotteries (Eeckhoudt and Schlesinger, 2006). Most of the previous papers that utilize this method find that prudence is a common characteristic of the utility function (Trautmann and van de Kuilen, 2018). However, there is good reason to suspect that this finding would not hold for groups exposed to high levels of income risk (Browning and Lusardi, 1996). By estimating prudence trough precautionary savings, Fuchs-Schündeln and Schündeln (2005) find that prudent individuals are more likely to preside in low risk occupations. In this paper we use the method from Eeckhoudt and Schlesinger (2006) to measure the prevalence of prudence among Chilean fishers, which can be considered a high risk groups.

The findings are in line with those of Fuchs-Schündeln and Schündeln (2005). Only 53.7% of fishers choose the prudent option, which does not significantly differ from chance and is significantly lower than in comparable studies (Noussair et al., 2014). The further key findings are that prudence correlates with a preference for more secure occupations, and second, prudence decreases strongly with the tenure and age of the fishers. This second finding can in part be attributed to a gradual process of out-selection by more prudent fishers.

The fourth paper studies the mechanisms that shape economic preference in populations of resource users. The paper features data gathered through a series of field surveys in Chile, Tanzania and Norway, in which risk- and social preferences are measured using incentivized choices. This data is analysed to test if preferences are shaped by the resource that the fishers harvest. In Chile and Tanzania, the same fishing communities are visited several times to collect repeated observations of the same fishers. This is done in an attempt to observe changes in preferences over time and disentangle the mechanisms that can change preferences.

Based on reports in the literature, the fisheries in all three countries are classified as either being stable or risky, and as either individualistic or collectivistic. To determine if riskier fisheries lead to more risk tolerant fishers, risk preferences are compared between fishers in the risky and stable fisheries, and similarly for social preferences. Additionally data-based measures are constructed for risk exposure and social exposure. For risk exposure, the variability in trip revenue is calculated using official trip-level fisheries landings data and for social exposure the average crew size is used. The data-based measures mostly validate the ex-ante classifications of the fisheries and allow for greater specificity, as these measures of exposure can be determined on an almost individual basis.

The results show that fishers active in riskier fisheries have stronger preferences for risk. A one standard deviation increase in risk exposure equates to a 0.08 standard deviation increase in risk preference. No such effect is found for social preferences and crew size, however fishers active in the fisheries classified as collectivistic have stronger social preferences. Risk preference increases with tenure in Chile and Norway, which either indicates that more risk-averse fishers are more likely to select out of fishing, or that fishers preferences adapt due to the risk exposure. Furthermore, fishers that chose fishing as their profession are more risk tolerant, even more so if they selected into the riskier fishery. This indicates that in-selection is an important mechanism for risk preference.

The panel structure of the data is used to further identify the mechanisms that drive this difference in preferences between fisheries. First, fishers are identified that might have selected out of fishing between the field surveys. Those that have been resampled in later waves of the survey have obviously not selected out of fishing, whilst those that could not be resampled might have. The resampled and non-resampled fishers are compared in their preferences, to see if these are indicative of out-selection. Contrary to expectations, the results show that fishers resampled in Tanzania have weaker social preferences. No differences are found in Chile.

Finally, the repeated observations are used to test for differences in preferences within participants between field surveys. The risk preference of the Chilean fishers active in the risky fishery increased significantly between field trips, whilst the preferences of those in the stable fishery remained unchanged. In Tanzania no such effect is found. The results taken together suggest that riskier and more collectivistic fisheries lead to more risk tolerant and prosocial fishers respectively. The mechanisms that create this effect differ. We find evidence for effects from both in-selection and exposure for risk preference. For social preferences we only find an effect for selection.

The data from the Norwegian survey is documented and curated by the Norwegian Center for Research Data and freely available for download at `http://dx.doi.org/10.18712/NSD-NSD2847-V3`. The data from the surveys in Chile and Tanzania and replication files for the analysis conducted in these papers is available at https://doi.org/10.11588/data/JAHIMY

Outlook

The papers in this dissertation tackle subjects related to the preferences and incentives of natural resources users. Whilst there is an overlap in the subject matter, the papers ultimately answer separate research question. Therefore there will be no additional concluding section at the end of the dissertation. Here, I summarize how the papers contribute to the literature and outline the research questions that emerge from the individual papers.

The first paper expands an evolutionary game theoretic framework of social norms to study whether community governance systems can control investments in harvesting capacity. The main insight is that controlling the incentive for potential defectors to overinvest can protect cooperation when enforcement capacity is lacking. The incentive to overinvest can be reduced by lowering the target resource stock. Whilst this protects cooperation, it comes at the cost of moving away from the bioeconomic social optimum.

Moving away from the social optimum is an option which is preferable to an erosion of the social norm and a collapse to open-access. However these are not necessarily the only two options. Most notably, external authorities can impose regulations. For example, they can promote cooperation by altering critical economic parameters, such as the cost of investments (Gallic and Cox, 2006). The external authority can also introduce monitoring and fines to further punish defectors, supplementing the enforcement power of the community.

A complication however, is that established social norms can be 'crowded out' when external regulators impose regulations (Cardenas et al., 2000), and therefore, if these regulations fail to enforce sustainable harvesting behaviour independently they can have a net negative effect on the resource. This gives rise to a central policy question: When do regulators step in? This decision not only depends on whether the social norm can be preserved, but also how far the current arrangement is from the first best outcome. The cost of crowding out the social norm is lower when the current arrangement is further from the bioeconomic first best (or closer to the open-access situation). An interesting avenue for further theoretical and experimental studies would be to find an optimal point of intervention for external regulators.

The second paper concludes that when regulations restrict the harvesting behaviour of fishers, the importance of precautionary savings as a consumption smoothing method increases. In the light of progressing climate change and increasing variability in resource dynamics (Yanez et al., 2001), it will be vital to further protect resources from overharvesting, and to build up the resilience of small-scale fishers (FAO, 2019; Badjeck et al., 2010). Therefore, further deliberating the preferences and capacity for income smoothing of natural resource users is warranted.

One such a deliberation could be extending the models that evaluate the well-known tradeoff between short-term and long-term welfare consequences of harvesting regulations, to include the effects on variability. More specifically, in the short-term, restricting harvest means reduced income for resource users. Whether this can be compensated by increased income in the long-term depends on the recovery rate of the resource, the discount rate, and the distributional consequences of the policy (Clark, 1990; Noack et al., 2018; Okonkwo and Quaas, 2020). Added to the long term welfare gain, would be the reduction in variability in stock levels and decreasing risk of stock collapse (Costello et al., 2008; Essington, 2010; Isaksen and Richter, 2019). Whilst in the short-term, the reduced role of the resource as an insurance would be added (Schaap et al., 2020). Whether these effects related to variability decrease or increase the expected welfare of a particular harvesting regulation will likely depend on the preferences of the resource users, how close they are to subsistence levels of income, the alternative consumption smoothing mechanisms and the availability of outside labour options (Jayachandran, 2006; Cinner et al., 2009).

An important task for future empirical studies on labour flexibility and precautionary savings is to better disentangle exogenous income risk from endogenous adaptations to it. This distinction is not readily observable from production or landings data (Just et al., 2010), but can be observed when the motivations of fishers are elicited. Such studies could draw on the target setting literature which test whether independent workers work towards certain short-term earning goals or adhere to the neo-classical framework of counteracting substitution and income effects.[12] For example Dupas et al. (2020) studies the labour supply decisions made by Kenyan bicycle-taxi drivers using log books. They find that hours worked is strongly correlated with daily cash needs. A further exciting path for further research would be to observe labour supply adjustments in response to productivity and risk, when financial buffers are controlled for. For example, would fishers be less prone to fish on high wind days when they have a substantial financial buffer.

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[12] The target setting literature is most well-know for its papers on New York taxi drivers (Farber, 2015). However, there are also several recent papers that test for target setting behaviour in fisheries (Hammarlund, 2018; Giné et al., 2017).

Not only is self-insurance through savings affected by harvesting regulations, the underlying preference, prudence, should be considered as well. Prudence, as an economic preference, is not prevalent among fishers, implying that fishers have a relative distaste for precautionary savings. Therefore assuming that fishers will shift from using the resource as an insurance to self-insure with precautionary savings might be overly optimistic. Increased reliance on self-insurance might therefore be unlikely, or will require extra interventions. The correlation found between prudence and age is particularly strong. Therefore, interventions targeted at younger individuals might be more successful. Alternatively, regulators could follow the advice from the FAO and attempt to include small-scale fishers more in social safety nets (FAO, 2019). A process which is currently ongoing in Chile.

The last paper shows that natural resources have a way of shaping the economic preferences of resource users. The results indicate that where there is a substantial difference in risk exposure, riskier fisheries are related to more risk tolerant fishers, and more collectivistic fisheries with more prosocial fishers. The analysis suggests that this could indeed be a casual effect for risk preference, driven by two mechanisms, selection and adaptation. Fishers that have selected into fishing in general, are on average more risk tolerant than those that joined because it was their only option or a family tradition, this effect is significantly stronger for fishers that selected into the riskier fisheries. Fishers with a longer tenure are also more risk tolerant. Moreover, we find that Chilean fishers in the riskier fishery have become more risk tolerant between observations, whilst this effect is not found in the stable fishery. Indicating that adaptation could be an important mechanism.

To conclude this introduction, I want to adapt the statement in the opening as follows: to align the preferences and incentives of resource users with sustainable behaviour, we need to not only know what the preferences and incentives are, but also how and why these change. The results presented in this dissertation show that the decisions made by resource managers, either in the form of community governance systems or formal regulators, can have a substantial impact on the incentives of resource users. Tempering the incentives to invest in harvesting capacity and recognizing the different modes of exploitation can prevent welfare losses brought forth by well-intentioned policies. Furthermore recognizing that fishers economic preferences can adapt to reflect the characteristics of the fishery will allow for a more precise alignment of preferences and incentives.

References

Axbard, S. (2016). Income opportunities and sea piracy in indonesia: Evidence from satellite data. *American Economic Journal: Applied Economics*, 8(2):154–94.

Badjeck, M.-C., Allison, E. H., Halls, A. S., and Dulvy, N. K. (2010). Impacts of climate variability and change on fishery-based livelihoods. *Marine Policy*, 34(3):375 – 383.

Batsleer, J., Hamon, K. G., van Overzee, H. M. J., Rijnsdorp, A. D., and Poos, J. J. (2015). High-grading and over-quota discarding in mixed fisheries. *Reviews in Fish Biology and Fisheries*, 25(4):715–736.

Berkes, F., Hughes, T., Steneck, R., Wilson, J., Bellwood, D., Crona, B., Folke, C., Gunderson, L., Leslie, H., Norberg, J., Nyström, M., Olsson, P., Österblom, H., Scheffer, M., and Worm, B. (2006). Ecology. globalization, roving bandits, and marine resources. *Science (New York, N.Y.)*, 311:1557–8.

Birkenbach, A. M., Kaczan, D. J., and Smith, M. D. (2017). Catch shares slow the race to fish. *Nature*, 544(7649):223–226.

Browning, M. and Lusardi, A. (1996). Household saving: Micro theories and micro facts. *Journal of Economic Literature*, 34(4):1797–1855.

Buggle, J. C. (2020). Growing collectivism: irrigation, group conformity and technological divergence. *Journal of Economic Growth*, 25(2):147–193.

Butchart, S. H. M., Walpole, M., Collen, B., van Strien, A., Scharlemann, J. P. W., Almond, R. E. A., Baillie, J. E. M., Bomhard, B., Brown, C., Bruno, J., Carpenter, K. E., Carr, G. M., Chanson, J., Chenery, A. M., Csirke, J., Davidson, N. C., Dentener, F., Foster, M., Galli, A., Galloway, J. N., Genovesi, P., Gregory, R. D., Hockings, M., Kapos, V., Lamarque, J.-F., Leverington, F., Loh, J., McGeoch, M. A., McRae, L., Minasyan, A., Morcillo, M. H., Oldfield, T. E. E., Pauly, D., Quader, S., Revenga, C., Sauer, J. R., Skolnik, B., Spear, D., Stanwell-Smith, D., Stuart, S. N., Symes, A., Tierney, M., Tyrrell, T. D., Vié, J.-C., and Watson, R. (2010). Global biodiversity: Indicators of recent declines. *Science*, 328(5982):1164–1168.

Cappelen, A., List, J., Samek, A., and Tungodden, B. (2020). The effect of early-childhood education on social preferences. *Journal of Political Economy*, 128(7):2739–2758.

Cardenas, J. C., Stranlund, J., and Willis, C. (2000). Local environmental control and institutional crowding-out. *World Development*, 28(10):1719 – 1733.

Cinner, J. E., Daw, T., and McClanahan, T. R. (2009). Socioeconomic factors that affect artisanal fishers' readiness to exit a declining fishery. *Conservation Biology*, 23(1):124–130.

Clark, C. W. (1990). *Mathematical bioeconomics: the optimal management of renewable resources*. Wiley, second edition.

Colding, J. and Barthel, S. (2019). Exploring the social-ecological systems discourse 20 years later. *Ecology and Society*, 24(1). 2.

Coomes, O. T., Takasaki, Y., Abizaid, C., and Barham, B. L. (2010). Floodplain fisheries as natural insurance for the rural poor in tropical forest environments: evidence from amazonia. *Fisheries Management and Ecology*, 17(6):513–521.

Copeland, B. R. and Taylor, M. S. (2009). Trade, tragedy, and the commons. *American Economic Review*, 99(3):725–49.

Costello, C., Gaines, S. D., and Lynham, J. (2008). Can catch shares prevent fisheries collapse? *Science*, 321(5896):1678–1681.

Costello, C., Lynham, J., Lester, S. E., and Gaines, S. D. (2010). Economic incentives and global fisheries sustainability. *Annual Review of Resource Economics*, 2(1):299–318.

Cox, M., Arnold, G., and Tomás, S. (2010). A review of design principles for community-based natural resource management. *Ecol. Soc.*, 15.

Debela, B., Shively, G., Angelsen, A., and Wik, M. (2011). Economic shocks, diversification, and forest use in uganda. *Land Economics*, 88(1):139–154.

Deck, C. and Schlesinger, H. (2010). Exploring Higher Order Risk Effects. *The Review of Economic Studies*, 77(4):1403–1420.

Diekert, F. K. (2012). Growth overfishing: the race to fish extends to the dimension of size. *Environmental and Resource Economics*, 52(4):549–572.

Duarte, C. M., Agusti, S., Barbier, E., Britten, G. L., Castilla, J. C., Gattuso, J.-P., Fulweiler, R. W., Hughes, T. P., Knowlton, N., Lovelock, C. E., Lotze, H. K., Predragovic, M., Poloczanska, E., Roberts, C., and Worm, B. (2020). Rebuilding marine life. *Nature*, 580(7801):39–51.

Dupas, P., Robinson, J., and Saavedra, S. (2020). The daily grind: Cash needs and labor supply. *Journal of Economic Behavior & Organization*, 177:399 – 414.

Eeckhoudt, L. and Schlesinger, H. (2006). Putting risk in its proper place. *American Economic Review*, 96(1):280–289.

Eigaard, O. R., Marchal, P., Gislason, H., and Rijnsdorp, A. D. (2014). Technological development and fisheries management. *Reviews in Fisheries Science and Aquaculture*, 22(2):156–174.

Essington, T. E. (2010). Ecological indicators display reduced variation in north american catch share fisheries. *Proceedings of the National Academy of Sciences*, 107(2):754–759.

Falk, A., Becker, A., Dohmen, T., Enke, B., Huffman, D., and Sunde, U. (2018). Global Evidence on Economic Preferences. *The Quarterly Journal of Economics*, 133(4):1645–1692.

FAO (2019). Social protection for small-scale fisheries in the mediterranean region- a review. Technical report, Food and Agriculture Organization of the United Nations. Rome.

FAO (2020). The state of world fisheries and aquaculture 2020. `http://www.fao.org/3/ca9229en/CA9229EN.pdf`. Sustainability in action. Rome. https://doi.org/10.4060/ca9229en.

Farber, H. S. (2015). Why you Can't Find a Taxi in the Rain and Other Labor Supply Lessons from Cab Drivers. *The Quarterly Journal of Economics*, 130(4):1975–2026.

Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L., and Holling, C. (2004). Regime shifts, resilience, and biodiversity in ecosystem management. *Annual Review of Ecology, Evolution, and Systematics*, 35(1):557–581.

Fuchs-Schündeln, N. and Schündeln, M. (2005). Precautionary savings and self-selection: Evidence from the german reunification "experiment". *The Quarterly Journal of Economics*, 120(3):1085–1120.

Gallic, B. L. and Cox, A. (2006). An economic analysis of illegal, unreported and unregulated (IUU) fishing: Key drivers and possible solutions. *Marine Policy*, 30(6):689 – 695.

Galor, O. and Özak, Ö. (2016). The agricultural origins of time preference. *American Economic Review*, 106(10):3064–3103.

Gautam, A. and Shivakoti, G. (2005). Conditions for successful local collective action in forestry: Some evidence from the hills of nepal. *Society and Natural Resources Vol. 18*, No. 2:153–171.

Giné, X., Martinez-Bravo, M., and Vidal-Fernández, M. (2017). Are labor supply decisions consistent with neoclassical preferences? evidence from indian boat owners. *Journal of Economic Behavior & Organization*, 142:331 – 347.

Gneezy, U., Leibbrandt, A., and List, J. A. (2016). Ode to the sea: Workplace organizations and norms of cooperation. *The Economic Journal*, 126(595):1856–1883.

Grafton, R., Arnason, R., Bjorndal, T., Campbell, D., Campbell, H., Clark, C., Connor, R., Dupont, D., Hannesson, R., Hilborn, R., Kirkley, J., Kompas, T., Lane, D., Munro, G., Pascoe, S., Squires, D., Steinshamn, S., Turris, B., and Weninger, Q. (2005). Incentive-based approaches to sustainable fisheries. *Canadian Journal of Fisheries and Aquatic Sciences*, 63.

Hammarlund, C. (2018). A trip to reach the target? – the labor supply of swedish baltic cod fishermen. *Journal of Behavioral and Experimental Economics*, 75:1 – 11.

Hannesson, R. (2002). A note on unsustainable fisheries and trends in fish catches. in report and documentation of the international workshop on factors of unsustainability and overexploitation in fisheries, bangkok, thailand. Technical report. Food and Agriculture Organization of the United Nations, Rome, Italy.

Hannesson, R., Salvanes, K. G., and Squires, D. (2010). Technological change and the tragedy of the commons: The lofoten fishery over 130 years. *Land Economics*, 86(4):746–765.

Hardin, G. (1968). The tragedy of the commons. *Science*, 162(3859):1243–1248.

Hilborn, R., Branch, T. A., Ernst, B., Magnusson, A., Minte-Vera, C. V., Scheuerell, M. D., and Valero, J. L. (2003). State of the world's fisheries. *Annual Review of Environment and Resources*, 28(1):359–399.

IPCH (1991). Iphc annual report 1991. `https://iphc.int/uploads/pdf/ar/IPHC-1991-Annual-Report.pdf`. International pacific halibut commission.

Isaksen, E. T. and Richter, A. (2019). Tragedy, property rights, and the commons: Investigating the causal relationship from institutions to ecosystem collapse. *Journal of the Association of Environmental and Resource Economists*, 6(4):741–781.

Jardine, S. L. and Sanchirico, J. N. (2012). Catch share programs in developing countries: A survey of the literature. *Marine Policy*, 36(6):1242–1254.

Jayachandran, S. (2006). Selling labor low: Wage responses to productivity shocks in developing countries. *Journal of Political Economy*, 114(3):538–575.

Just, D. R., Khantachavana, S. V., and Just, R. E. (2010). Empirical challenges for risk preferences and production. *Annual Review of Resource Economics*, 2(1):13–31.

Kimball, M. S. (1990). Precautionary saving in the small and in the large. *Econometrica*, 58(1):53–73.

Lee, K. (2019). Prudence and precautionary effort. *Journal of Risk and Insurance*, 86(1):151–163.

Leland, H. E. (1968). Saving and uncertainty: The precautionary demand for saving. *The Quarterly Journal of Economics*, 82(3):465–473.

Lugilde, A., Bande, R., and Riveiro, D. (2018). Precautionary saving: A review of the empirical literature. *Journal of Economic Surveys*, 0(0).

Nguyen, Q. (2011). Does nurture matter: Theory and experimental investigation on the effect of working environment on risk and time preferences. *Journal of Risk and Uncertainty*, 43(3):245–270.

Noack, F., Riekhof, M.-C., and Quaas, M. (2018). Development in a dual economy: The importance of resource-use regulation. *Journal of the Association of Environmental and Resource Economists*, 5(1):233–263.

Noussair, C. N., Trautmann, S. T., and van de Kuilen, G. (2014). Higher order risk attitudes, demographics, and financial decisions. *The Review of Economic Studies*, 81(1):325–355.

Okonkwo, J. U. and Quaas, M. F. (2020). Welfare effects of natural resource privatization: a dynamic analysis. *Environment and Development Economics*, page 1–21.

Ostrom, E. (1990). *Governing the commons-The evolution of institutions for collective actions*. Political economy of institutions and decisions.

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, 325(5939):419–422.

Ostrom, E. (2014). Do institutions for collective action evolve? *Journal of Bioeconomics*, 16(1):3–30.

Ostrom, E., Janssen, M. A., and Anderies, J. M. (2007). Going beyond panaceas. *Proceedings of the National Academy of Sciences*, 104(39):15176–15178.

Palomares, M. L. D. and Pauly, D. (2019). On the creeping increase of vessels & fishing power. *Ecology and Society*, 24(3). 31.

Pfeiffer, L. and Gratz, T. (2016). The effect of rights-based fisheries management on risk taking and fishing safety. *Proceedings of the National Academy of Sciences*, 113(10):2615–2620.

Richter, A. and Grasman, J. (2013). The transmission of sustainable harvesting norms when agents are conditionally cooperative. *Ecological Economics*, 93:202 – 209.

Richter, A., van Soest, D., and Grasman, J. (2013). Contagious cooperation, temptation, and ecosystem collapse. *Journal of Environmental Economics and Management*, 66(1):141–158.

Rothschild, M. and Stiglitz, J. E. (1970). Increasing risk: I. a definition. *Journal of Economic Theory*, 2(3):225 – 243.

Rustagi, D., Engel, S., and Kosfeld, M. (2010). Conditional cooperation and costly monitoring explain success in forest commons management. *Science*, 330(6006):961–965.

Schaap, R., Diekert, F., Gonzalez Poblete, E., and Silva, K. (2020). Risk, restrictive regulations and income smoothing.

Schaap, R. and Richter, A. (2019). Overcapitalization and social norms of cooperation in a small-scale fishery. *Ecological Economics*, 166:106438.

Schildberg-Hörisch, H. (2018). Are risk preferences stable? *Journal of Economic Perspectives*, 32(2):135–54.

Sethi, R. and Somanathan, E. (1996). The evolution of social norms in common property resource use. *The American Economic Review*, 86(4):766–788.

Tavoni, A., Schlueter, M., and Levin, S. (2012). The survival of the conformist: Social pressure and renewable resource management. *Journal of Theoretical Biology*, 299:152–161.

Trautmann, S. T. and van de Kuilen, G. (2018). Higher order risk attitudes: A review of experimental evidence. *European Economic Review*, 103:108 – 124.

Viteri, C. and Chávez, C. (2007). Legitimacy, local participation, and compliance in the galápagos marine reserve. *Ocean & Coastal Management*, 50(3):253 – 274. The Galapagos Islands and the Archipelago of San Andres.

Vollan, B. and Ostrom, E. (2010). Cooperation and the commons. *Science*, 330(6006):923–924.

Yanez, E., Barbieri, M., Silva, C., Nieto, K., and Espindola, F. (2001). Climate variability and pelagic fisheries in northern chile. *Progress in Oceanography*, 49(1):581 – 596. Pacific climate variability and marine ecosystem impacts.

Paper 1

Overcapitalization and social norms of cooperation in a small-scale fishery

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Abstract: The increasing technological efficiency of harvesting equipment has been identified as one of the main causes of overcapacity and overexploitation of natural resources. In this paper, a formal model is developed which studies the effects of technological efficiency as an endogenous variable within a bioeconomic system. We model capital investments in a fishery, where investment decisions are made less frequently than the allocation of variable inputs. We study how the possibility to invest in capital affects open access dynamics, and also the evolution of cooperative harvesting norms. We find that the possibility to make large capital investments can destabilize cooperation, especially if enforcement capacity is low. Further, we find that communities can preserve cooperation by agreeing on a resource level that is lower than socially-optimal. This reduces the incentive to deviate from the cooperative strategy and invest in capital.

Keywords: Social-ecological systems, Cooperation, Investment, Social norms, Technological efficiency, Fisheries, Overcapacity, Evolutionary game theory.

1.1 Introduction

Globally, overexploitation of marine resources remains a major societal problem (Costello et al., 2016; Melnychuk et al., 2017). A common property regime, crafted by local communities has been shown to have the potential to successfully govern marine resources, especially if formal regulations are infeasible (Gutierrez et al., 2011; Ostrom, 1990). In such a setting, social norms can be a powerful mechanism to enforce sustainable harvesting strategies (Ostrom, 2009; Lubchenco et al., 2016; Nyborg et al., 2016). At the same time, social norms can be fragile, especially if individual agents can take advantage of cooperative efforts by others and are tempted to over-harvest (Richter et al., 2013). A key factor determining the ability to over-harvest are investments in fishing vessels, gear, and other equipment (Hilborn et al., 2003; Worm et al., 2009).

In this paper, we analyse whether social norms of cooperation can successfully regulate investment in fishing capacity. We develop a theoretical model that features a small community having access to a common pool resource. Main novelty of the model is that harvesting efficiency is not constant, but dependent on the amount of capital that each agent has accumulated. Essentially, each agent decides on the amount of (i) short term inputs and (ii) long term capital to be invested in a fishery. We assume that the use of all variable inputs (e.g. fuel, labour) that determines fishing intensity for a given capital stock is allocated frequently (potentially daily) and is therefore the faster changing variable. The decision how much to spend on maintaining or upgrading equipment is based on the expected net return from the investment, and will be the slower changing variable. This creates a dynamic system in which the allocation of variable inputs becomes a function of the capital stock. This implies that variable inputs are chosen optimally based on the state of the resource and the amount of capital an agent has accumulated. Such fast-slow dynamics add realism, while preserving analytical tractability.

We analyse how the ability to invest in harvesting capacity affects cooperative resource exploitation based on social norms. We follow the seminal evolutionary game theory framework by Sethi and Somanathan (1996), in which cooperative harvesting norms are enforced through punishment. Agents act either cooperatively and harvest the resource sustainably or act selfishly and maximize their individual gains by building up capital stocks that are larger than collectively optimal. Agents will stop cooperating if it offers a higher utility to do so. The framework is therefore consistent with the principle of the "rational criminal" which states that a risk neutral individual would commit an illegal act when the expected benefit from that illegal act is higher than the expected cost (Becker, 1968).

Understanding how capital investments affect the fate of a fishery is relevant for several reasons. The increasing efficiency of fishing vessels creates multiple complications in fisheries management, as it can affect stock assessments (Maunder et al., 2006; Eigaard et al., 2014), generate or sustain overcapacity (Villasante and Sumaila, 2010; Clark, 2006; Eigaard et al., 2014), and create incentives for illegal fisheries (Agnew et al., 2009; Gallic and Cox, 2006). While the bulk of literature assumes efficiency – usually expressed as catchability – to be exogenous, we specifically take into account that efficiency is endogenous and dependent on investment. Investments may include new or larger vessels, fish finding equipment, improved gear designs and more powerful engines. All of those may have a positive effect on catchability and therefore lower the per unit harvesting costs (Squires and Vestergaard, 2013). The introduction of such innovations is primarily an investment decision, where the cost of the investment has to be earned back over the lifetime of the investment (Whitmarsh, 1990). However, the increase in efficiency will – if unregulated – increase the capacity of the fishery and the pressure that is exerted on the fish stock (Eigaard et al., 2014).

We make two contributions to the literature. First, we formalize endogenous capital in a fisheries model taking into account that capital is revised less frequently than effort. While the observation that certain factors of production – such as capital – are fixed in the short run is common in microeconomic modelling (Varian, 1992), and also reflected in many empirical fisheries models (e.g. Huang and Smith (2014)), formalizing such dynamics is a novel contribution in the field of fisheries.[1] Second, we add to the literature on the evolution of social norms for common pool resource harvesting. While many papers have looked at different mechanisms that may stabilize cooperation, such as punishment (Sethi and Somanathan, 1996; Noailly et al., 2003), ostracism (Tavoni et al., 2012), moral persuasion (Richter et al., 2013), identity considerations (Bulte and Horan, 2010), conditional cooperation (Richter and Grasman, 2013), or spatial structure (Noailly et al., 2007), the focus of this paper is to what extent social norms can regulate the investment of capital in a fishery. In particular, we take into consideration how cooperation can be stabilized in such case.

In Sethi and Somanathan (1996), a community either features full cooperation or defection, depending on specific parameters, such as punishment strength and technological efficiency. If efficiency were to increase, cooperation would simply break down at a certain point. An open question remains how the community may be able to actively preserve social norms of cooperation. We show that the size of the resource stock is a potential device through which the community may stabilize cooperation. If the community aims for a lower than socially optimal resource stock, cooperation is maintained. So a second-best solution actually stabilizes cooperation if a first best is not available. This mechanism is akin to the "modesty may pay" principle in coalition theory reflecting that international environmental agreements may be stable if targets are not too ambitious (Finus and Maus, 2008). The idea is also reflected in Copeland and Taylor (2009) who model the evolution of property rights regimes at a country level. In their model, the government sets a harvest level that is tolerated, taking into account agents' incentive to cheat. Resource exploitation is thus dependent on what the government can enforce. Our paper shows that those findings may also translate to the case of community governance, where a community may agree on a second-best harvesting level to maintain cooperation.

Our model is presented in section 2. In section 3, we analyse endogenous capital in an open-access fisheries, which may present the case where cooperation has disappeared or has never evolved in the first place. Section 4 looks closer at the interaction of capital investments and social norms. Section 5 concludes, and briefly discusses our main findings.

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[1] Of course, there is a substantial literature on investment behaviour and capacity adjustments in fisheries; see Nøstbakken et al. (2011) for an excellent review and Boyce (1995); McKelvey (1985); Clark et al. (1979) for key papers. However, no paper has explicitly considered that capital may evolve at a slower rate than variable inputs.

1.2 The model

We assume that N members of a closed community have access to a common pool resource. There are clear boundaries to the system, which means there is no migration of resource units or people in or out of the system. We assume that only villagers are tolerated on the resource grounds and no outside labour can be hired, which is often the case in common property regimes (Baland and Platteau, 1996; Ostrom, 1990). Consequently, the costs of fishing are not constant (as would be the case if there was a market wage), but marginally increasing, as each fisher has an increasing opportunity cost as fishing effort increases.

1.2.1 Resource dynamics and harvesting

As a starting point, we take the canonical Gordon-Schaefer fisheries model (Clark, 1990). The change of resource abundance over time is dependent on the natural growth of the resource and the exploitation by fishers. The natural growth of the resource is described by the logistic growth function

$$G(S) = rS(t)\left(1 - \frac{S(t)}{S_{max}}\right), \tag{1.1}$$

where $S(t)$ is the resource abundance at time t. S_{max} indicates the carrying capacity of the biological system and r gives the intrinsic growth rate of the resource. We make the simplifying assumption that all short term variable inputs can be expressed in one variable, which we coin effort. The harvests of each agent $h_i(t)$ are linearly dependent on effort $e_i(t)$, a technology variable $q_i(t)$ and the resource abundance and can be given as

$$h_i(t) = e_i(t)q_i(t)S(t). \tag{1.2}$$

The technology variable $q_i(t)$ is akin to the well-known catchability coefficient in the Gordon Schaefer model. The only difference is that the technology variable is varying over time and individuals. The harvest of all agents is summed to determine the total harvest $H = \sum_{i=1}^{N} h_i$. The change in resource abundance over time can then be determined by subtracting the aggregate harvest from the natural growth as given by

$$\dot{S} = G(S) - H. \tag{1.3}$$

The net return on harvesting for each fisher is determined by his harvest and the cost of effort. Each harvested unit is sold for the constant price P. The costs of harvesting are convex, where the cost parameter for effort is given by v. This gives the net return on harvesting as

$$y_i(t) = Pe_i(t)q_i(t)S(t) - ve_i(t)^2. \tag{1.4}$$

1.2.2 Endogenous technology

The technology variable $q_i(t)$ is dependent on the capital $k_i(t)$ that has been accumulated by agent i and a capital to technology conversion rate γ. We assume that $q_k > 0$ and $q_{kk} < 0$, which implies that there is a marginally decreasing return from capital on technological efficiency. Specifically, the relationship between capital and the technology variable is given by

$$q_i(t) = \gamma k_i^z(t), \quad \text{where} \quad 0 < z \leq 0.5. \tag{1.5}$$

The upper bound on z assures that the relation between harvesting revenue and capital investments remains weakly concave, $\pi_{kk} \leq 0$. Inserting the technology variable into the harvest function would give the harvest function the form of a standard Cobb-Douglas production function, with inputs for labour (effort) and capital.

$$h_i(t) = k_i^z(t)\gamma S(t)e_i(t). \tag{1.6}$$

The investment to improve technological efficiency is costly. Due to insufficient capital markets, those investments have to be paid out of the stream of current incomes. Therefore, profit π_i depends on revenues and costs of harvesting, as well as investment I_i and is given as

$$\pi_i(t) = k_i^z \gamma PS(t)e_i(t) - ve_i(t)^2 - I_i(t). \tag{1.7}$$

The capital stock of each agent changes over time. Agents invest I_i into their capital stock, while a fraction δ of their current capital stock depreciates. We assume that the capital is fully malleable, and the change of the capital stock k_i can be given as

$$\dot{k}_i = I_i - k_i\delta, \quad \textit{with} \quad -k_i \leq I_i \leq \pi_i. \tag{1.8}$$

Note that each agent possesses two control variables, effort e_i and investment I_i. We assume that the choice of effort is revised more frequently, and will be optimized based on the state of both the resource stock and the capital stock. Capital investments are a long-term decision, and we assume that agents make capital investments if they expect them to be profitable in the long run. Such choices may depend on social norms and are described in more detail in sections 1.3 and 1.4.

1.2.3 Evolution of social norms

The socially optimal level of resource extraction is lower than the level which would maximize the income of an individual agent. If agents act selfishly this would lead to overexploitation and lower – if not zero – economic rents generated by the resource in equilibrium. Hence, we face a social dilemma.

To analyse the evolution of cooperative social norms, we rely on the evolutionary game-theoretic framework proposed by Sethi and Somanathan (1996). We assume that there are three groups of agents: (i) cooperators, (ii) defectors, and (iii) enforcers. The community comprises N_c cooperators, N_d defectors and N_p enforcers, where $N = N_c + N_d + N_p$. Cooperators are willing to adhere to the social optimum, while defectors act selfishly and may overexploit the resource if this gives them higher utility. Enforcers adhere to the same harvest strategy as cooperators and punish defectors to enforce cooperation. Punishment is costly, both for the punisher, as well as for the receiver. An enforcer faces costs β for each defector that is punished, while each defector is bearing costs α per punishment instance. Total utility is given as the sum of profits from harvesting π and the costs of imposing or receiving sanctions. The utility for cooperators (U_c), defectors (U_d) and enforcers (U_p) is determined by the following set of functions:

$$U_c(t) = \pi_c(t), \tag{1.9}$$

$$U_d(t) = \pi_d(t) - \alpha N_p(t) \quad \text{with} \quad \alpha > 0, \tag{1.10}$$

$$U_p(t) = \pi_c(t) - \beta N_d(t) \quad \text{with} \quad \beta > 0. \tag{1.11}$$

The utility of cooperators is only determined by profits, since they neither punish, nor are punished. For defectors, the utility loss is particularly high if N_p is high, i.e. if there are many enforcers in the community. For enforcers, it is particularly costly if many defectors (N_d) are in the community. Note that the monetary profits of enforcers and cooperators are identical. Enforcers, however, face the costs of punishing peers. The evolutionary process is based on the replicator equation (Taylor and Jonker, 1978) that determines the change of strategies. This process is based on imitation dynamics, where agents will revise their strategy if a better one is available. If a strategy gives higher than average utility, the fraction of agents using it increases. Formally, the number of players following strategy x, where $x = c, d, p$ is given by N_x. So the fraction of each strategy changing over time is given by the set of differential equations

$$\frac{\dot{N}_x}{N} = \frac{N_x}{N}(U_x - \bar{U}), \quad \text{where } \bar{U} = \sum_{x=1}^{3} \frac{N_x}{N} U_x. \tag{1.12}$$

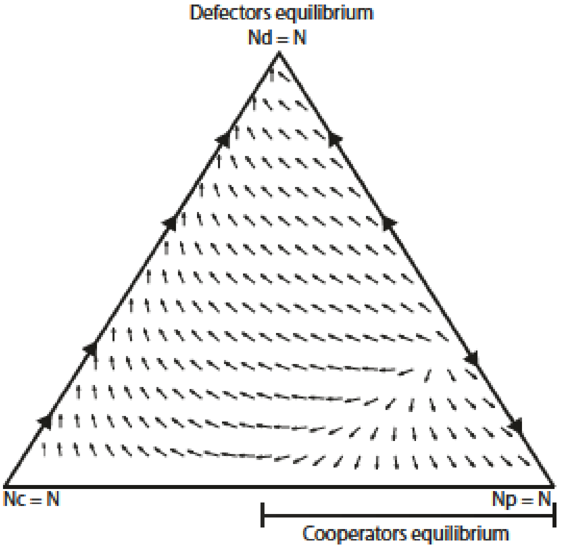

Figure 1.1: The figure illustrates how the composition of strategies changes, based on the current population. The corners of the triangle represent a population consisting of only one strategy. The lines between the corners represent some combination of two strategies, and in the interior all three strategies are present. The simulation shows the case where $\pi_d - \pi_c = 40$, $N = 100$, $\alpha = 1$, $\beta = 0.8$.

From equation 1.12 it follows that an equilibrium requires utility of all chosen strategies in the equilibrium to be the same. The system as proposed by Sethi and Somanathan (1996) has two stable equilibria: either full cooperation or full defection. A stable state with all three strategies present is not possible. If defectors are present, enforcers would perform strictly worse than cooperators, due to the strictly positive cost of punishing. A stable state consisting of cooperators and defectors is not possible, under the condition that $\pi_d > \pi_c$, as the the defector strategy strictly dominates the cooperator strategy in the absence of enforcers.[2] Lastly, a community comprising both enforcers and defectors cannot be a stable equilibrium, because a mixed community will always be attracted towards full cooperation or full defection. The intuition is that if the fraction of enforcers increases, relative utility of defectors decreases (as they are punished by more agents), leading to a further erosion of defection. For similar reasons, an increasing fraction of defectors will imply higher costs for enforcers and lead to an erosion of enforcers. Hence the system has two stable states: full defection or full cooperation. Fig. 1.1 illustrates the change in composition of strategies in a stable bioeconomic system and the attraction towards either full cooperation or full defection. The nature of both stable states will be described in more detail in section 1.4.

Section	Model assumptions	Literature
1.2.1	Gordon-Schaefer model for open-access fisheries	(Gordon, 1954; Clark, 1990)
1.2.2	Harvesting efficiency dependence on capital	(Eigaard et al., 2014)
1.2.2	Malleability of capital, reversibility of investments	(Rust et al., 2016; Clark et al., 1979) (Clark, 1990, P.110),(Allison and Ellis, 2001)
1.3.1 1.3.2	Dynamic between effort and capital	(Nøstbakken et al., 2011; Clark, 1990)
1.2.2	Myopic agents	(Yletyinen et al., 2018)
1.2.3	Evolutionary game-theoretic framework	(Sethi and Somanathan, 1996)
1.2.3	Replicator dynamic for social norms	(Taylor and Jonker, 1978)
1.3.5	Maximum economic yield as a benchmark	(Clark, 1990, P.42-43)

Table 1.1: List of assumptions used in the model and related literature

1.3 The open access equilibrium and social optimum

In this section the open-access equilibrium is determined, followed by the socially optimal resource and capital stock. The social optimum is the stable state which maximizes the collective benefits and is only stable if all agents are cooperators or enforcers. The open-access equilibrium is the stable state associated with the "defector equilibrium" of the social norms model of Sethi and Somanathan (1996), which implies that all cooperators have disappeared and everyone is defecting. Of course, the open access equilibrium also resembles a situation where social norms have never evolved in the first place and everyone has been pursuing his own interest from the start. In such a situation agents try to claim any resource rents available, which may happen by either investing effort or capital.

To determine the open-access equilibrium, we assume that all agents behave selfishly and try to maximize their immediate gains, consistent with an open access fishery. In doing so, they will change effort or the size of their capital stock if this will increase their income. A

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[2] Note that cooperators and defectors can co-exist if profits are zero, which is ruled out in Sethi and Somanathan (1996). We explore this situation in section 1.4.4.

steady state implies that neither the resource stock, the capital stock, nor effort changes over time. In the paper we only present the case of $z = 0.5$, as this yields easily interpretable closed form solutions.[3] We summarize all other key model assumptions and the literature related to each assumption in table 1.1.

1.3.1 Choice of effort – short run dynamics

Each fisher decides how much effort to spend on harvesting the resource. This decision obviously depends on the resource stock, but also on the equipment he possesses. The optimal amount of effort can be found by deriving the profit function with respect to effort and setting it to zero, as given by $\frac{\partial \pi_i}{\partial e_i} = \sqrt{k_i}\gamma SP - 2ve_i = 0$. Then, the optimal amount of effort[4] is given by

$$e_i = \frac{\sqrt{k_i}\gamma SP}{2v}. \tag{1.13}$$

We see that the agent uses more effort if (i) he possesses more capital (k), (ii) the resource abundance (S) is high, and (iii) sales price (P) is high. Higher harvesting costs (v) decrease the amount of effort. This condition for the allocation of effort (1.13) can be substituted into the harvest function (1.2), which gives

$$h_i = \frac{k_i\gamma^2 S^2 P}{2v}. \tag{1.14}$$

This condition for the allocation of effort (1.13) can be substituted into the profit function (1.7). This substitution simplifies further analysis as now profit is only dependent on investments and capital, but no longer on effort. Therefore,

$$\pi_i = \frac{k_i\gamma^2 S^2 P^2}{4v} - I_i. \tag{1.15}$$

1.3.2 Choice of capital stock – long run dynamics

In the long run, agents decide how much to invest in their capital stock. Positive investments will improve the technological efficiency of harvesting equipment, and will increase harvests per unit of effort. Furthermore, as can be seen in equation (1.13) it will increase the amount of effort exerted by the agent in future time periods. However, there is a marginally decreasing effect on the increase in technological efficiency from a growing capital stock and also the capital depreciates over time.

As the fishers are in an open-access fisheries, they are motivated by increasing their individual profits. They will only invest if the expected return on the investment is higher than

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[3] If effort is chosen optimally, the partial output elasticity of capital is equal to one in such case. This implies that a one unit increase in capital leads to a one unit increase in harvests, which is akin to the properties in the standard Gordon-Schaefer model. For values of $z < 0.5$, we have a concave harvest function with respect to capital, so a one unit increase in capital leads to a less than one unit increase in harvests. It seems quite plausible to see those diminishing returns in real-world fisheries, though see Gordon (1954) for a discussion on why diminishing returns may not unfold in the fishing industry. For values of $z > 0.5$, we have a convex harvest function with respect to capital, which means a one unit increase in capital leads to a larger than one unit increase in harvests. Those increasing returns to capital do not seem very realistic and at odds with economic principles, though see Mirza et al. (2019) for a model that features locally increasing returns to scale.

[4] As the second derivative is negative ($\frac{\partial^2 \pi_i}{\partial e_i^2} = -2v$), we can conclude that this is a maximum.

the cost. This implies that the cost of an investment has to be returned over its lifetime. Since individuals are not the sole owner of the resource, they cannot rely on an optimal investment path. Also, we assume that fishers use the current resource abundance to estimate revenue in later time periods and do not predict changes in resource abundance.

The assumption made in equation (1.8) states that the capital stock is fully malleable, meaning that capital can be disinvested without loss of value.[5] In equilibrium, $I_i = k_i\delta$, which we can insert into profit function (1.15). To determine if an investment would garner a net profit, the profit function is derived with respect to the capital stock and set to zero:

$$\frac{\partial \pi_i}{\partial k_i} = \frac{\gamma^2 S^2 P^2}{4v} - \delta = 0. \tag{1.16}$$

The only variable which appears in the derivative is the state of the resource stock. We can solve for S to obtain a threshold value of resource abundance $\hat{S} = \frac{2\sqrt{\delta}\sqrt{v}}{P\gamma}$, which determines whether an investment will be profitable. The marginal profit from capital increases monotonically with resource abundance. Therefore, if the resource stock is above the threshold value $\hat{S}$ the agent can increase his income by increasing his capital stock, whilst at resource abundance levels below $\hat{S}$ the agent will make a net loss on each unit of capital. This creates a bang bang solution with three types of solutions. If the resource stock is below the minimum threshold for investment, the agent stops his investments altogether and will disinvest if possible. When the stock is above the threshold, the agent will want to increase his capital stock, and at $\hat{S}$ the agent will maintain his capital stock by replacing any depreciated capital. Therefore, investment can be given as

$$I_i = \begin{cases} \pi_i & if \quad S(t) > \hat{S} \\ k_i\delta & if \quad S(t) = \hat{S} \\ -k_i & if \quad S(t) < \hat{S}. \end{cases} \tag{1.17}$$

To determine the nullcline for the capital stock, the results from equation 1.17 are inserted into the differential equation for capital, equation 1.8. The nullcline for the capital stock is plotted in Fig. 1.2:

$$\dot{K} = 0 \quad if \quad \hat{S} = \frac{2\sqrt{\delta}\sqrt{v}}{P\gamma}. \tag{1.18}$$

1.3.3 Resource stock

To determine how resource abundance is affected by harvesting, we insert the size of the aggregate capital stock $K = \sum_{i=1}^{N} k_i$ into the harvest function (1.14), which gives aggregate

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[5] Obviously, this is a simplification, though in line with observations from the field, as described in Allison and Ellis (2001) p.383: "However, for most artisanal fisheries, and especially those in low-income countries, the assets tied up in fishing are not that great and mobility is relatively high." An alternative approach would have been to use non-malleable capital, i.e. non-reversible investments (cf. Rust et al. (2016); McKelvey (1985)), which is more realistic, but challenging, if not impossible to combine with a model of social norms. After all, there is strategic interaction, so that agents would have to from beliefs about investment of peers (potentially guided by norms) and the development of the stock.

harvests

$$H(t) = \frac{K\gamma^2 S^2 P}{2v}. \tag{1.19}$$

Total harvests increase linearly with the aggregate capital stock and quadratically with the size of the resource stock.[6] The resource stock will be in equilibrium if harvests equal the natural growth, i.e. $rS(1-\frac{S}{S_{max}}) = \frac{K\gamma^2 S^2 P}{2v}$. This equation can be solved with respect to the size of the capital stock, giving the critical capital stock $\hat{K}$ needed to harvest the resource in equilibrium

$$\dot{S} = 0 \quad if \quad \hat{K} = \frac{2rv(1-\frac{S}{S_{max}})}{PS\gamma^2}. \tag{1.20}$$

This critical capital stock $\hat{K}$ decreases as resource abundance increases, meaning that less (more) capital is needed to have a high (low) resource level in equilibrium. Equation (1.20) gives the nullcline of the resource, which is shown graphically in Fig. 1.2.

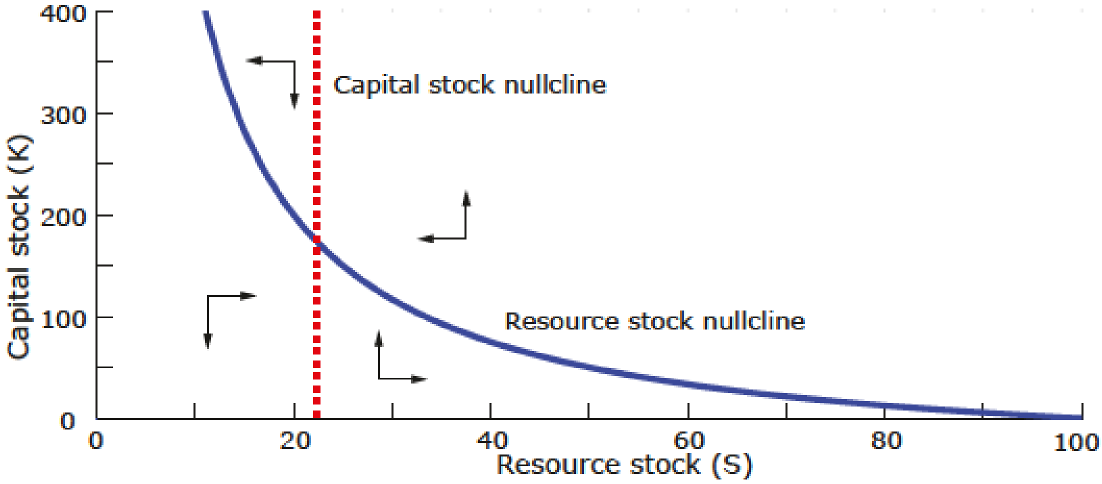

Figure 1.2: The capital and resource stock nullclines describe the dynamics of the system. The open-access equilibrium is located at the intersection of both nullclines. The arrows indicate the direction in which the variables would change over time.

1.3.4 The open-access equilibrium

For the complete bioeconomic system to be in a steady state both resource abundance and capital have to remain constant at the same time. We can find the equilibrium by substituting the investment threshold (1.18) into the nullcline for resource abundance (1.20). This yields the steady state values, corresponding to the intersection of two nullclines in Fig. 1.2:

$$\hat{K} = \frac{r\sqrt{v}(1-\frac{2\sqrt{\delta}\sqrt{v}}{P\gamma S_{max}})}{\gamma\sqrt{\delta}} \quad \text{and} \quad \hat{S} = \frac{2\sqrt{\delta}\sqrt{v}}{P\gamma}. \tag{1.21}$$

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[6] Considering that agents can have differing technology coefficients and effort levels, it may seem surprising that aggregate harvests rise linearly with aggregate capital stock. However, the linear relationship between individual capital and harvest makes it possible to determine the aggregate harvest directly from the aggregate capital stock.

At the investment threshold $\hat{S}$, no agent is able to raise his profit by either increasing harvesting effort or by investing in technological efficiency. At the open-access equilibrium in the Gordon-Schaefer model no economic rents remain (Seijo et al., 1998). Hence, our open access equilibrium is consistent with the Gordon-Schaefer model in that regard.

1.3.5 Optimal management

In this section, we are going to determine how the community can achieve the largest collective sustainable profit – the maximum economic yield. Maximum economic yield is a standard management objective, essentially maximizing the net present value using a zero percent discount rate. The main purpose of this analysis is to establish a benchmark for cooperation, which is why we refrain from using a positive discount rate – the insights would be similar, but the analysis would be unnecessarily complicated.

The cooperators agree on a socially optimal capital stock K^*, whilst allocation of effort remains dependent on the resource stock and the agent's capital stock; see equation (1.13). Each cooperator invests the fair share of capital, i.e. $k_c = K^*/n$. In equilibrium, the resource stock cannot change over time, meaning the harvest has to equal the natural growth of the resource. Maximum economic yield is found by solving the following problem

$$\max \quad \pi = \frac{K\gamma^2 S^2 P^2}{4v} - K\delta \quad \text{subject to} \quad G(S) = H(K, S). \tag{1.22}$$

The capital stock $\hat{K}$ that supports a sustainable resource stock, i.e. $\dot{S}(t) = 0$, is given in equation (1.20) and substituted in the objective function (1.22) to obtain

$$\pi^* = -\frac{r(S - S_{max})(\gamma^2 S^2 P^2 - 4\delta v)}{2\gamma^2 S P S_{max}}, \tag{1.23}$$

where π^* indicates the profits that can be generated by sustainably harvesting the resource. Note that sustainable profits depend on only one variable: resource abundance. To maximize function (1.23) we derive it with respect to the size of the resource stock to yield

$$\frac{\partial \pi^*}{\partial S} = -\frac{r(2\gamma^2 S^3 P^2 - \gamma^2 S^2 P^2 S_{max} - 4\delta v S_{max})}{2\gamma^2 S^2 P S_{max}}. \tag{1.24}$$

Setting the derivative to zero gives an optimal level of resource abundance S^* at which sustainable exploitation grants the highest aggregate profit[7], which can be expressed as

$$S^* = \frac{{S_{max}}^2}{36A} + \frac{S_{max}}{6} + A, \tag{1.25}$$

$$\textit{where} \quad A = \sqrt[3]{\sqrt{(B+C)^2 - B^2} + B + C},$$

$$\textit{where} \quad B = \frac{{S_{max}}^3}{216}, \quad C = \frac{v\delta S_{max}}{P^2\gamma^2}.$$

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[7] The second derivative is given by, $\frac{\partial^2 \pi^*}{\partial S^2} = -\frac{r(\gamma^2 S^2 P^2 + 4\delta v S_{max})}{\gamma^2 S^3 P S_{max}}$, where all parameters are non-negative. As the second derivative is strictly negative we can conclude that the reported solution is a maximum.

1.4 Community governance

In our model, cooperators agree on a socially optimal capital and effort level that ensures a stable level of resource abundance at which economic rents are produced. The replicator dynamics (1.12) show that agents will be attracted towards the most successful strategy. To maintain a state in which the cooperative strategy remains dominant, it has to be the one offering the highest utility. Thus, for a cooperative stable state to be stable, the cost of being punished has to be higher than the additional revenue that could be attained from defecting. In the next section we analyse under which conditions a cooperative state is stable.

1.4.1 Cooperative stable state

Within the framework of Sethi and Somanathan (1996) it is impossible for cooperators and defectors to co-exist in a stable state. Hence, the cooperative stable state implies that all agents are cooperating and no one is defecting. To ensure that a cooperative state is stable, the change in both resource and capital stock over time has to remain zero. Furthermore, no agent should be tempted to defect and utility of cooperating should be strictly higher than utility of defecting. Note that the utility of cooperators is equal to enforcers if defectors are absent and given by

$$U_c = \frac{k_c \gamma^2 S^2 P^2}{4v} - k_c \delta. \tag{1.26}$$

As all agents are cooperating, their capital is optimized to sustainably harvest the resource stock, and effort is chosen optimally, as given by equation (1.13). While there is no possibility to increase profits by increasing effort, agents could be tempted to defect by making investments I_d into the capital stock that go beyond the cooperative level. These investments could increase the agent's individual profits, but would trigger punishments by enforcers, equal to αN_p. Hence, the utility of defectors is given by

$$U_d = \frac{(k_c + I_d)\gamma^2 S^2 P^2}{4v} - (k_c + I_d)\delta - \alpha N_p. \tag{1.27}$$

A cooperator will only be tempted to defect and overinvest, if it increases his utility. Hence, we need to compare the utility functions of cooperators (1.26) and defectors (1.27). In equation (1.28), we see that the difference in utility between cooperators and defectors is composed of the return on the investment and the punishment by enforcers. Defection occurs if the revenue gained from the overinvestment is greater than the costs of the overinvestment and the cost of being punished, as given by

$$U_d - U_c = \frac{I_d \gamma^2 S^2 P^2}{4v} - I_d \delta - \alpha N_p. \tag{1.28}$$

In the cooperative stable state each unit of capital invested has a positive net return, while punishment is constant and independent on the size of the investment. In the following two sections we will analyse how investments affect cooperation when the limit to investments is either set exogenously or is determined endogenously by the agents' total profit in the previous period.

1.4.2 Exogenous investments

In this section we describe how cooperation is affected by investments when the limit to investment is set exogenously. A cooperative state can be invaded if defecting yields a higher utility than cooperating. The investment capability of a potential defector I_d is salient, because the investment needs to be large enough to negate the received punishment. This means that as the punishment capacity of the community rises, larger investments are necessary to pass the investment threshold $\hat{I}_d$, beyond which larger investments make defection profitable; see Fig. 1.3.

Essentially, whether cooperation can be enforced is determined by the ability to invest I_d and the received punishment αN_p. Obviously, the ability to administer severe punishments helps in maintaining a cooperative stable state. The critical level of enforcement needed to maintain a cooperative stable state is given by

$$\alpha N_p = \frac{I_d \gamma^2 S^2 P^2 - 4 I_d v \delta}{4v}. \tag{1.29}$$

We find that higher enforcement is needed if the resource stock is high, the sales price is high, and the costs of effort are low. Indeed, these are all factors that make harvesting more profitable, increasing the temptation to defect. The minimum investment needed to compensate for the received punishment can be determined by

$$\hat{I}_d = \frac{4v N_p \alpha}{\gamma^2 S^2 P^2 - 4v\delta}. \tag{1.30}$$

We find that larger investments are needed to break even (I_d is larger) if there are more enforcers in the community, and punishment is more effective. The investment threshold is smaller when the resource stock is large, the sales price is high and the technology γ is more efficient.

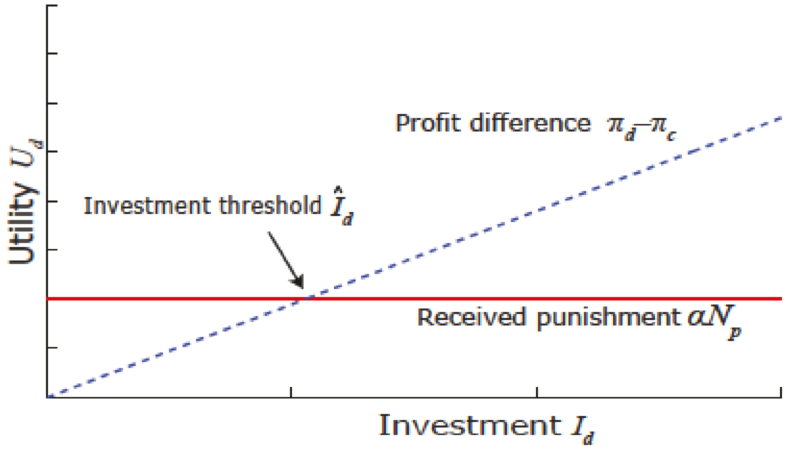

Figure 1.3: There is an investment threshold $\hat{I}_d$ at which utility from cooperation and defection are the same. Any higher investment level will favour defection, while any lower investment level favours cooperation. The intuition behind it is that the income of the agent rises linearly with investment, while the punishment received for this 'illegal' investment is constant.

The interaction between investment and punishment is influenced by a third variable, the level of resource abundance at the cooperative steady state. The increase in revenue by each invested unit of capital is positively dependent on the level of resource abundance. Less punishment capacity would be needed to enforce a cooperative stable state at lower levels of resource abundance. The highest possible resource stock at which a cooperative stable state can be enforced, can be determined by

$$\bar{S} = \sqrt{\frac{4vN_p\alpha + 4I_d v\delta}{I_d\gamma^2P^2}}. \tag{1.31}$$

This shows that aside from stronger enforcement there is a second device which can control whether the system can be invaded by defectors, and that is the agreed upon size of the resource stock. When enforcement power is insufficient to enforce the first best, cooperative agents can agree to harvest the resource at a lower level of resource abundance. To sum up, when investment capacity is determined exogenously there are three different types of stable state possible.

$$\bar{S} = \begin{cases} S^* & if \quad \bar{S} \geq S^* \\ \bar{S} & if \quad \hat{S} < \bar{S} < S^* \\ \hat{S} & if \quad \bar{S} \leq \hat{S} \end{cases} \tag{1.32}$$

1. There is enough enforcement power to achieve the socially optimal state, as no one is able or willing to make an investment large enough to destabilize it. The resource will be harvested sustainably at the optimal level of abundance S^*.

2. The enforcement power is not strong enough to achieve the socially optimal state, but a resource stock higher than the open-access equilibrium can be enforced, creating a suboptimal cooperative stable state at the resource level $\bar{S}$.

3. There is no enforcement power in the community, as all agents have defected. The only stable state is the open-access equilibrium. The resource is harvested at the abundance level $\hat{S}$.

Model parameters	Description	Value
N	Number of agents	100
r	Intrinsic resource growth rate	1
S_{max}	Carrying capacity	100
P	Resources sales price	200
v	Cost of effort	100
γ	Capital to efficiency conversion rate	0.002
δ	Capital depreciation rate	0.05
α	Cost of being punished	10
β	Cost of punishing	0.5
I_d	Investment capacity	400

Table 1.2: Model parameters

By changing various key parameter we analyse how they affect the equilibrium resource stock of the open-access fisheries $\hat{S}$, optimal management S^* and the highest enforceable co-operative stable state $\bar{S}$. We assess the effect of changing the resource price P, the costs of effort v and the capital-technology conversion rate γ, by plotting the equilibrium resource stock as a function of these parameters; see Fig. 1.4 and Table 1.2 for parameter values. When the price of the resource rises and the costs of harvesting decrease, the resource abundance at which the maximum economic yield is attained S^* decreases and approaches the maximum sustainable yield.[8] When price (P) rises or when the cost of harvesting (v) or efficiency (γ) drops, the increase in revenue per unit of (over-)invested capital increases, decreasing the highest enforceable cooperative stable state $\bar{S}$. The open-access equilibrium stock $\hat{S}$ gradually increases when the cost of effort increases. However when resource prices or the capital-technology conversion rate increase it rapidly declines. Note that if the highest enforceable resource stock $\bar{S}$ is higher than the optimal resource stock S^*, it means that the optimal policy can be enforced. Similarly, no management is needed if the optimal resource abundance and open-access equilibrium $\hat{S}$ coincide.

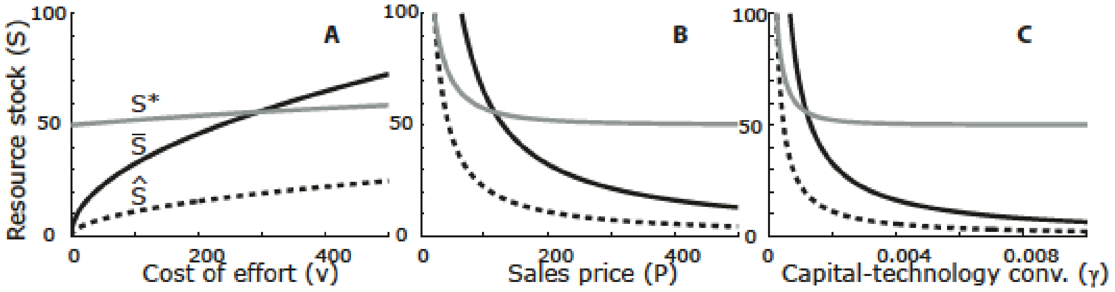

Figure 1.4: Each of the three panels shows the equilibrium resource abundance of the possible stables states as the function of one variable; A) Cost of effort v. B) Price of the resource P. C) Conversion rate from capital to technological efficiency γ. P and v are varied between 0 and 500 and γ between 0 and 0.01, whilst all other variables are kept constant at the values in table 1.2. The solid grey line indicates MEY S^*, the dashed line the open-access resource stock $\hat{S}$ and the black solid line shows the maximum resource abundance that can be enforced $\bar{S}$.

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[8] Maximum sustainable yield is a policy objective with the aim to maximize the equilibrium harvests. For the standard logistic growth function this is achieved at resource levels of half the carrying capacity, which in this case is 50.

1.4.3 Endogenous investments

In this section investment capacity is endogenously determined. The agents have no access to capital markets, so investments have to be paid out of the stream of current incomes. Considering that each unit of capital has a positive net return when the resource stock is at a higher level than the open-access equilibrium, a defector would always want to maximize his investment. The maximum investment an agent is able to make, is equal to his profit from the previous period. We analyse whether a cooperative state can be invaded, so the maximum investment made by a potential defector is equal to the profit of a cooperator in the stable state as determined in equation (1.23), thus $I_d = \pi_{i,t-1} = \pi_c^*(S)$.[9]

The agreed upon resource stock at the cooperative equilibrium now determines the temptation to defect in two ways. The first being the revenue earned per invested unit of capital and the second being the investment capacity of potential defectors. An increase in the cooperators profits would thus have the adverse effect of increasing the investment capacity of potential defectors.

As seen in Fig. 1.5, the investment capacity rises until the resource stock reaches the first best solution (maximum economic yield). At resource stock levels higher than the first best, the size of the defectors investment capacity declines, but the profit gained from defecting continues to increase due to the higher return on each invested unit of capital. As the stock approaches the carrying capacity the declining investment capacity becomes limiting for the defector's profits.

Fig. 1.6 shows how the temptation to defect, given by the difference in profits between defectors and cooperators ($\pi_d - \pi_c$) varies with the size of the resource stock. As before, the punishment defectors receive for over investing (αN_p) is independent of the resource stock and a cooperative stable state can be maintained if the punishment is larger than the profit difference.

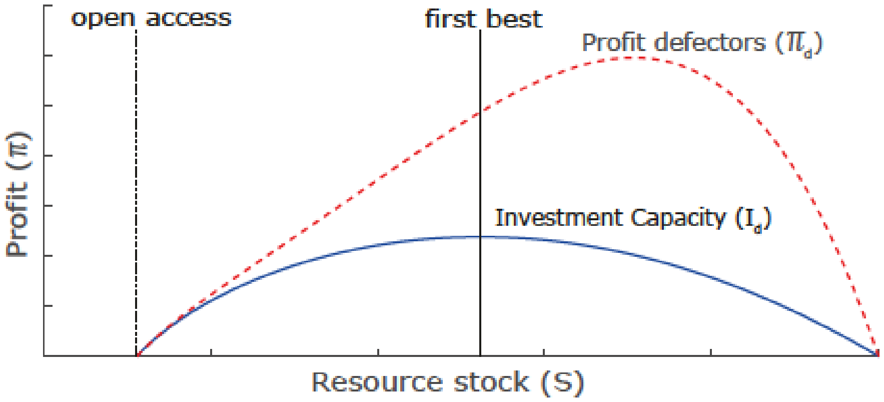

Figure 1.5: The graph shows the profit for defectors and their investment capacity as a function of the resource stock. The investment capacity is equal to the profit of cooperators. The two vertical lines indicate the open-access resource stock and the first best for cooperators.

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[9] If punishments are monetary, the investment potential of a defector is reduced by any punishments received. We explore this assumption in section 1.4.4.

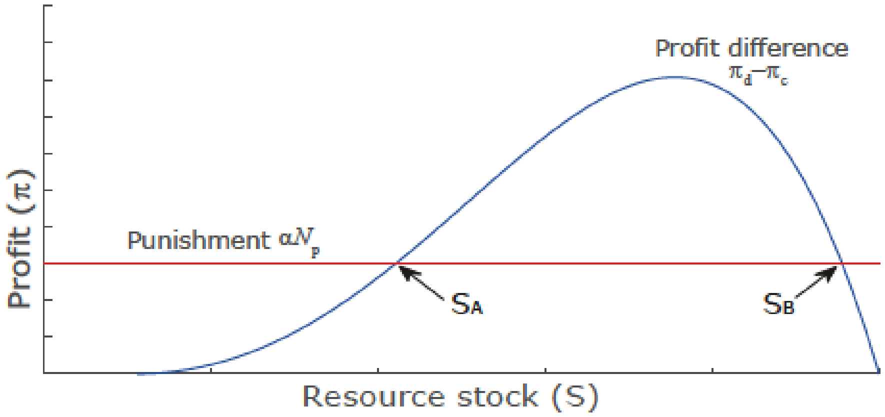

Figure 1.6: The graph shows the difference in profit between defectors and cooperators and the punishment defectors would receive. At two points the lines intersect, these are threshold points S_a and S_b. The difference in profits is only plotted if agents make positive profits by following their chosen strategy.

When investment capacity is determined endogenously, there are two resource stock levels 'S_A' and 'S_B' at which the additional profits from harvesting gained by defecting are equal to the received punishment. These resource stock levels can be interpreted as threshold values, as cooperators could agree to either harvest the resource at levels lower than 'S_A' or higher than 'S_B' and cooperation would be stable. However, a cooperative state would not be stable in-between those values.

The difference in profits between cooperators and defectors is the same at both threshold values. However, the first threshold value S_A is characterized by a relatively low resource stock, while S_B, is characterized by a high resource stock level. As the investment has to be paid out of the agents' stream of incomes, the investment capacity reduces as the profits diminish. If the resource is harvested sustainably at very high levels of abundance, profits are relatively low. Even though the return on each invested unit of capital is very high at S_B, agents are not able to make an investment large enough to destabilize the cooperative state. Which allows for cooperation to be stable at high levels of resource abundance.

We can numerically determine S_A and S_B by solving equation (1.28) with $I_d = \pi_c$[10], which after substitution can be written as

$$U_d = U_c \quad \text{if} \quad \frac{r(S_{max} - S)(\gamma^2 S^2 P^2 - 4\delta v)^2}{8\gamma^2 S P v S_{max}} - \alpha N_p = 0. \tag{1.33}$$

At both threshold values a small increase in the gain from defecting could induce agents to adopt the defector strategy and destabilize the cooperative state. This may be triggered by an exogenous shock, such as an increase in resource price, technological efficiency or a decrease in opportunity cost or depreciation of capital. In Fig. 1.7 we plot the threshold values S_A and S_B, indicating the range in which cooperation is stable.

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[10] No satisfactory analytical solution could be obtained and therefore we resort to a numerical analysis. Solving equation (1.33) for S yields 5 solutions, three of these are always outside of the used parameter space. Therefore these are omitted.

Fig. 1.7 illustrates how the threshold values vary dependent on the following parameters: price (P), cost of effort (v), the capital to technology conversion rate (γ) and the degree of capital decay (δ). The upper threshold value S_B is generally close to carrying capacity, whilst the lower threshold value is similar to those plotted in Fig. 1.4.[11] Enforcement becomes more difficult as either prices or the capital to harvesting efficiency conversion rate increases. An increase in the costs of effort or the rate of capital decay increases the range in which a cooperative stable state is possible.

To conclude, when investment capacity is limited by previously earned profits, cooperation is stable above and below separate threshold values of the resource stock. When the resource stock is sustainably exploited at levels below S_A or above S_B, agents do not have enough income to make an investment large enough to offset the punishment they will receive for defecting. This is in contrast to when exogenous investments are available, as then a cooperative stable state at high levels of resource abundance would not be possible.

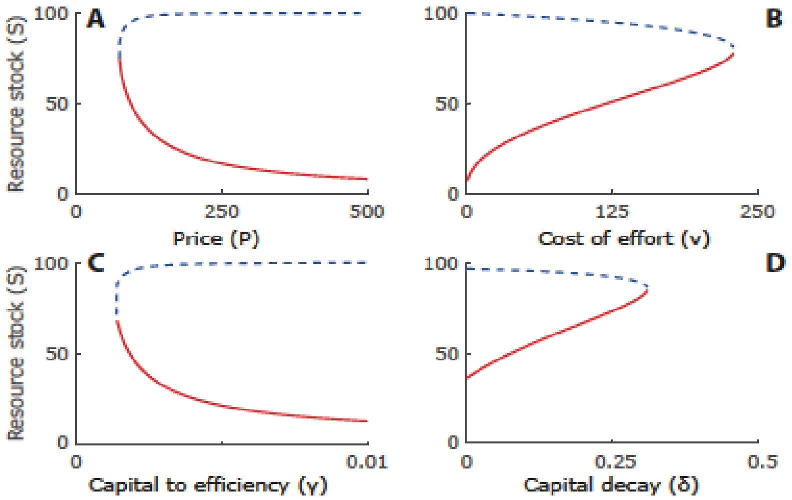

Figure 1.7: Each of the four graphs shows at which levels of the resource stock cooperation would be possible as a function of one parameter; A) Price of the resource P, B) Cost of effort v, C) Conversion rate capital to technological efficiency γ, D) Capital decay δ. The dashed blue line shows the upper threshold value S_B and the red solid the lower threshold value S_A. No cooperative equilibrium is possible in the area between the lines. When there are no lines for a given parameter value, this indicates that cooperation is possible at every level of the resource stock.

1.4.4 Transition dynamics

In this section we determine to which stable state the system converges when out of equilibrium. We run the model as a system of differential equations, where we vary the starting capital stock and the starting resource stock. The dynamics are explained using multiple time series which illustrate the different manners in which the system can develop.

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[11] All parameters are given in Table 1.2, except the resource sales price, which is $P = 100$.

We assume that cooperative agents behave in the following manner. In the initial period cooperators and enforcers set a target for the cooperative resource stock, $\bar{S}$. All agents receive an equal share of the capital stock necessary to harvest $\bar{S}$ sustainably as determined by equation (1.20). We denote the aggregate starting capital stock as K_c, of which each agent receives $k_c = K_c/N$. At each positive starting level of the resource stock, the system will converge to $\bar{S}$ if harvested with the aggregate capital stock K_c.

Defectors start with the same capital stock as cooperators. However, they maximize their income by investing their profits according to equation (1.17). Their investment capacity is determined endogenously, as specified in section 1.4.3, with the added assumption that punishments are monetary and therefore reduce investment capacity, thus $I_{d,t} = \pi_{d,t-1} - \alpha N_{p,t-1}$. As a consequence defectors are only able to make a positive investment if the gains from harvesting are higher than the received punishment. For simplicity we assume that all defectors hold the same representative capital stock.[12] The capital that defectors have in excess of k_c is denoted as $k_{d,t}$. We simulate the model by running the differential equations for resource abundance (1.3), capital stock (1.8) and agent strategies (1.12) until an equilibrium is reached.[13]

The upper panel of Figure 1.8 shows to which equilibrium the system converges based on the starting resource stock S_0 and the cooperative capital stock K_c. The blue line indicates the resource abundance at the cooperative stable state, $\bar{S}$, as determined by the capital stock K_c. The system converges to the open-access equilibrium if the starting conditions are between the two solid black lines. Below the lower black line, and above the upper black line, the system converges to a cooperative stable state.

Within figure 1.8 there are four initial conditions marked with A,B,C and D. The correspondingly marked panels show how the system dynamics unfold at these points. Time series A illustrates how the system develops if the cooperative capital stock K_c is high enough to deter defection. The number of defectors declines to zero and the resource stock converges to the cooperative target stock. All defectors switch to the enforcer and cooperator strategy. We see that the share of enforcers drops slightly over time, as they switch to the cooperator strategy due to the cost of punishing defectors. At starting point B, the initial resource abundance is substantially higher than the cooperative target stock, opening a window for defection to invade the cooperative equilibrium. Due to the higher stock, the profits of all agents are temporally higher, which increases the investments capacity of defectors and making defecting the most profitable strategy. Therefore, the share of enforcers drops rapidly, and the system converges to the open-access equilibrium.

The time plot at starting point C shows the case where the cooperative capital stock is too low to deter defection. Initially, defection is not profitable, but an erosion of enforcement is taking place as enforcers switch to a cooperative strategy. Approximately at $t = 7$, the number of enforcers falls below the minimum needed to prevent defectors from accumulating capital, and consequently k_d starts to increase. Due to the increase in capital, defecting becomes profitable and more agents switch to the defector strategy. Enforcement power continues to

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[12] Defectors can increase their capital stock each period. An agent that has switched to the defector strategy in t = 1 would have a different capital stock than an agent that has switched in t = 2. Accounting for this heterogeneity would require an agent-based modelling approach.

[13] Simulations were run in the GRIND package for Matlab, http://www.sparcs-center.org/resources/dynamical-modelling-tools.html

drop and the resource stock converges to the open-access equilibrium. The time series at starting point D illustrates the case for low levels of k_c. Due to the low starting capital of all agents, the profits from harvesting are limited. Hence, defectors are unable to increase their capital stock and the number of defectors decrease over time. The resource stock approaches the equilibrium stock $\bar{S}$.

From the time series we observe that preventing defectors from accumulating capital is pivotal in maintaining cooperation. Investments increase profits of defectors, which further increases investments and widens the gap in profits between cooperators and defectors. Therefore an important tipping point exists at the point where defectors profits exceed the received

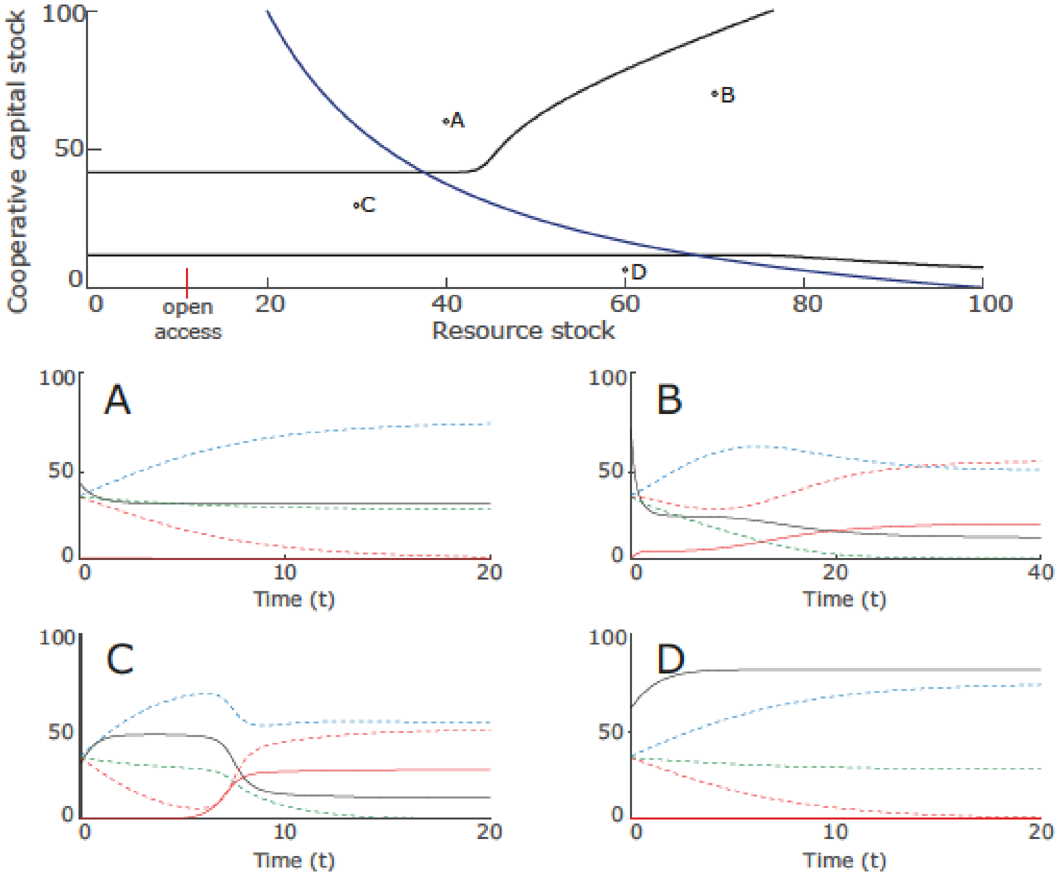

Figure 1.8: The upper panel illustrates the behaviour of the system with different initial conditions A–D for initial resource stock and cooperative capital stock k_c. The blue line indicates the resource abundance at the cooperative stable state, as determined by the cooperative capital stock. If the starting conditions are between the two black lines, the system will converge to the open-access equilibrium. Below the lower black line, and above the upper black line, the system converges to a cooperative stable state. Panels A–D show the dynamics of the system at points A,B,C and D. The lines represent the following variables: black solid (S), red solid ($10k_d$), red dashed (N_d), green dashed (N_p), blue dashed (N_c). We assume that in the first time period the strategies are distributed evenly ($N_p = 33, N_d = 33, N_c = 34$) and set $\alpha = 0.8$; all other parameters are set according to table 1.2. Panel specific parameters, A:($\hat{k} = 60$, $S_0 = 40$), B:($\hat{k} = 70$, $S_0 = 70$), C:($\hat{k} = 30$, $S_0 = 30$), D:($\hat{k} = 6$, $S_0 = 60$).

punishment, $\pi_{d,t-1} > \alpha N_p$.

We also observe that even if the initial conditions favour cooperation, defection can invade if the number of enforcers erodes over time. Under the condition that defectors are not able to make any investments, e.g. $k_d = 0$, the profits from harvesting are identical for all strategies $\pi_d = \pi_c = \pi_p$. If this condition is met, the change of strategies over time is completely driven by the cost of punishing, and the cost of being punished. Hence, as long as defectors are present, enforcers will be tempted to become cooperators (and stop enforcing). The system will flip towards a defective stable state if the remaining number of enforcers becomes insufficient to prevent investments by defectors.

The two horizontal lines in figure 1.8 are located at the points where the remaining number of enforcers is sufficient to prevent investments, $\alpha N_p = \pi_c(\bar{S})$. The necessary enforcement power needed to maintain the cooperative equilibrium is a function of the cooperators profits, and thus K_c. The lines bend outward at higher levels of the starting resource stock, which implies higher initial profits, which allows defectors to make investments and invade the cooperative equilibrium.

In time series B and C we see that defectors and cooperators co-exist at the open-access equilibrium resource stock ($\hat{S}$). As mentioned in section 1.2.3 a cooperator-defector equilibrium is not possible if the profits from harvesting are positive. If punishment is absent $\pi_d > \pi_c$ implies $U_d > U_c$. However at $\hat{S}$ the average profit per unit of capital is zero, and therefore the profit from harvesting for both strategies is zero. As the profits for both strategies are equal and there is no punishment a cooperator-defector equilibrium is possible at $\hat{S}$ provided that enforcers have disappeared.

1.5 Discussion

It is a well established idea that community arrangements to harvest a resource sustainably can be undermined by continuous technological improvement in harvesting efficiency (Richter and Dakos, 2015; Taylor, 2011). In particular, investment in fishing capacity may lead to overcapacity that jeopardizes successful management of a fishery (Eigaard et al., 2014). We formalize these observations in a mathematical model to explore under which conditions social norms of cooperation erode, but may also adapt in light of the possibility to invest in fishing capital. Our paper points to an important tension in the field. If investments can be financed via exogenous capital markets, a large resource stock would trigger high investments, as profits can be made by exploiting the resource. If investments are endogenous and have to be financed through the current stream of incomes, low levels of capital would not generate the necessary income to support such large investments and stable cooperation may be observed at very high resource levels.

We added technological efficiency as an endogenously determined variable in the Gordon-Schaefer model, treating capital as a slowly changing variable and effort as a fast variable. Capital investments determine the harvesting efficiency of fishing vessels which consequently influences allocation of harvesting effort. This has been integrated in the evolutionary game theoretic framework developed by Sethi and Somanathan (1996) in which social norms of cooperation regarding capital investments evolve over time.[14]

Our model shows that in an open access regime, the cost and depreciation rate of capital investments are important in determining the resource abundance at the open-access equilibrium. Further, we find that cooperative resource exploitation can be destabilized by the potential to make large capital investments, and may be further challenged by high prices or low costs of effort. Finally, we find that communities have an interesting device at their disposal to discourage agents from defecting: the collectively agreed resource stock. When the regulatory power is insufficient to enforce optimal management, cooperative resource exploitation can be protected by lowering the level of abundance at which the resource is exploited.

To protect cooperative resource exploitation it is important to understand what incentives motivate fishers to refrain from selfish behaviour such as illegal fishing or over-investing. Reducing incentives to cheat by lowering the resource stock is not socially optimal, but could help prevent collapses to open-access in situations where enforcement capacity is limited. The results from our model support the idea established by Copeland and Taylor (2009), that when regulatory power is insufficient to dissuade agents from over-harvesting by punishment, it can be compensated for by reducing the incentives to cheat. Copeland and Taylor (2009) classified economies into three distinct groups. The first group consists of so called "Hardin economies", which lack the power to enforce any regulation. Resources in these economies will be depleted and harvested at the open-access equilibrium. The second group, "Ostrom economies" have the regulatory power to enforce suboptimal harvesting policy. However if they were to attempt to enforce the optimal harvesting policy, the incentive for agents to cheat would outweigh the expected punishment. The last group, "Clark economies" have sufficient regulatory power to enforce the optimal harvesting policy (Copeland and Taylor, 2009). The three distinct economies devised by Copeland & Taylor closely resemble the three types of stable states we presented in equation (1.32). Thus, we show that these results carry over to the case where not a regulator sets a harvesting policy, but it is in the hands of local communities guided by social norms. Our results could also be relevant in the debate concerning community governance structures. The assumption that people always try to maximize their own short term benefits has been challenged, and an increasing awareness has developed for other concepts such as trust, social norms and conditional cooperation (Janssen, 2015). Informal institutions that have developed over time, rely on the cooperation of exploiters and the willingness to impose sanction on free riders to succeed (Vollan and Ostrom, 2010). The imposed management can often be suboptimal with regard to bioeconomic theory, but allows for the resource to be harvested sustainably. Due to the theoretical nature of the work, we can obviously not conclude how relevant these mechanisms are in the field. However, the main implications of our work could be tested using case studies or economic experiments. In particular, it would be interesting to investigate how important technology is compared to other variables when

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[14] If capital and effort were revised simultaneously, the model would require a different setup. First, one would have to solve the use of inputs jointly, which is possible if one departs from the Gordon Schafer model. Using a model with decreasing returns to scale (e.g. Cobb Douglas technology), one would be able to find some kind of optimal mix of capital and effort; see for example Richter et al. (2018). Second, and more fundamentally, it is not so clear what cooperators would coordinate on (low effort, low capital or both). So it is not obvious how our findings translate to such setting.

considering sustainability in the commons (Ostrom, 2009).

A key feature of our model is that capital is the slow control variable, while effort is the fast one. The importance of fast-slow processes in social-ecological systems has been pointed out before (Crépin, 2007; Crépin et al., 2011; Walker et al., 2012). Those papers have considered fast-slow dynamics of state variables (e.g. corals and fish stock), while we consider time scales of control variables. Similar in this respect, Biggs et al. (2009) investigate how regime shifts can be avoided if they are triggered by either mechanisms which can be manipulated rapidly (fishing effort) or only gradually (coastal development). Indeed, the importance of time scales on sustainability and resilience of social-ecological systems has been increasingly recognized (Biggs et al., 2012). The challenges for modellers is to formalize and parametrize models incorporating different time scale, without drowning in complexity.

Any model, such as this one has limitations. First, while our model is deterministic, in reality the ecological or socio-economic system may be exposed to natural variation. The transition dynamics in section 1.4.4 show that a higher resource stock, for example brought about by natural variation, increases profits and therefore allows defectors to invest more, potentially eroding cooperation. In such case, cooperation can be maintained if the system is sufficiently far from a threshold value and enough enforcement power is present to prevent investments from accumulating. However sufficiently large shocks in resource growth may trigger a shift from cooperation to defection.

Second, we follow Sethi and Somanathan (1996) in assuming that punishment is constant and independent of the severity of the infraction. It would be an interesting extension to consider punishment strength to be conditional on the magnitude of defection, i.e. the size of the investment. It is not obvious whether it would be better to be either strict or lenient on small violations, as strict punishments would discourage defection, but also pose higher costs on enforcers.

Third, we assume that capital is malleable, which is not implausible for a small scale fishery. However, assuming some kind of hysteresis and irreversibility in investments would certainly be more realistic (Huang and Smith, 2014; Dixit, 1992). Such an approach would require agents to form expectations about the future, and make optimal decisions in such context. In our model agents are myopic and do not form beliefs about social and resource dynamics, which is in line with how social norms are usually modelled in the literature. In reality, agents are probably not as rational as assumed in optimal investments models, nor as myopic as assumed in many evolution of cooperation models. Yet, a bridge between these two approaches is missing in the literature. This would certainly be an interesting avenue for further research and could also potentially reconcile the two polar assumptions in classical game theory (full rationality) and evolutionary game theory (myopia). One would expect that the degree to which fishers form beliefs and also adapt to the future depends on the underlying uncertainty and volatility of their environment, though the empirical evidence is sparse; but see Yletyinen et al. (2018).

Our results raise one important policy question, and that is how external authorities can prevent the erosion of cooperative harvesting norms. First, dependent on the source of the investments, the regulator could promote cooperation by implementing policies affecting key economic parameters, such as the cost of effort (see Fig. 1.4 for exogenous investments and

Fig. 1.7 for endogenous investments). Altering the price and cost structure is considered an important tool to discourage illegal and unregulated harvesting (Gallic and Cox, 2006). Second, there is also the question at what point an external regulator should step in, for example by introducing external fines and monitoring. It has been observed that rules established by external authorities, such as governments, aimed at increasing the productivity of such resources can have negative consequences. The success of external regulation would highly depend on whether such formal punishments would substitute or complement existing informal managements (Lazzarini et al., 2004). Many cases have shown that externally imposed rules can replace existing arrangements, and hence, "crowd out" the established social norms (Cardenas et al., 2000). Our case shows that the decision when to step in for a regulator is complex as it depends not only on whether social norms can be preserved, but also how far from the first-best outcome the current arrangement is. An erosion of social norms is less costly if collectively enforced resource level is very low. So there is probably an optimal point of intervention, which is clearly below the optimal stock level, but also higher than the open access level. This could be an exciting path for further theoretical, and also experimental studies.

References

Agnew, D. J., Pearce, J., Pramod, G., Peatman, T., Watson, R., Beddington, J. R., and Pitcher, T. J. (2009). Estimating the worldwide extent of illegal fishing. *PLoS ONE*, 4(2):e4570.

Allison, E. H. and Ellis, F. (2001). The livelihoods approach and management of small-scale fisheries. *Marine policy*, 25(5):377–388.

Baland, J.-M. and Platteau, J.-P. (1996). *Halting degradation of natural resources: is there a role for rural communities?* Food & Agriculture Org.

Becker, G. S. (1968). Crime and punishment: An economic approach. *Journal of Political Economy*, 76(2):169–217.

Biggs, R., Carpenter, S. R., and Brock, W. A. (2009). Turning back from the brink: detecting an impending regime shift in time to avert it. *Proceedings of the National Academy of Sciences of the United States of America*, 106(3):826–831.

Biggs, R., Schlüter, M., Biggs, D., Bohensky, E. L., BurnSilver, S., Cundill, G., Dakos, V., Daw, T. M., Evans, L. S., Kotschy, K., Leitch, A. M., Meek, C., Quinlan, A., Raudsepp-Hearne, C., Robards, M. D., Schoon, M. L., Schultz, L., and West, P. C. (2012). Toward principles for enhancing the resilience of ecosystem services. *Annu. Rev. Environ. Resour.*, 37(1):421–448.

Boyce, J. R. (1995). Optimal capital accumulation in a fishery: A nonlinear irreversible investment model. *Journal of Environmental Economics and Management*, 28(3):324–339.

Bulte, E. H. and Horan, R. D. (2010). Identities in the Commons: The Dynamics of Norms and Social Capital. *The BE Journal of Economic Analysis & Policy*, 10(1):Art.13.

Cardenas, J. C., Stranlund, J., and Willis, C. (2000). Local environmental control and institutional crowding-out. *World Development*, 28(10):1719 – 1733.

Clark, C. (2006). *The Worldwide Crisis in Fisheries: Economic Models and Human Behavior.* Cambridge University Press, first edition.

Clark, C., Clarke, F., and Munro, G. (1979). The optimal exploitation of renewable resource stocks: Problems of irreversible investments. *Econometrica*, 47(1):25–47.

Clark, C. W. (1990). *Mathematical bioeconomics: the optimal management of renewable resources*. Wiley, second edition.

Copeland, B. R. and Taylor, M. S. (2009). Trade, tragedy, and the commons. *American Economic Review*, 99(3):725–49.

Costello, C., Ovando, D., Clavelle, T., Strauss, C. K., Hilborn, R., Melnychuk, M. C., Branch, T. A., Gaines, S. D., Szuwalski, C. S., Cabral, R. B., Rader, D. N., and Leland, A. (2016). Global fishery prospects under contrasting management regimes. *Proceedings of the National Academy of Sciences*, 113(18):5125–5129.

Crépin, A. S. (2007). Using fast and slow processes to manage resources with thresholds. *Environmental and Resource Economics*, 36(2):191–213.

Crépin, A.-S., Nörberg, J., and Mäler, K.-G. (2011). Coupled economic-ecological systems with slow and fast dynamics – modelling and analysis method. *Ecological Economics*, 70(8):1448–1458.

Dixit, A. (1992). Investment and hysteresis. *The Journal of Economic Perspectives*, 6(1):107–132.

Eigaard, O. R., Marchal, P., Gislason, H., and Rijnsdorp, A. D. (2014). Technological development and fisheries management. *Reviews in Fisheries Science and Aquaculture*, 22(2):156–174.

Finus, M. and Maus, S. (2008). Modesty may pay! *Journal of Public Economic Theory*, 10(5):801–826.

Gallic, B. L. and Cox, A. (2006). An economic analysis of illegal, unreported and unregulated (IUU) fishing: Key drivers and possible solutions. *Marine Policy*, 30(6):689 – 695.

Gordon, S. (1954). The economic theory of a common-property resource: The fishery. *Journal of Political Economy*, 62(2):124–142.

Gutierrez, N. L., Hilborn, R., and Defeo, O. (2011). Leadership, social capital and incentives promote successful fisheries. *Nature*, 470(7334):386–389.

Hilborn, R., Branch, T. A., Ernst, B., Magnusson, A., Minte-Vera, C. V., Scheuerell, M. D., and Valero, J. L. (2003). State of the world's fisheries. *Annual Review of Environment and Resources*, 28(1):359–399.

Huang, L. and Smith, M. D. (2014). The dynamic efficiency costs of common-pool resource exploitation. *American Economic Review*, 104(12):4071–4103.

Janssen, M. A. (2015). A behavioral perspective on the governance of common resources. *Current Opinion in Environmental Sustainability*, 12:1–5.

Lazzarini, S. G., Miller, G. J., and Zenger, T. R. (2004). Order with some law: Complementarity versus substitution of formal and informal arrangements. *Journal of Law, Economics, and Organization*, 20(2):261–298.

Lubchenco, J., Cerny-Chipman, E. B., Reimer, J. N., and Levin, S. A. (2016). The right incentives enable ocean sustainability successes and provide hope for the future. *Proceedings of the National Academy of Sciences*, 113(51):14507–14514.

Maunder, M. N., Sibert, J. R., Fonteneau, A., Hampton, J., Kleiber, P., and Harley, S. J. (2006). Interpreting catch per unit effort data to assess the status of individual stocks and communities. *ICES Journal of Marine Science: Journal du Conseil*, 63(8):1373–1385.

McKelvey, R. (1985). Decentralized regulation of a common property renewable resource industry with irreversible investment. *Journal of Environmental Economics and Management*, 12(4):287 – 307.

Melnychuk, M. C., Peterson, E., Elliott, M., and Hilborn, R. (2017). Fisheries management impacts on target species status. *Proceedings of the National Academy of Sciences*, 114:178–183.

Mirza, M. U., Richter, A., van Nes, E. H., and Scheffer, M. (2019). Technology driven inequality leads to poverty and resource depletion. *Ecological Economics*, 160:215 – 226.

Noailly, J., van den Bergh, J., and Withagen, C. A. (2003). Evolution of harvesting strategies: replicator and resource dynamics. *Journal of Evolutionary Economics*, 13(2):183–200.

Noailly, J., Withagen, C. A., and van den Bergh, J. (2007). Spatial Evolution of Social Norms in a Common-Pool Resource Game. *Environmental and Resource Economics*, 36(1):113–141.

Nøstbakken, L., Thébaud, O., and Sørensen, L.-C. (2011). Investment behaviour and capacity adjustment in fisheries: a survey of the literature. *Marine Resource Economics*, 26(2):95–117.

Nyborg, K., Anderies, J. M., Dannenberg, A., Lindahl, T., Schill, C., Schlüter, M., Adger, W. N., Arrow, K. J., Barrett, S., Carpenter, S., Chapin, F. S., Crépin, A.-S., Daily, G., Ehrlich, P., Folke, C., Jager, W., Kautsky, N., Levin, S. A., Madsen, O. J., Polasky, S., Scheffer, M., Walker, B., Weber, E. U., Wilen, J., Xepapadeas, A., and de Zeeuw, A. (2016). Social norms as solutions. *Science*, 354(6308):42.

Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press.

Ostrom, E. (2009). A general framework for analyzing sustainability of social-ecological systems. *Science*, 325:419–422.

Richter, A. and Dakos, V. (2015). Profit fluctuations signal eroding resilience of natural resources. *Ecological Economics*, 117(0):12–21.

Richter, A., Eikeset, A. M., van Soest, D., Diekert, F. K., and Stenseth, N. C. (2018). Optimal management under institutional constraints: Determining a total allowable catch for different fleet segments in the northeast arctic cod fishery. *Environmental and Resource Economics*, 69(4):811–835.

Richter, A. and Grasman, J. (2013). The transmission of sustainable harvesting norms when agents are conditionally cooperative. *Ecological Economics*, 93(0):202–209.

Richter, A., van Soest, D., and Grasman, J. (2013). Contagious cooperation, temptation, and ecosystem collapse. *Journal of Environmental Economics and Management*, 66(1):141–158.

Rust, S., Jennings, S., and Yamazaki, S. (2016). Excess capacity and capital malleability in a fishery with myopic expectations. *Marine Resource Economics*, 31(1):63–81.

Seijo, J., Defeo, O., and Salas, S. (1998). Fisheries bioeconomics: Theory, modeling and management. Fisheries Technical Paper 368, FOA.

Sethi, R. and Somanathan, E. (1996). The evolution of social norms in common property resource use. *American Economic Review*, 86(4):766–788.

Squires, D. and Vestergaard, N. (2013). Technical change in fisheries. *Marine Policy*, 42:286–292.

Tavoni, A., Schlueter, M., and Levin, S. (2012). The survival of the conformist: Social pressure and renewable resource management. *Journal of Theoretical Biology*, 299:152–161.

Taylor, M. S. (2011). Buffalo Hunt: International Trade and the Virtual Extinction of the North American Bison. *American Economic Review*, 101(7):3162–3195.

Taylor, P. D. and Jonker, L. B. (1978). Evolutionarily stable strategies and game dynamics. *Mathematical biosciences*, 40(2):145.

Varian, H. R. (1992). *Microeconomic analysis*. Norton & Company.

Villasante, S. and Sumaila, U. R. (2010). Estimating the effects of technological efficiency on the european fishing fleet. *Marine Policy*, 34(3):720 – 722.

Vollan, B. and Ostrom, E. (2010). Cooperation and the commons. *Science*, 330(6006):923–924.

Walker, B. H., Carpenter, S. R., Rockstrom, J., Crépin, A.-S., and Peterson, G. D. (2012). Drivers, "slow" variables, "fast" variables, shocks, and resilience. *Ecology and Society*, 17(3).

Whitmarsh, D. (1990). Technological change and marine fisheries development. *Marine Policy*, 14(1):15–22.

Worm, B., Hilborn, R., Baum, J. K., Branch, T. A., Collie, J. S., Costello, C., Fogarty, M. J., Fulton, E. A., Hutchings, J. A., Jennings, S., Jensen, O. P., Lotze, H. K., Mace, P. M., McClanahan, T. R., Minto, C., Palumbi, S. R., Parma, A. M., Ricard, D., Rosenberg, A. A., Watson, R., and Zeller, D. (2009). Rebuilding global fisheries. *Science*, 325(5940):578–585.

Yletyinen, J., Hentati-Sundberg, J., Blenckner, T., and Bodin, r. (2018). Fishing strategy diversification and fishers' ecological dependency. *Ecology and Society*, 23(3)(3):28.

Paper 2

Risk, restrictive quotas, and income smoothing

In collaboration with Florian Diekert, Exequiel Gonzalez-Poblete, and Karin Loreto Silva Aedo.

Abstract: Income shocks due to climate change or overexploitation can result in severe hardships for natural resource users who are unable to smooth consumption. Artisanal fishers in Chile vary in their ability to smooth consumption due to regulatory differences. Utilizing these regulatory differences, we find that survey participants that harvest species which are governed by restrictive quotas have preferences for more precautionary savings compared to survey participants whose harvest is not restricted. The inability to adjust harvest increases the importance of self-insurance through saving. Especially in developing countries, where formal saving opportunities are limited, policies that aim at stabilizing resource productivity through restrictive quotas need to account for available consumption smoothing strategies to avoid unintended welfare losses.

Keywords: Bioeconomics, Labour flexibility, Property rights, Higher order risk preferences, Precautionary saving, Fisheries

2.1 Introduction

Access to natural resources provides insurance, both along the extensive margin, as a "livelihood of last resort" (Hannesson et al., 2010), and along the intensive margin, when resource users increase labour in response to negative shocks (Béné et al., 2010; Kleemann and Riekhof, 2018). However, increasing harvesting in times of need imposes an externality on other resource users by reducing yields and increasing resource variability (in its extreme form, overharvesting may lead to stock collapse). In times of low productivity, users would ideally draw on savings or seek labour elsewhere. Still, when outside options are limited, financial services are underdeveloped, and mobility is low, people can have little choice except to harvest more (Jayachandran, 2006). This feedback loop of using natural resources as insurance, which increases resource variability, which in turn increases the need for insurance gives rise to a particular form of a poverty trap: an "ecological insurance trap" (Berry et al., 2019).

In many countries, policies that restrict harvesting have been implemented to stabilize catch levels and secure resource productivity, breaking the vicious cycle of an ecological insurance trap.[1] However, the introduction of restrictive harvest quotas implies a well-known trade-off between short-term and long-term welfare. In the short-term, restricting harvest means reduced income. Whether this can be compensated by increased income in the long-term depends on the recovery rate of the resource, the discount rate, and the distributional consequences of the policy (Clark, 1990; Noack et al., 2018; Okonkwo and Quaas, 2020).

In this paper, we highlight an additional trade-off that comes with imposing restrictive regulations. On the one hand, harvesting regulations can reduce resource variability and reduced variability generates a long-term welfare gain for resource users: The reason is simply that the chance of temporary or sustained reductions in resource productivity, which can result in harmful periods of low income, decreases. On the other hand, restrictive harvesting regulations reduce the ability of resource users to increase their harvesting effort in response to negative shocks (Béné et al., 2010; Nunan, 2014). As a consequence, resource users will have to rely more on precautionary savings or other strategies for smoothing income and consumption. Alternative income smoothing strategies and holding precautionary savings may be costly, insufficient, or non-existent, leading to a short-term welfare loss.

The long-term/short-term trade-off in the variability domain has been largely overlooked in the literature, but it is particularly relevant as more and more developing and middle-income countries strive to improve resource governance by issuing restrictive harvest quotas. Policy makers need to understand how limiting labour flexibility (through restrictive quotas) is associated with an increased demand for precautionary savings, and how this is related to income variability. To the best of our knowledge, the only empirical study on this topic comes from Kasperski and Holland (2013). The authors show that the introduction of individual quotas in the US West-Coast fisheries has reduced the ability of resource users to diversify. By implication, resource users are less able to buffer negative income shocks.

Here, we provide direct evidence for the empirical link between restrictive quotas, income variability and the need for precautionary savings. Specifically, we present results from an

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[1] For fisheries, there is by now ample evidence that capping overall harvest has succeeded in reducing variability in stock levels and decreasing the risk of stock collapse (Costello et al., 2008; Essington, 2010; Isaksen and Richter, 2019).

economic survey and experiment among Chilean artisanal fishers that we combine with official fisheries data. We determine whether fishers whose harvest opportunities are restricted require different amounts of precautionary savings than fishers that are not restricted. Further, we compare the income variability of restricted and unrestricted fishers and explore whether the effect of larger income variability on the need for savings depends on the degree to which fishers' harvest set is restricted. The artisanal fisheries in Chile offer a unique setting to study these questions because the fisheries vary strongly in the spatial availability of different commercial species and in the degree to which harvesting is restricted.

Chile is a middle-income country that shares elements of developed economies with modern industries and relatively well functioning governance institutions as well as elements of developing economies with low uptake of formal savings accounts (Dupas et al., 2018) and limited social security expenditure (OECD, 2019; Benítez and Nava, 2016). Hence, understanding the trade-off from imposing restrictive regulations on harvesting is relevant in Chile in its own right, but it is also of interest for natural resource management in other regions of the world.

Our dataset contains survey answers on income variability and precautionary savings as well as incentivized choices on prudence and risk-aversion from 433 fishers in the Coquimbo, Valparaíso and Bío-bío regions of Chile. We classify fishers' labour flexibility based on the fraction of their income generated from harvesting species with restrictive quotas, and find that the restricted group considers their income from fishing to be less variable compared to the non-restricted group. Still, restricted fishers require, on average, an additional nine weeks of expenses saved up in order to feel secure. Furthermore, we find that the perceived income variability increases the need for savings, but only for those fishers whose harvesting opportunities are restricted. We show that these results are not due to risk-aversion or prudence preferences. Furthermore, we exploit the spatial variability in the Chilean setting and show that the results also hold in a sub-sample of fishers that concentrate on the same portfolio of species but are differently restricted because their portfolio weights differ due to differences in resource availability. Finally, we make use of the fact that some of our respondents have a long tenure in their fishery. Hence, we can rule out selection effects by conducting our analysis on a sub-sample of fishers that have started fishing at a time when there were no restrictions on any species.

2.2 Literature review and conceptual framework

In the following, we give a brief overview of the literature on how flexible labour is used to smooth income and on harvesting variability in fisheries (section 2.2.1 and 2.2.2), to serve as the background for the conceptual framework that we develop to frame the empirical analysis (section 2.2.3).

2.2.1 Income smoothing and labour flexibility

Failure to smooth income can have severe negative welfare impacts, such as the loss of productive assets (Debela et al., 2011), food insufficiency leading to malnutrition (Leete and Bania, 2010), and children dropping out of education (Dercon, 2002). Individuals and households can adopt both ex-ante and ex-post strategies to smooth consumption. A common method is to transfer consumption between periods, either through saving in good periods, or by borrowing in bad periods. Another strategy is insurance. Policies such as health or unemployment insurance that can significantly reduce the impacts of particular shocks. Also informal risk sharing networks among family and or peers can reduce the impacts of shocks when financial markets are insufficiently developed or too costly to use. Finally, adjusting labour supply can increase income after a negative shock. However, this strategy is not available for all households as labour flexibility and outside options are often limited.

When labour supply is fixed and there are no other income smoothing options, a negative shock to income or an unexpected expense, such as the need to care for parents or children, will directly translate to a reduction in consumption. However, when labour supply is flexible, households can increase labour in order to mitigate the loss in consumption (Bodie et al., 1992). Whilst increasing labour comes at a cost, the overall harm of the bad financial outcome will be lower. Early evidence of this is presented by Kochar (1995), who shows that Indian farmers with access to non-farming labour markets are better able to mitigate idiosyncratic income shocks. However, as. Kochar (1995) points out, non-farm labour is not a suitable smoothing mechanism for other shocks that affect the labour capacity of the household, such as sickness or loss of family members.

By now, there is a large empirical literature that shows how labour flexibility can be used to reduce the impact of negative shocks for individuals. Dupas et al. (2020), for example, study labour supply and daily cash needs of Kenyan bicycle taxi-drivers. They find that drivers work longer hours if their cash needs for that particular day are greater, and are more likely to stop working when their cash needs are met. In developed countries the rise of flexible labour platforms, such as MTurk, Uber, and Lyft, has given individuals a method to supplement income and buffer negative shocks (Farrell and Greig, 2016; Chen et al., 2019).

Labour flexibility also plays an important role in common shocks that affect larger groups simultaneously. During the Asian financial crisis, the entire Indonesian population was hit as the consumer price index rose by 80% in 1998. In response, households worked 25 hours more per week to compensate for the reduction in real wages (Frankenberg et al., 2003). Whilst the increase in labour allows households to compensate for the decrease in productivity, it means working longer hours for a lower wage. Jayachandran (2006) highlights that workers in underdeveloped regions are particularly vulnerable to shared productivity shocks, as they lack the ability to make transfers between periods or migrate in response to low wages. The author studies the labour supply of agriculture workers in response to productivity shocks in Indian districts that differ in financial development and finds that agricultural wages fluctuate significantly less when there is a higher level of banking activity and lower transaction costs to use financial markets.

Both idiosyncratic fluctuations and common shocks are particularly relevant for natural resource users. First, natural resource users often face substantial occupational hazards at the same time as living in rural and peripheral areas with limited opportunities to provide care for children or parents, and lower financial development. Second, the resource base itself varies due to natural causes and increasingly due to climate change or overexploitation. However, increasing extraction to smooth consumption in times of low productivity is a double-edged sword as it may exacerbate negative resource shocks, leading to an ecological insurance trap.

2.2.2 Labour flexibility and fisheries

In the absence of formal constraints on effort or landings, fishers have a high degree of labour flexibility as they control how many trips they make and when to return on a trip. The allocation of effort will be determined by the combination of the fishers' preferences and the expectations about the returns from the fishing trip (Hammarlund, 2018; Giné et al., 2017). Traditionally, small-scale fishers are modelled as rational profit maximizers. In aggregate, fishers will increase harvesting effort up until the point that the marginal gain is zero (Clark, 1990). In this framework, harvesting effort increases in response to higher prices or productivity, and declines when costs increase. However, individual fishers can adjust effort for different motivations, such as reaching a minimal level of consumption. Upon experiencing a negative shock, such as an unexpected expense, fishers are able to increase their harvesting effort in order to reach this minimal level of consumption. If the need for additional income is great enough, even a decrease in the resource price or productivity could cause an increase in effort, as the fisher has to work longer in order to reach the same level of income (Panayotou, 1982).

In other words, harvesting effort is used as a consumption smoothing mechanism. However, there is a point at which the resource is so depleted or prices are so low, that it is no longer feasible to increase effort to reach the break-even point. Prolonged low levels of productivity will motivate some fishers to leave the fishery (Cinner et al., 2009; Daw et al., 2012). Yet, even when it is economically rational to exit the fishery, fishers are often reluctant to do so due to non-malleable capital investments, lack of marketable skills or occupational identity. leading fishers to use more effective but destructive gear types (Cinner et al., 2009) or become involved in other illegal activities such as piracy (Axbard, 2016).

To curb the negative biological consequences of open-access, almost all commercially important fisheries in developed countries have regulations that restrict effort or landings. The most common types of regulation is a limit on the total allowable catch (TAC). The TAC is the upper limit for the collective harvest of a certain species or group of species for a year or fishing season. Limits on catches can restrict labour flexibility, as fishers are no longer able to increase their effort if this would violate the upper limit set by the TAC. In high value fisheries, the limit on fishing opportunities can create strong incentives to land fish as quickly as possible (Birkenbach et al., 2017). In these scenarios of "regulated open-access" (Homans and Wilen, 1997), labour flexibility is limited, as all income has to be generated in a short time window and the maximum earning is capped. Conversely, there are fisheries such as the Swedish Baltic cod fishery, where the TAC is so high that even at the end of the fishing season it is still possible for fishers to land more (Hammarlund, 2018). In this scenario, fishers' labour flexibility is similar to that of an unrestricted fishery.

To avoid the social inefficiencies of regulated open-access, an increasing number of fisheries are managed with catch shares, where individuals or groups are granted exclusive rights to a percentage of the TAC. In these fisheries, individual fishers or cooperatives receive a quota at the start of the season, which in some cases can be traded with other eligible fishers. The key positive effect of catch shares is to remove incentives for competition as the individual quota is guaranteed (Birkenbach et al., 2017). So whilst catch shares limit the maximum harvest and income, they allow for flexible allocation of effort over time. The flexibility to spread effort over time, for example, allows for reduced risk taking by fishers (Pfeiffer and Gratz, 2016). Nevertheless, the individual harvest, and hence the opportunity to smooth consumption in reaction to income shocks, is restricted by the individual quota (unless, of course, there is a functioning market for quotas).

Given restrictive quotas, fishers may adjust effort to smooth consumption by diversifying their harvesting activities to other restricted or non-restricted resources. However, doing so can be costly when it requires the acquisition of new gears and permits (Kasperski and Holland, 2013). Diversification is furthermore often limited by the local availability of natural resources. Alternatively, fishers can engage in illegal fishing, by harvesting the same species even though its quota is exhausted (Gallic and Cox, 2006). When outside labour markets are available, labour supply can also be displaced to non-fishing occupations in order to smooth consumption. That said, many fishing communities are in peripheral and underdeveloped areas where outside opportunities are scarce.

Recent papers have been generally positive about the role of catch shares in reducing income variability for fishers. The implementation of catch share in North American fisheries has been successful in reducing inter-annual variation in landings and biomass (Essington, 2010). Furthermore, Isaksen and Richter (2019) find that the introduction of catch shares leads to a 7-10% reduction in the risk of a stock collapse in a global panel of over 800 species and 170 exclusive economic zones. As Isaksen and Richter (2019) highlight, catch shares are particularly effective when strong ownership protection and transferability of quotas are given. Their finding echoes the point made by Copeland and Taylor (2009) who highlight that the positive effects of catch shares is facilitated by the strong regulatory power of developed economies. Whether catch shares would be effective in developing countries is uncertain, as the institutional framework for these policies is often lacking (Jardine and Sanchirico, 2012). In particular, the aspect of quota tradability – which would re-introduce flexibility – is politically challenging and requires substantial institutional capacity.

Restrictive regulations and catch shares are important tools for the sustainable governance of natural resources. However in the absence of a functioning market for catch shares, restrictive regulations effectively shut down an important channel for consumption smoothing.

Alternative methods for smoothing consumption are necessary to prevent welfare losses due to unmitigated fluctuations in income and consumption. To date, there is no study that analyses how restrictive regulations affect individual fishers and their ability to cope with income variability.

2.2.3 Conceptual framework

Here, we introduce a simple framework to organize our empirical analysis of labour flexibility (restrictive quotas), income variability, and the need for precautionary savings. To focus directly on the need for precautionary savings y, we define y as the gap between expenses x and current income π (which is a function of effort e) for a given realization of a shock ε to either wealth or productivity:

$$y = x - \pi(e) + \varepsilon \tag{2.1}$$

For simplicity, we consider that ε is the only random variable. It captures all risk that is not further insurable and cannot be covered by smoothing consumption along other margins such as relying on informal networks or outside opportunities. One could also think that income from harvesting has a deterministic component $f(e)$ as well as a random component ε such that $\pi(e) = f(e) - \varepsilon$. Alternatively, one could think that total period expenses (x) consist of a constant base level of expenses (x_0) and a period specific shock (ε) such that $x = x_0 + \varepsilon$. Equation (2.1) is a budget-balance condition that could result from a more complete intertemporal optimal savings and effort problem that we do not model here.

We assume that income from fishing is increasing in effort ($\pi' > 0, \pi'' < 0$) but that there is an implicit cost of effort such that an agent would choose a level of effort e^*, even if the random shock were zero or positive.[2] Now for a negative shock to income or wealth, $\varepsilon < 0$, the agent can either increase effort beyond e^*, or consume savings. Without any restrictions on effort, e is chosen so that the marginal cost of increasing effort beyond e^* equals the marginal cost of precautionary savings (which could be substantial in a developing country). [3] When effort is restricted to $e \leq \bar{e}$, however, the agent may end up in a situation where she cannot adjust effort, but the constraint $\bar{e}$ becomes binding. In this case, she would need more savings to cover her expenses. Figure 2.1 illustrates the effort allocation by a restricted and an unrestricted agent in response to a negative shock.

The simple conceptual framework has three implications: First, because restricted agents are not flexible to adjust effort according to needs, they will have a lower variability in fishing

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[2] Such an assumption is well in line with models where agents have to cover basic needs, e.g. (Kleemann and Riekhof, 2018), and with the empirical observations from flexible labour supply, e.g. (Dupas et al., 2020)

[3] The marginal cost of precautionary savings consists of the loss in consumption in the savings period, discounting, and transaction costs. These include the risk of theft in the informal sector, banking costs in the formal sector, search costs, and any mark-ups by formal or informal agents.

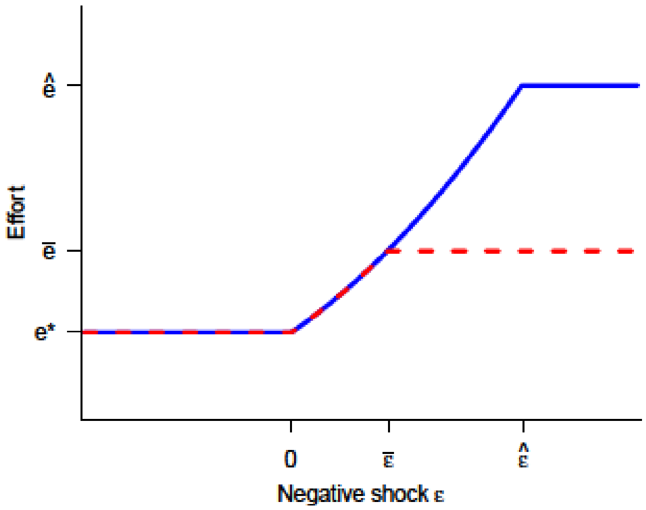

Figure 2.1: The graph illustrates how effort allocation (e) changes in response to a negative shock ε. The blue solid line indicates the level of effort that the unrestricted agent exerts. The restricted agent (red dashed line) follows the same path, but can only increase effort till $\bar{e}$, corresponding to a shock $\bar{\varepsilon}$. After this point, expenses have to be covered by savings. The unrestricted agent will turn to savings only after a shock of size $\hat{\varepsilon}$. At this point, relying on savings is more efficient than increasing effort beyond $\hat{e}$.

income than unrestricted agents. Conversely, unrestricted agents can adjust effort according to needs, which translates into a larger variability of fishing income.[4]

Second, restricted agents need to rely on savings to a larger extent (once the constraint $e \leq \bar{e}$ becomes binding). In contrast, unrestricted agents can buffer larger income shocks and only turn to savings after large negative shocks, namely when the marginal cost of savings exceed the marginal cost of adjusting effort (the level $\hat{e}$ in Figure 2.1).

Third, the budget-balance condition, equation (2.1), highlights that more risk (in terms of a mean-preserving spread of ε) translates to an increased need for savings y, especially for agents whose effort is restricted. For these agents, a mean-preserving spread of ε implies more variable income from harvesting, but also more cases in which the constraint $e \leq \bar{e}$ becomes binding and in which the agent has to turn to precautionary savings to cover expenses. For

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[4] To show this formally, presume that there are just two, equally likely, realizations of the shock ε^{pos} and ε^{neg} with $\varepsilon^{neg} \in (\bar{\varepsilon}, \hat{\varepsilon})$. Since e^* is the optimal effort choice given ε^{pos} for both the restricted and the unrestricted agent, but the restricted agent has to choose $\bar{e}$ given ε^{neg}, while the unrestricted agent can choose $e > \bar{e}$, we have:

$$\mathrm{var}[\pi^{R=1}] < \mathrm{var}[\pi^{R=0}]$$

$$\Leftrightarrow$$

$$\frac{1}{2}\pi(e^*)^2 + \frac{1}{2}\pi(\bar{e})^2 - \left(\frac{1}{2}\pi(e^*) + \frac{1}{2}\pi(\bar{e})\right)^2 < \frac{1}{2}\pi(e^*)^2 + \frac{1}{2}\pi(e)^2 - \left(\frac{1}{2}\pi(e^*) + \frac{1}{2}\pi(e)\right)^2$$

$$\Leftrightarrow$$

$$\frac{1}{2}\left(\pi(\bar{e})^2 - \pi(e)^2\right) < \frac{1}{4}\left((\pi(\bar{e}) + \pi(e^*))^2 - (\pi(e) + \pi(e^*))^2\right)$$

$$\Leftrightarrow$$

$$2\pi(e^*) < \pi(\bar{e}) + \pi(e)$$

unrestricted agents, a mean-preserving spread of ε also implies more variable income from harvesting (as effort can be adjusted), but it translates into a larger need for precautionary savings only when the costs of savings are lower than the costs of adjusting effort (the point $\hat{\varepsilon}$ in Figure 2.1).

The following summarizes the three predictions that we should observe empirically:

Prediction. *Compared to an unrestricted agent (R=0), a restricted agent (R=1):*

1. *Has a lower variability of fishing income:* $\text{var}[\pi^{R=1}] < \text{var}[\pi^{R=0}]$
2. *Requires more savings to balance their budget:* $y^{R=1} > y^{R=0}$
3. *Is more sensitive to a mean-preserving spread in X (requires more additional savings the larger the variance in X).*

If we just consider the budget balancing condition, the relation between the experienced shock, the limitations to effort and necessary amount of savings is mechanical, and should therefore be independent of risk preferences. Simply put, those with unconstrained effort can cover income shocks with either increased effort or savings, whilst those that are constrained can only rely on savings. Everything else being equal, the restricted agent would always need more savings than the unrestricted agent to balance the budget.

However, when determining the optimal level of savings in a multi-period model, the agent's risk aversion and prudence will have to be taken into account. Risk aversion influences the optimal distribution of expected utility, effort and consumption between periods, and prudence influences the agent's optimal level of precautionary savings for the given level of uncertainty. The extent to which the agent's degree of risk-aversion and prudence affects these decision differently if effort is restricted is theoretically ambiguous.[5] Therefore, we control for the agent's levels of risk aversion and prudence in the empirical analysis.

Note that our conceptual model does not say anything on the long-term gains in terms of increased stock levels and reduced resource variability from restricting flexibility. These long-term gains are likely to be substantial and may by far outshadow short-term losses. The point here is to emphasize welfare losses due to the limited ability to smooth consumption. These welfare losses are particularly relevant when financial markets are inaccessible.

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[5] Flodén (2006) and Nocetti and Smith (2011) touch upon these issues in their respective models. For example, Flodén (2006) shows that the standard measure of prudence by Kimball (1990) would give inaccurate predictions for precautionary savings when labour supply decisions are endogenous. Nocetti and Smith (2011) highlight with a numerical example under Cobb-Douglas utility that risk aversion can have different effects on precautionary saving based on the source of the risk. They show that for certain parameter values increasing risk aversion, decreases saving for wage risks, whilst it increases saving for non-wage risks.

2.3 Field setting

Chile is considered to be at the forefront in Latin America regarding the use of rights based fisheries management. The adoption of catch share systems and territorial use rights severely restricted harvesting in the early 2000s. This management effort was instrumental in the recovery of several Chilean marine resources (Gelcich et al., 2010). At the same time, a large part of Chilean marine resources remains under de-facto open-access regimes or existing TAC quotas are far from binding. The resulting diversity in regulatory regimes makes Chile an ideal setting to study how restrictive regulations affect fishers' ability to cope with income variability.

The Chilean fishing sector is divided into the industrial sector, which is comprised of a small number of larger vessel and the artisanal sector. The artisanal fishing sector is substantial, employing roughly 91.000 people and landing 1.159.000 tons of fish in 2019 (SERNAPESCA, 2019a). [6] The individual artisanal fishers operate on a relatively small scale as they are only allowed to own up to two vessels, which are limited in size (length: 18m, hold capacity 80m^3, combined gross tonnage of both vessels: 50 tons).

Artisanal fishers need to be registered in a national database and are required to hold licenses for the gear they utilize and the species they land. Most of the economically relevant fisheries are closed to new entrants. It is common for fishers to organize in fisheries orga-

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[6] Please refer to Castillo and Dresdner (2012) for information on the different sectors and Castilla (2010) for an overview and history of the Chilean fisheries and aquaculture law.

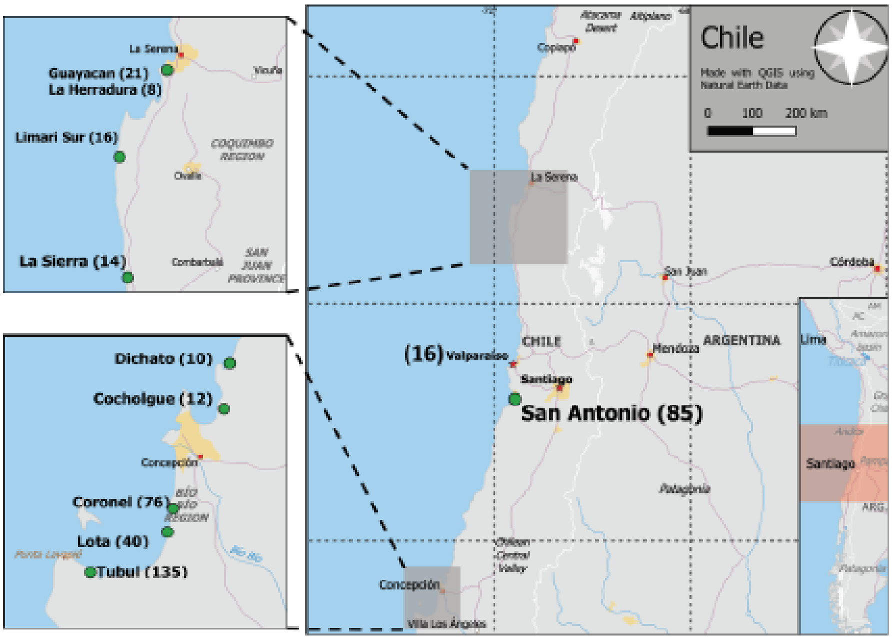

Figure 2.2: Map of Chile with green dots indicating visited locations. The number between brackets indicates fishers sampled from that location. Most of the visited locations were either near Concepción in the Bío-bío region or near La Serena in the Coquimbo region. These areas are marked with a grey overlay and a higher resolution zoom of these areas is presented on the left.

nization, which are necessary to gain access to certain types of fishing rights. Organizations generally consist of fishers living in the same location (often called fishing cove or 'caleta'). Within the organizations there is often significant overlap in the chosen fishing activities. There are organizations specifically for pelagic fishers and for benthic fisheries associated with harvesting molluscs (such as Almeja, Macha and Loco) and macroalgae through diving and beach collecting, but there are also more general organizations. The fisheries organizations are also used as contact point between fishers and the government to deal with various management and development issues.

The Chilean coast is a productive, yet variable marine ecosystem. The upwelling caused by the Humboldt current supplies the coastal waters with abundant nutrients, but the strength of the Humboldt current oscillates due to climatic events. The upwelling of nutrient rich waters is stronger during La Niña periods that alternate with El Niño periods with weaker upwelling (Gomez et al., 2012). Due to the variable availability of nutrients, the productivity and growth of the resources dependent on it is also variable. The most notable species affected by this are the small pelagic fish species: anchovy (*Engraulis ringens*) and common sardine (*Strangomera bentincki*), which accounted for 39% of the total tonnage landed by the Chilean artisanal fishing sector in 2017. There are considerable variations in abundance of the two species between years, as both species are fast growing and heavily dependent on yearly recruitment for biomass (Cubillos et al., 2002). This is reflected in the variability of yearly landings, with the most pronounced decline between 2012 and 2013, where artisanal landings dropped from 583 thousand tons to 172 thousand tons.

The anchovy and common sardine fishery was closed to new entrants in 2001 and a TAC was instituted to protect the stock from overexploitation (Estrada et al., 2018). In 2004 the Chilean government introduced a catch share system called the Régimen Artesanal de Extracción(RAE). Through the RAE, qualifying fisheries organizations were able to get exclusive rights to a share of the TAC. The size of the share was based on the history of fishing of the organizations' members. The fisheries organizations were then able to distribute the quota to its members internally. Over the years there has been dissatisfaction about the low level of the obtained quotas. In 2019, the Chilean government agreed to raise the TAC (SERNAPESCA, 2019b).

2.4 Methods and data

In order to study empirically whether limiting labour flexibility (through restrictive quotas) is indeed associated with an increased need for precautionary savings, and how this is related to income variability, we combine official fisheries data with data from an economic survey and experiment among Chilean artisanal fishers.

Based on this data, we construct a measure of fishers' labour flexibility: We order fishers by the share of their income that comes from harvesting species with restrictive quotas. This ordering yields a continuous measure R_i (between 0 and 1) of fishers' degree of labour flexibility. Further, we use this measure to classify fishers as either belonging to the restricted group (if R_i>0.5), or the unrestricted group (if $R_i \leq 0.5$).

In order to test the first two theoretical prediction that restricted fishers (1) have a lower variability in fishing income and (2) require more precautionary savings, we compare the distributions of the respective measures across the two groups. We then turn to regression analysis to test our third theoretical prediction that restricted fishers respond stronger to an increase in income variability than unrestricted fishers. Our regression model takes the following form:

$$y_i = \beta_0 + \beta_1 R_i + \beta_2 V_i + \beta_3 (R_i \times V_i) + \mathbf{X}_i \gamma + \varepsilon_i \tag{2.2}$$

where y_i is the perceived need for savings, R_i is our measure of labour flexibility, and V_i is our measure of income variability. We thus test whether the coefficient β_3 in (2.2) is positive. In addition, the regression analysis allows us to control for a vector of observable control variables $\mathbf{X}_i$ that may influence the perceived need for precautionary savings.

Note that the dependent variable measures the need for precautionary savings in weeks of expenses, not the actual level of precautionary savings. In contrast to the actual level of savings, the standardized need for savings is not affected by the wealth level of the individual. This allows us to measure precautionary savings without having a measure of wealth, which participants are weary of sharing information on. Furthermore, to address the potential concern that differences in the need for precautionary savings are not due to differences in how restricted fishers are, but due to other factors, such as the mode of production, we exploit the fact that a range of pelagic fishers use the same type of gears and target the same set of species, but – due to geographical differences – have very different portfolios weights of restricted and unrestricted catches. Repeating our regression analysis on this sub-sample can thus alleviate concerns about omitted variable bias. To address potential concerns about selection bias, we can exploit the fact that a large share of our participant pool has a long tenure in fishing and started before harvest has become restricted for some species in the early 2000s.

2.4.1 Experimental sessions

Between the 29th of October and the 24th of November 2018 we held 25 experimental sessions, with a total of 433 participants in the Coquimbo, Valparaíso and Bío-bío regions of Chile, see Figure 2.2 for a map indicating the visited locations[7]. Fisheries organisations were approached

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[7] In the analysis we omit the data of 14 participants whose household income from fishing was less than 25%.

by researchers of the Pontificia Universidad Católica de Valparaíso (PUCV) during a round of preparatory visits in September 2018. When there was interest from the fisheries organization to participate, the contact person of this fisheries organization was asked to invite participants for the session. If a minimum number of fishers agreed to participate, a meeting was scheduled. The sessions had between 8 and 22 participants. Organizations were selected such that the following fishing activities would be included in our sample: (1) fishers for small pelagics (sardine and anchovy), (2) Humboldt squid fishers, (3) crab fishers and (4) a range of benthic gatherers, including beach collectors and divers, for molluscs, kelp, and algae. The specifications for these groups are broad and we expected substantial heterogeneity within the target groups. Therefore, we elicited the set of target species and classified each fisher individually.

Each session consisted of a series of incentivized preference questions and a demographics survey. We measured risk aversion, prudence, and cooperative preferences using incentivized choices. At the end of the sessions one of the three preference questions was randomly chosen to be paid out. The preference questions and demographic survey were answered on tablets running OpenDataKit survey software (Hartung et al., 2010). The sessions lasted between 1.5 and 2 hours. Participants were paid 10,000 Chilean pesos (CLP) for finishing the survey and could earn an additional 24,000 CLP with the incentivized preference questions. The average payout was 18,100 CLP, which at the time was equivalent to 23.76 Euro.

2.4.2 Measuring the need for precautionary savings

To measure the need for income smoothing trough precautionary saving we ask the participants a survey question used in the Bank of Italy Surveys on Household Income and Wealth (SHIW) in 2002 and 2004. We diverge from the SHIW by asking the participants to express their answer in weeks of expenses, as opposed to a quantity of money.[8] We did so to standardize for income, as the subject pool is weary of sharing data regarding their income and wealth. Our question was phrased as follows:

> *People save in various ways, (depositing money in a bank account, hiding it under their mattress, buying property, or other assets) and for different reasons. A first reason is to prepare for a planned event, such as the purchase of a house, children's education, etc. Another reason is to protect against uncertainty about future earnings or unexpected expenses (owing to health problems or other emergencies). About how many weeks of expenses do you and your family need to have in savings, to meet such unexpected events?*

We intentionally do not elicit the current level of precautionary savings, as their savings can be depleted due to previously experienced shocks or saving could have been infeasible due to low levels of income (Deidda, 2013). By asking for the perceived need for precautionary savings we measure the level of income smoothing which has to be done through savings, as opposed to risk sharing networks or labour flexibility.

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[8] The original question reads: "People save in various ways (depositing money in a bank account, buying financial assets, property, or other assets) and for different reasons. A first reason is to prepare for a planned event, such as the purchase of a house, children's education, etc. Another reason is to protect against contingencies, such as uncertainty about future earnings or unexpected outlays (due to health problems or other emergencies). About how much do you think you and your family need to have in savings to meet such unexpected events?"

2.4.3 Measuring labour flexibility

To measure participants' labour flexibility, we classify to what extent participants operate under restrictive regulations. This is expressed as the fraction of their income which is generated by harvesting species which have a restrictive quota. We consider a species to be managed with a restrictive quota, when the quota for said species was filled for more than 95% in 2018, and non restricted if either the 2018 quota was not met, or no quota was present. See Appendix A-1 for the lists of restricted and unrestricted species and the respective quota system per species per region.

During the sessions, participants were presented with a nearly exhaustive list of commercially fished species. They were asked to mark all species that contribute significantly to their income and were given the option of writing down any missing species in an open text field. The set of target species of participant i is indicated with X_i, the subset of target species with restrictive regulations is indicated by X_i^R. The measure for exposure to restrictive regulation R_i is calculated by dividing the income generated from target species with restrictive regulations with the income generated by the complete set of target species, see equation (2.3). The income of fishers is approximated with landings data on the level of the fishing cove (caleta) and was averaged over the period from 2008 to 2018. We utilized the official landing and price figures of the Chilean fisheries service (SERNAPESCA).[9]

$$R_i = \frac{\sum_x^{X_i^R} \pi_{x,i,j}}{\sum_x^{X_i} \pi_{x,i,j}} \tag{2.3}$$

The distribution of R_i over our sample is presented in Figure 2.3. The graph shows a bimodal distribution in which most fishers either harvest only species with restrictive quotas or only species without restrictive quotas, but there are also some fishers that harvest a mix of restricted and unrestricted species. We refer to those fishers that mostly harvest restricted species ($R_i > 0.5$) as the restricted group and to those fishers that harvest mostly unrestricted species ($R_i \leq 0.5$) as the unrestricted group.

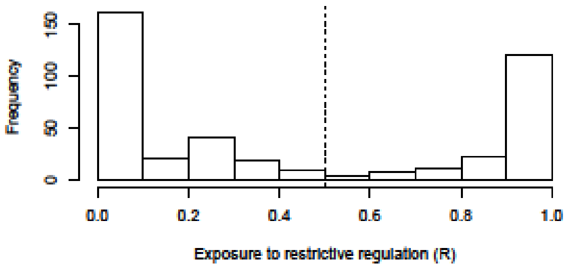

Figure 2.3: The distribution of R_i, showing how restricted fishers' harvesting opportunities are.

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[9] For certain years price data of a species was missing, in these cases the average of the nearest available years was used.

2.4.4 Measuring income variability from harvesting

Our method for eliciting perceived income variability from harvesting is based on a series of questions originally used in the 1995 Bank of Italy Survey of Households Income and Wealth (SHIW).[10] We elicit the expected variability in next year's fishing income. To do so we ask the participants to give their maximum (Y_{max}) and minimum expected income (Y_{min}) from fishing for the next year. The responses were elicited as fractions of a typical yearly income. We also ask the chance that they will earn less than a typical year (z). The questions are phrased as follows:

(i) *Suppose that in the next year you will continue fishing. What is the minimum income that you expect to earn from fishing, compared to a typical year?*
(ii) *Suppose that in the next year you will continue fishing. What is the maximum income that you expect to earn from fishing, compared to a typical year?*
(iii) *What are the chances that you will earn less than you would in a typical year?*

The fist two questions elicit the range of possible outcomes. To give a likelihood to each outcome we assume a double triangular distribution. Under this distribution the typical yearly income is the most likely and the extremes are least likely, as in Figure 2.4. The third question distributes the probability mass between the two triangular distributions.[11] Based on the constructed distribution we calculate the standard deviation of expected income using equation which will be used as the participants' value for variability V_i.[12]

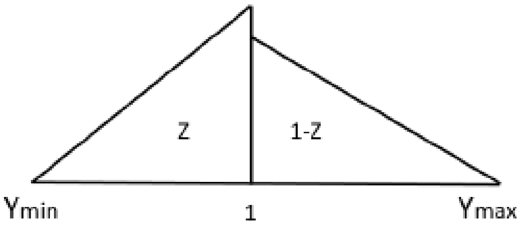

Figure 2.4: Depiction of the double triangular income distribution, where Y_{min} is the minimum expected income from harvesting, Y_{max} is the maximum expected income from harvesting, and z is the subjective probability for earning less than a typical year. We assume that the density of the distribution is highest at a typical yearly income and normalize this value to 1.

2.4.5 Control variables

We present the socio-economic characteristics of our participants split between the restricted and unrestricted groups in Table 2.1. The presented variables will be used as controls in later

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[10] Results from this data can be found in Guiso et al. (2002). Other applications use the SHIW question to estimate returns from labour and marriage markets (Attanasio and Kaufmann, 2017) and returns from schooling in a labour market field experiment in Uganda (Alfonsi et al., 2020).

[11] If reported expected minimum income was greater than the expected maximum income, the two values were switched. If the answer to question (i) was missing we assumed the probability to be 50%.

[12] Specifically, we have: $V_i = \left(z\frac{Y_{min}^2+2Y_{min}+3}{6} + (1-z)\frac{Y_{max}^2+2Y_{max}+3}{6} - z\frac{Y_{min}+2}{3} - (1-z)\frac{Y_{max}+2}{3} \right)^{\frac{1}{2}}$, where Y_{min} is the respondent's answer to the first question, Y_{max} is the respondent's answer to the second question and the probability weight on the lower triangle, z, is the answer to the third question. See Guiso et al. (2002) for details.

regression and were chosen based on a recently conducted review of the empirical precautionary savings literature (Lugilde et al., 2018). We utilize age as a proxy for health status.

	Restricted	Unrestricted	p-values
Age	50.27	46.7	0.004
Gender (male = 1)	0.91	0.71	≤ 0.001
Children (yes/no)	0.83	0.76	0.694
Parents live here	0.74	0.80	0.231
City	0.52	0.27	≤ 0.001
Formal Network	0.48	0.40	0.159
Share Fishing income	0.9	0.86	0.985
Invested $<$ 500.000	0.63	0.33	≤ 0.001
Invested $<$ 10 Mil	0.17	0.46	≤ 0.001
Invested $>$ 10 Mil	0.19	0.21	0.87
Boat Owner	0.16	0.32	≤ 0.001

Table 2.1: The table contains the summary statistics from the participants. Participants are grouped based on whether the majority of their fishing income comes from species with restrictive quotas. For each variable we test if the difference is significantly different between the groups (two sample t-tests for Age, and Share Fishing income, chi-squared tests for the remaining variables).

Our sample is on average 48.39 years old, which is characteristic for the population of fishers (INE, 2010). Restricted fishers are on average 3.61 years older than unrestricted fishers ($p = 0.003$) and restricted fishers are also more likely to be male ($p < 0.001$). The latter fact is expected as most of the restricted fisheries are male dominated, whilst there is substantial female participation in several unrestricted fisheries such as beach collecting (SERNAPESCA, 2019a). The restricted fisheries are also more likely to be located in cities ($p < 0.001$). That said, all but two of the visited locations are within 20 minutes of travel of a larger town or city (> 30.000 population).[13]

There are no significant differences in family composition between the groups, with the majority of fishers having children. Similarly, the two groups do not differ in whether they would rely formal or informal risk sharing networks.[14] Interestingly, we find that about half the fishers would prefer to have a secure job in an office or factory as opposed to fishing. There is no difference between the restricted and the unrestricted group in this respect. Similarly, there is no difference in the percentage of household income that comes from fishing between the two groups; it is between 80% and 90%. These two facts highlight that non-fishing labour possibilities in the surveyed fishing communities are scarce.

Fishers do differ in their level of capital investments and whether they are boat owners. Many participants from the restricted group are crew members on larger pelagic vessel that need no equipment of their own and therefore require no investments. In the pelagic fisheries it is only the boat owner that makes substantial investments into the gear and fishing vessels. Therefore, we see that a considerable portion of restricted fishers has little capital invested in

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[13] The two more remote locations were Caleta La Sierra and Caleta Limari, both are small fishing coves. It takes 90 minutes by car from either location to get to the nearest larger town Ovalle in the Coquimbo Region. In both locations the most important resource is the macro algae Huiro palo, which has a restrictive quota.

[14] Formal networks are banks and the government. Informal networks are family, friends, the fish buyer and other members of their fisheries organization.

fishing gear (< 500.000 CLP). The unrestricted group has a higher proportion of fishers who have done medium level investments into the fishery (between 500.000 and 10 million CLP). The fraction of participants who have made high level investments (> 10 million CLP) into fishing gear is comparable across the two groups.

2.4.6 Preferences for prudence and risk aversion

In addition to the observable characteristics discussed above, participants may differ systematically with respect to their economic preferences, in particular prudence and risk aversion. Prudence is an economic preference akin to risk-aversion and, in theory, an important determinant of precautionary savings. An agent's degree of prudence influences the optimal precautionary response to their level of income risk, as in that more prudent agents would save more when faced with the same amount of risk. For our analysis this means that a correlation of prudence and R_i could cause a bias for the desired level of precautionary savings (Fuchs-Schündeln and Schündeln, 2005). For example, if people that target restricted species are on average more prudent and save more than those that target unrestricted species, everything else equal, it would be unclear whether the extra savings are due to presence of restrictive quotas as theoretically predicted, or due to their higher level of prudence.

Agents are said to be prudent if their marginal utility function is convex $U'''(.) > 0$. This convexity generates a higher marginal utility for future consumption if income is uncertain. Therefore, prudent agents are more motivated to lower consumption now and generate additional precautionary savings when future income is uncertain (Leland, 1968; Sandmo, 1970). To test whether our participants have a convex marginal utility function, we use the lottery pairs designed by Eeckhoudt and Schlesinger (2006). Participants have to choose between allocating a mean-zero risk to either the good or bad outcome of another lottery, see figure 2.5. The prudent option is to allocate the risk to the good outcome.[15] The intuition is that a prudent participant would rather face the risk in a high wealth state as in a low wealth state because they would then be less affected by the bad outcome.

We ask participants to make five choices between lottery pairs, each with a prudent and an imprudent option. The first lottery pair is presented in Figure 2.5. Agents can always choose between option A and B. In the first stage of the lottery participants receive either 9 or 6 points with equal probability, as the good and bad outcome respectively. Before the outcome of the first lottery is determined by a coin flip, participants are asked to allocate a mean-zero (+4/-4) lottery to either the bad outcome (option A in Figure 2.5) or the good outcome (option B in Figure 2.5). The next four choices between lottery pairs are the same in design, but with different payouts. We do so to measure whether participants are willing to deviate from their initial choice. In the second lottery pair we increase the expected payout of the prudent option by one additional point compared to the first lottery. In the third we increase the expected payout of the imprudent option by one additional point compared to the first lottery. In the fourth and fifth lottery, we increase the expected payouts of the prudent and imprudent options by 2 points, respectively.

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[15] See Eeckhoudt and Schlesinger (2006) for the proof and Trautmann and van de Kuilen (2018) for a review concerning the experimental work on prudence.

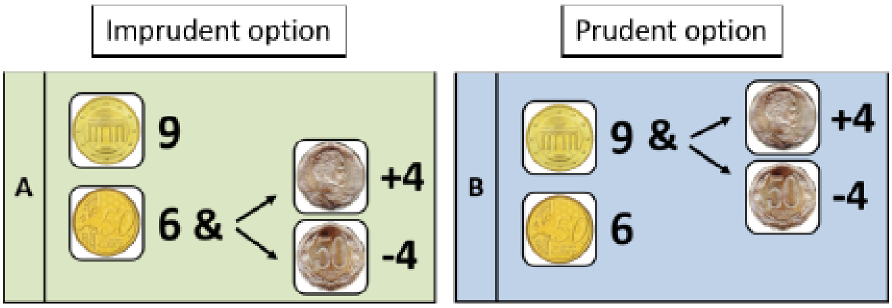

Figure 2.5: The figure shows the two options participants can choose between when measuring prudence. In both options participants have to flip a coin, they receive the good outcome of 9 points when they throw heads and the bad outcome of 6 points when they throw tails. Beforehand participants make the choice of allocating a risk to either the good outcome or the bad outcome. In the imprudent option (A) participants allocate a mean-zero risk of +4/-4 to the bad outcome of the first lottery. Meaning that they will only flip the second coin if they threw tails in the first coin-flip. When the participants choose the prudent option (B) they only flip the second coin if they threw heads in the first coin-flip.

As an additional robustness control, we measure participants' risk aversion using the risky-investment method (Gneezy and Potters, 1997). Previous studies have found that risk-aversion is correlated with prudence (Trautmann and van de Kuilen, 2018; Noussair et al., 2014). The Gneezy-Potters task is simpler than the prudence elicitation task and it has been tested extensively in lab-in-the-field settings (Gneezy et al., 2015).

2.5 Results

We present our results in three steps. First, we show that compared to the unrestricted group, fishers in the restricted group have a lower variability in fishing income, but a higher need for precautionary savings. Then, we turn to regression models to explore the interaction between income variability and restrictive quotas as well as the role of further explanatory variables. Finally, we discuss and address potential threats to causal inference.

2.5.1 Differences in income variability and need for savings

Figure 2.6 shows the group averages and 95% confidence intervals of income variability (on the left) and the need for precautionary savings (on the right).

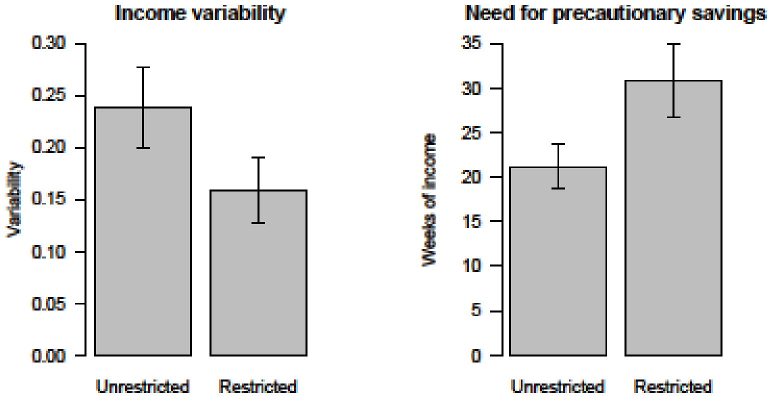

Figure 2.6: Average variability V_i (left panel) and the average need for precautionary savings for the unrestricted and restricted group, respectively. Error bars show 95% CI.

First, we compare the average values for income variability V_i between restricted group ($R_i > 0.5$) and the unrestricted group ($R_i \leq 0.5$). We find that on average the unrestricted group has a higher income variability from harvesting. The mean value of V_i for the restricted group is 0.16 and the mean value of V_i for the unrestricted group 0.24. The difference is substantial and significant (Wilcoxon rank sum test, $p = 0.018$). There is also more variation in V_i for the unrestricted group, such that standard deviation of V_i for the unrestricted group is 0.3, compared to 0.2 of the restricted group.

Second, we compare the need for precautionary savings y between the restricted group and the unrestricted group. The respective sample means of the two groups are 30.8 and 21.2 weeks of expenses as savings. Based on a 2-sample Wilcoxon rank sum test we find that that the means of the two group differ significantly ($p < 0.001$). This indicates that restricted fishers need about nine weeks of expenses worth of savings more than unrestricted fishers in order to smooth consumption.

In sum, we can confirm the theoretical predictions that restricted agents report lower variability in income from harvesting but require more precautionary savings. Our theoretical model implicitly assumed that restricted and unrestricted agents are exposed to the same level of risk. In reality, variability in income may differ not only due to different endogenous adaptations but also due to differences in the exogenous risks that agents face.

We find no evidence for strong differences in exposure to production risk. In the Appendix, we show that unrestricted fishers are not exposed to larger fluctuations in prices than restricted fishers (Figure A-2). Similarly, we show that the trip-to-trip variation in harvested volume does not differ between restricted and unrestricted fishers (Figure A-3). Acknowledging that it is ultimately impossible to disentangle exogenous and endogenous risk exposure from production data (Just et al., 2010), we note that if the larger income variability that we document for the unrestricted group were driven by a greater exposure to exogenous risk, it would be even more remarkable that the unrestricted group requires less precautionary savings than the restricted group, despite the fact that the latter group reports lower income variability.

In the next subsection, we turn to the results from our regression analysis where we (1) control for additional variables that explain the need for precautionary savings and (2) explore the interaction of the R_i and V_i, that is, whether fishers in the restricted and the unrestricted group react differently to increases in income variability.

2.5.2 Regression analysis

To discuss the regression results, it is useful to restate the extensive form of our generic model stated in equation (2.2)

$$y_i = \beta_0 + \beta_1 R_i + \beta_2 V_i + \beta_3 (R_i \times V_i) + \mathbf{X}_i \gamma + \varepsilon_i$$

The dependent variable y_i in all model specifications is the perceived need for savings for individual i. The main explanatory variable is R_i. It is the fraction of income from species with restrictive quotas. We control for income variability with V_i, which is the standard deviation of the elicited income distribution. $\mathbf{X}_i$ is the vector of demographic controls and ε_i is the robust error term, clustered at the session level. Coefficient estimates for various specifications of the model and different subsets of the data are presented in Table 2.2.

In the specification presented in column (1), we include age, age-squared and a dummy variable whether the parents live in the same household or community with the fisher ("Parentshere") in addition to R_i. We find that restricted labour flexibility, in terms of an increased share of harvest that comes from species with binding quota restrictions is related to an increased need for precautionary savings. Specifically, a fisher whose harvest exclusively comes from quota-restricted species ($R_i = 1$) requires 12.15 more weeks of precautionary savings than a fisher whose harvest comes exclusively from unrestricted species ($R_i = 0$). This effect is significant at the 5 percent level.

Furthermore, we find that age is positively associated with the need for precautionary savings, which could reflect differences in the need to smooth consumption over the life cycle or differences in health status that are correlated with age. Importantly, we document a strong and highly significant effect for the dummy variable that controls for whether the fisher's parents live close by (implying that he or she has some responsibility to provide care). Merely 30% of fishers in Chile are part of any type of social security system and only 1.71% are

	Dependent variable:		
	Weeks of savings		
	(1)	(2)	(3)
Quota restrictions R_i	12.15**	12.96**	9.96*
	(5.78)	(5.77)	(6.05)
Income variability V_i		3.94	−1.11
		(4.92)	(6.14)
Restrictions×Variability			18.28**
			(9.22)
Age	1.04*	1.13**	1.18**
	(0.53)	(0.47)	(0.46)
Age-squared	−0.01*	−0.01**	−0.01**
	(0.01)	(0.005)	(0.005)
Parentshere	7.79***	7.95***	8.31***
	(2.04)	(2.24)	(2.25)
Constant	−11.35	−14.61	−15.12
	(11.99)	(10.66)	(10.26)
Observations	404	379	379
R^2	0.08	0.09	0.09
Adjusted R^2	0.07	0.08	0.08

Note: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Table 2.2: OLS Regression results. Robust standard errors are clustered at the session level. From the sample of 433 observations, 25 participants did not wish to answer the savings question, 4 are removed due to non-answers for control variables and 25 did not have a valid income distribution.

part in a pension system (Benítez and Nava, 2016). Our finding that fishers report that they need about 8 weeks more savings when their parents live in their household or their vicinity highlights the importance of various income smoothing mechanisms, also in countries like Chile.

Further controls, such as gender, a dummy whether children live in the household, the fraction of household income that does not come from fishing, and the amount invested in the fishery all have only negligible and non-significant influence on the regression results. These additional controls were hence excluded in the model selection process. (Results for model specifications that include these variables are presented in Table A-2 in the Appendix.)

In the model specification presented in column (2) of Table 2.2, we add the reported income variability V_i as additional control. Doing so has virtually no effect on the other coefficients, and the effect of income variability itself is not significant. However, when we differentiate between the restricted and the unrestricted group by adding the interaction term $R_i \times V_i$ in the model specification presented in column (3) of Table 2.2, we see that higher income variability is linked to a stronger need for precautionary savings for restricted fishermen. The effect is sizeable and significant at the 5 percent level. Correspondingly, the effect of harvesting quota restricted species as such decreases and loses significance ($p = 0.10$).

The positive coefficient on the interaction term $R_i \times V_i$ confirms the third prediction of our theoretical model. While a larger income variability does not lead to a stronger need for precautionary savings for unrestricted fishers, this is not the case for restricted fishers. Quota restricted fishers cannot buffer income variability by increasing extraction and hence need more precautionary savings.

2.5.3 Addressing causality

The regression analysis documents a robust relationship between the degree to which fishers are restricted by catch quotas and an increased need for precautionary savings. In particular, the analysis highlights that larger variability in income is not related to a stronger need for precautionary savings for unrestricted fishers, but it is related to a stronger need for precautionary savings for restricted fishers. In this subsection, we present three pieces of evidence that address potential concerns about the internal validity of our results.

First, we investigate whether our results might be driven by different preferences for prudence or risk aversion. To this end, we use the data from the incentivized choice experiment in our survey. Specifically, we compare the average number of prudent choices between the unrestricted and restricted group. We find no difference with 2.79 and 2.74 prudent choices out of 5 for the unrestricted and restricted group respectively ($p = 0.68$, Wilcoxon rank sum test). The left panel in Figure 2.7 shows the average number of prudent choices for the two groups. In the first lottery 0.55% of the unrestricted group and 0.51% of the restricted group choose the prudent option, this difference is again not significant ($p = 0.42$). This indicates that there is no self-selection into restricted or unrestricted fisheries based on higher-order risk preferences. The right panel in Figure 2.7 shows the average number of points invested in the risky option in the Gneezy-Potter risk elicitation task. Here we find that the restricted group is slightly less risk averse, with an average of 3.87 invested points versus an average of 3.55 in the unrestricted group ($p = 0.02$, Wilcoxon rank sum test).

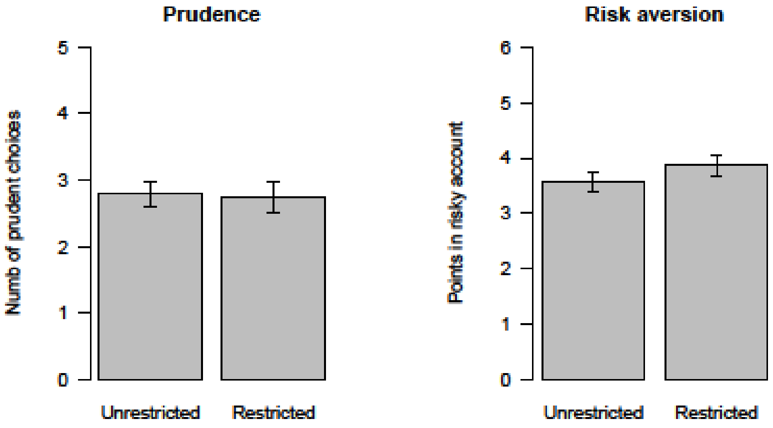

Figure 2.7: Average level of prudence and risk aversion for unrestricted and restricted group, respectively. Error bars show 95% CI.

In Table 2.3 we include prudence and risk-aversion as control variables jointly, see specification (1). In specifications (2) and (3) we present the results of regressions with either prudence or risk-aversion. We find that prudence has negative coefficient that is marginally significant. This is unexpected, as prudence is generally predicted to have a positive correlation with precautionary savings (Kimball, 1990). However, empirical evidence showing a relation between experimentally elicited prudence and precautionary savings remains scarce (Trautmann and van de Kuilen, 2018). Regarding the coefficients on the degree to which fishers are restricted by quotas, R_i, and the interaction with variability, we find that values remain unchanged, but the interaction term is no longer significant. The coefficient on R_i, in turn, is more significant.

The second concern that we address is that the documented differences in the need for precautionary savings may not be due to differences in how restricted fishers are, but due to other factors, such as the mode of production. Here, we exploit the fact that a range of fishers use the same type of gears and target the same set of species, but – due to geographical differences – have very different portfolios of restricted and unrestricted catches. Specifically, in four of the visited locations there are fishers that are active in both the largest unrestricted fishery (Humboldt squid) and the largest restricted fishery (anchoveta and sardina común)[16]. Between the locations the relative importance of the respective fisheries differs substantially. (See Figure A-1 in the Appendix for the relative revenues within locations.) For example in Tubul and San Antonio the squid fishery generates more revenue, with the reverse being true in Coronel and Lota. As a consequence fishers participating in the same fishing activities have different levels of R_i.

We use this spatial variability to test whether the observed correlation between restrictive quotas on perceived need for savings holds when the set of fishing activities remains largely constant. Although we are left with a relatively small sample of 78 fishers, the results in

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[16] Largest as in most tons landed per year in the visited regions.

Table 2.3: Additional OLS regression results, model specifications with prudence and risk aversion and for different sub-samples. By including prudence the sample size drops by 13, as the instructions for the elicitation task were slightly changed after the first session.

	Dependent variable:					
	Weeks of savings					
	(1)	(2)	(3)	(4)	(5)	(6)
Quota restrictions R_i	9.78**	10.05**	9.68**	15.41**	13.18**	9.77
	(3.99)	(3.93)	(4.01)	(6.98)	(6.50)	(6.36)
Income variability V_i	−1.40	−1.20	−1.45	12.00	3.47	−2.36
	(5.12)	(5.06)	(5.18)	(15.90)	(5.27)	(6.41)
Restrictions × Variability	18.22	17.74	18.58			22.68**
	(17.62)	(17.50)	(17.96)			(10.57)
Age	1.01*	1.04**	1.06**	2.53	1.17*	1.13*
	(0.53)	(0.53)	(0.52)	(2.51)	(0.61)	(0.64)
Age-squared)	−0.01*	−0.01*	−0.01*	−0.02	−0.01**	−0.01**
	(0.01)	(0.01)	(0.01)	(0.03)	(0.01)	(0.01)
Parentshere	7.30***	7.35***	7.96***	5.09	7.12***	7.07***
	(2.69)	(2.70)	(2.68)	(7.45)	(2.48)	(2.57)
Prudence	−1.49*	−1.50*				
	(0.80)	(0.80)				
Risk aversion	0.60		0.63			
	(0.86)		(0.86)			
Constant	−6.31	−5.14	−13.85	−53.35	−13.78	−11.08
	(12.65)	(12.45)	(11.92)	(58.44)	(15.15)	(16.57)
Observations	366	366	366	78	276	276
R^2	0.10	0.10	0.09	0.11	0.08	0.08
Adjusted R^2	0.08	0.08	0.07	0.04	0.06	0.06

Note: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

column (4) of Table 2.3 show that also in this subsample, fishers that are restricted by quotas require more savings.

Finally, we address the potential for selection bias. To this end, we can exploit the fact that a large share of our participant pool has a long tenure in fishing and started before harvest has become restricted for some species in the early 2000s. Hence, fishers that have been active before the year 2000 cannot have selected into a restricted or unrestricted fishery. Column (5) and (6) in Table 2.3 show the regression results for this subsample of 276 fishers corresponding to specifications (2) and (3) in Table 2.2, respectively. Also for this subsample, we find that fishers whose harvesting flexibility is restricted need more precautionary savings. Moreover, an increase in income variability is related to a stronger need for precautionary savings in the restricted group, but not in the unrestricted group.

In sum, we can show that our results are not due to risk-aversion or prudence preferences, and hold both in a sub-sample of fishers that similarly concentrate on pelagic species but are differently restricted due to geographical differences, and in a sub-sample of fishers that have started at a time when no species were quota restricted yet. This supports the notion that our results may indeed be causal.

2.6 Discussion

In this paper, we emphasize a short-term/long-term trade-off that has received little attention so far. In addition to the well-known trade-off between the reduction in *average* short-term income and the gain in *average* long-term income that comes with restricting resource extraction (Clark, 1990), there is a trade-off with respect to the *variability* of income. In the long-term, restricting resource extraction can lead to significant reductions in income variability as resource dynamics become more stable and the chance of stock collapse decreases (Isaksen and Richter, 2019; Essington, 2010). In the short-term, however, restricting resource extraction means that the channel to buffer negative shocks by increasing labour supply is effectively shut down. This income smoothing strategy is particularly relevant in developing countries, where natural resources serve as an important insurance, or even as a "livelihood of last resort" (Berry et al., 2019; Hannesson et al., 2010).

We present survey results from a sample of Chilean fishers whose harvest opportunities are restricted to varying degrees and combine these with official landings data. We show that those fishers that harvest species with restrictive quotas, and whose labour flexibility is hence limited, require more precautionary savings to smooth their consumption. This result holds despite the fact that fishers in the restricted group report lower levels of income variability.

It is likely that savings possibilities and decisions of fishers are linked to their level of income. When fishers in the unrestricted group would have lower wealth or income because stocks are more depleted in these fisheries, unrestricted fishers could have lower savings not because they do not need them, but because they cannot afford them. Our precautionary savings question is therefore phrased such that it only elicits the need for savings and it is expressed in weeks of expenses, which is a target measure that is relative to income. Based on the same question, (Jappelli et al., 2008) find that the absolute target level of precautionary savings increases as income increases, whilst the target level relative to income decreases. We do not have income or wealth data of the individual participants. However, (Benítez and Nava, 2016) report that fishers in the restricted group have a higher average income. Therefore, any effect of income on precautionary savings would likely be in the other direction, which would strengthen our results.

The fact that restrictive fishers report lower income variability from harvesting could be due to two reasons: On the one hand, it could reflect that the restrictive regulations in Chile are successful in reducing resource fluctuations. On the other hand, it could reflect that the income from harvesting is endogenous for the unrestricted group. Exactly because these fishers can harvest more to smooth consumption, a higher income variability may reflect fluctuations in the extent to which expenses and basic needs have to be covered (Kleemann and Riekhof, 2018).

The second reason is supported by our finding that restricted and unrestricted fishers respond differently to income variability. Fishers restricted by quotas require substantially higher savings if they consider their income from harvesting to be variable, whilst unrestricted fishers do not. When fishers have a high degree of labour flexibility, their income variability does not only contain exogenous variations such as changing prices, but also their own responses to changing circumstances such as an increase in their hours worked when they need additional income. Therefore, when labour is flexible a higher degree of income variability might indicate either more risk or more adaptability.

An important task for future work is to design studies that disentangle exogenous income risk from endogenous adaptations to it. A better understanding how the fishers themselves manage the risk they face would be informative for regulations that aim to improve fishers' welfare. During periods with low income, fishers often use political pressure in order to attain additional quotas or income subsidies. It is not uncommon that as result, long term resource conservation objectives are sacrificed at the expense of increasing short-term economic goals and social welfare (Leal et al., 2010). For example, subsidies aimed at keeping fishers' income above some minimum level can reduce levels of fish stocks in the long-run and stimulate risk-seeking behaviour (OECD, 2006).

It is possible for fishers to adapt to negative shocks using mechanisms beyond savings. Most notable, restricted fishers could diversify into non-restricted fishing activities. There are limitations to doing so however, as the availability of alternative fishing activities varies over space due to variation in natural resource endowments. We captured this in our measure for exposure to restrictive regulation (R_i), as it is dependent on the relative sizes of unrestricted and restricted fisheries in each location. We show in our robustness check that fishers active in the same fishing activities can still have different portfolios of restricted and unrestricted catches. Moreover, we find that the need for precautionary savings increases when only the balance between restricted and unrestricted catches changes.

Restrictions on harvesting are only effective if fishers comply to the regulation (Diekert et al., 2020). In the absence of sufficient enforcement, fishers can still increase harvests of restricted species in order to generate more income. The Food and Agriculture Organization of the United Nations (FAO) recognizes that the pressure to generate a liveable income is one of the main motivations for fishers to participate in illegal, unreported, and undeclared fishing (FAO, 2018), which is exacerbated in the absence of sufficient income opportunities (Gallic and Cox, 2006; Axbard, 2016). SERNAPESCA estimates that in 2019, 324.000 tons of marine resources have been illegally extracted, with an estimated value of 397 million USD.[17]

More work is needed to understand the long-term repercussions on the stability and variability of socio-ecological systems when resource users have to meet income requirements for subsistence but cannot use resource extraction as a smoothing strategy. Will political pressure to increase quotas or subsidies lead to reinforcing dynamics that undermine the attempt to safeguard resource productivity? To what extent will the inability to harvest more within the legal framework increase the propensity to violate rules and regulations? What are the consequences for community cooperation and informal management schemes? Answering these types of questions are an important avenue for a research agenda that addresses the interplay between risk exposure, risk management, and the long-term sustainability of socio-ecological systems.

In a first-best world, overall harvest is restricted to ensure the long-term viability and stability of the resource stock while individual catch shares and a functioning quota market ensures that resource users can buffer negative shocks. In reality, functioning quota markets do often not exist, and in many developing countries, also other means to smooth consumption via savings, financial markets, or insurance schemes are severely limited. At the same time, resource users in developing countries are particularly exposed to risk, both by shocks to their income, such as fluctuating prices, but also by shocks to their wealth, such as unexpected expenses for health care of household members.

It is important to highlight that our work is not an argument against restricting harvest per se. To the contrary, restricting overall harvests is necessary to overcome the tragedy of the commons. Our paper merely emphasizes that restrictive quotas ought to be flanked by measures that enable resource users to smooth income fluctuations. As more and more developing countries adapt management policies that limit open access to natural resources, finding ways to avoid unintended welfare losses is an increasingly important objective.

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[17] Personal communication from the director of SERNAPESCA. https://www.sonapesca.cl/324-000-toneladas-de-pesca-ilegal-sonapesca-califica-de-grave-situacion-y-entrega-10-propuestas-para-combatirla/)

References

Alfonsi, L., Bandiera, O., Bassi, V., Burgess, R., Rasul, I., Sulaiman, M., and Vitali, A. (2020). Tackling Youth Unemployment: Evidence from a Labor Market Experiment in Uganda. CEPR Discussion Papers 14973, C.E.P.R. Discussion Papers.

Attanasio, O. P. and Kaufmann, K. M. (2017). Education choices and returns on the labor and marriage markets: Evidence from data on subjective expectations. *Journal of Economic Behavior & Organization*, 140:35 – 55.

Axbard, S. (2016). Income opportunities and sea piracy in indonesia: Evidence from satellite data. *American Economic Journal: Applied Economics*, 8(2):154–94.

Béné, C., Hersoug, B., and Allison, E. H. (2010). Not by rent alone: Analysing the pro-poor functions of small-scale fisheries in developing countries. *Development Policy Review*, 28(3):325–358.

Benítez, J. V. G. and Nava, A. F. (2016). Contribución de la pesca artesanal a la seguridad alimentaria, el empleo rural y el ingreso familiar en países de américa del sur. Technical report, FAO.

Berry, K., Fenichel, E. P., and Robinson, B. E. (2019). The ecological insurance trap. *Journal of Environmental Economics and Management*, 98:102251.

Birkenbach, A. M., Kaczan, D. J., and Smith, M. D. (2017). Catch shares slow the race to fish. *Nature*, 544(7649):223–226.

Bodie, Z., Merton, R. C., and Samuelson, W. F. (1992). Labor supply flexibility and portfolio choice in a life cycle model. *Journal of Economic Dynamics and Control*, 16(3):427 – 449.

Castilla, J. C. (2010). Fisheries in chile: Small pelagics, management, rights, and sea zoning. *Bulletin of Marine Science*, 86(2):221–234.

Castillo, C. and Dresdner, J. (2012). Effort optimisation in artisanal fisheries with multiple management objectives, collective quotas and heterogeneous fleets. *Australian Journal of Agricultural and Resource Economics*, 57(1):104–122.

Chen, M. K., Chevalier, J. A., Rossi, P. E., and Oehlsen, E. (2019). The value of flexible work: Evidence from uber drivers. *Journal of Political Economy*, 127(6).

Cinner, J., Daw, T., and McClanahan, T. (2009). Socioeconomic factors that affect artisanal fishers' readiness to exit a declining fishery. *Conservation Biology*, 23(1):124–130.

Clark, C. W. (1990). *Mathematical bioeconomics: the optimal management of renewable resources*. Wiley, second edition.

Copeland, B. R. and Taylor, M. S. (2009). Trade, tragedy, and the commons. *American Economic Review*, 99(3):725–49.

Costello, C., Gaines, S. D., and Lynham, J. (2008). Can catch shares prevent fisheries collapse? *Science*, 321(5896):1678–1681.

Cubillos, L. A., Bucarey, D. A., and Canales, M. (2002). Monthly abundance estimation for common sardine strangomera bentincki and anchovy engraulis ringens in the central-southern area off chile (34–40s). *Fisheries Research*, 57(2):117 – 130.

Daw, T. M., Cinner, J. E., McClanahan, T. R., Brown, K., Stead, S. M., Graham, N. A. J., and Maina, J. (2012). To fish or not to fish: Factors at multiple scales affecting artisanal fishers' readiness to exit a declining fishery. *PLOS ONE*, 7(2):1–10.

Debela, B., Shively, G., Angelsen, A., and Wik, M. (2011). Economic shocks, diversification, and forest use in uganda. *Land Economics*, 88(1):139–154.

Deidda, M. (2013). Precautionary saving, financial risk, and portfolio choice. *Review of Income and Wealth*, 59(1):133–156.

Dercon, S. (2002). Income risk, coping strategies, and safety nets. *World Bank Research Observer*, 17(2):141–166.

Diekert, F., Nøstbakken, L., and Richter, A. (2020). Modern compliance policies in fisheries. Working Paper 01/20, SNF Center for Applied Research.

Dupas, P., Karlan, D., Robinson, J., and Ubfal, D. (2018). Banking the unbanked? evidence from three countries. *American Economic Journal: Applied Economics*, 10(2):257–97.

Dupas, P., Robinson, J., and Saavedra, S. (2020). The daily grind: Cash needs and labor supply. *Journal of Economic Behavior & Organization*, 177:399 – 414.

Eeckhoudt, L. and Schlesinger, H. (2006). Putting risk in its proper place. *American Economic Review*, 96(1):280–289.

Essington, T. E. (2010). Ecological indicators display reduced variation in north american catch share fisheries. *Proceedings of the National Academy of Sciences*, 107(2):754–759.

Estrada, G. A. C., Suazo, M. A. Q., and Dresdner Cid, J. D. (2018). The effect of collective rights-based management on technical efficiency: The case of chile's common sardine and anchovy fishery. *Marine Resource Economics*, 33(1):87–112.

FAO (2018). Estrategia regional para prevenir, desalentar y erradicar la pesca ilegal, no declarada y no reglamentada con énfasis en aguas jurisdiccionales y comunidades pesqueras. Technical report, Food and Agriculture Organization of the United Nations.

Farrell, D. and Greig, F. (2016). Paychecks, paydays, and the online platform economy: Big data on income volatility.

Flodén, M. (2006). Labour supply and saving under uncertainty. *The Economic Journal*, 116(513):721–737.

Frankenberg, E., Smith, J. P., and Thomas, D. (2003). Economic shocks, wealth, and welfare. *Journal of Human Resources*, XXXVIII(2):280–321.

Fuchs-Schündeln, N. and Schündeln, M. (2005). Precautionary savings and self-selection: Evidence from the german reunification "experiment". *The Quarterly Journal of Economics*, 120(3):1085–1120.

Gallic, B. L. and Cox, A. (2006). An economic analysis of illegal, unreported and unregulated (iuu) fishing: Key drivers and possible solutions. *Marine Policy*, 30(6):689 – 695.

Gelcich, S., Hughes, T. P., Olsson, P., Folke, C., Defeo, O., Fernández, M., Foale, S., Gunderson, L. H., Rodríguez-Sickert, C., Scheffer, M., et al. (2010). Navigating transformations in governance of chilean marine coastal resources. *Proceedings of the National Academy of Sciences*, 107(39):16794–16799.

Giné, X., Martinez-Bravo, M., and Vidal-Fernández, M. (2017). Are labor supply decisions consistent with neoclassical preferences? evidence from indian boat owners. *Journal of Economic Behavior & Organization*, 142:331 – 347.

Gneezy, U., Leibbrandt, A., and List, J. A. (2015). Ode to the sea: Workplace organizations and norms of cooperation. *The Economic Journal*, 126(595):1856–1883.

Gneezy, U. and Potters, J. (1997). An experiment on risk taking and evaluation periods. *The Quarterly Journal of Economics*, 112(2):631–645.

Gomez, F., Montecinos, A., Hormazabal, S., Cubillos, L. A., Correa-Ramirez, M., and Chavez, F. P. (2012). Impact of spring upwelling variability off southern-central chile on common sardine (strangomera bentincki) recruitment. *Fisheries Oceanography*, 21(6):405–414.

Guiso, L., Jappelli, T., and Pistaferri, L. (2002). An empirical analysis of earnings and employment risk. *Journal of Business & Economic Statistics*, 20(2):241–253.

Hammarlund, C. (2018). A trip to reach the target? – the labor supply of swedish baltic cod fishermen. *Journal of Behavioral and Experimental Economics*, 75:1 – 11.

Hannesson, R., Salvanes, K. G., and Squires, D. (2010). Technological change and the tragedy of the commons: The lofoten fishery over 130 years. *Land Economics*, 86(4):746–765.

Hartung, C., Lerer, A., Anokwa, Y., Tseng, C., Brunette, W., and Borriello, G. (2010). Open data kit: Tools to build information services for developing regions. In *Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development*, ICTD '10, pages 18:1–18:12, New York, NY, USA. ACM.

Homans, F. R. and Wilen, J. E. (1997). A model of regulated open access resource use,. *Journal of Environmental Economics and Management*, 32(1):1–21.

INE (2010). *Primer Censo Nacional Pesquero y Acuicultor. Año Censal 2008-2009.*

Isaksen, E. T. and Richter, A. (2019). Tragedy, property rights, and the commons: Investigating the causal relationship from institutions to ecosystem collapse. *Journal of the Association of Environmental and Resource Economists*, 6(4):741–781.

Jappelli, T., Pistaferri, L., and Padula, M. (2008). A direct test of the buffer-stock model of saving. *Journal of the European Economic Association*, 6(6):1186–1210.

Jardine, S. L. and Sanchirico, J. N. (2012). Catch share programs in developing countries: A survey of the literature. *Marine Policy*, 36(6):1242 – 1254.

Jayachandran, S. (2006). Selling labor low: Wage responses to productivity shocks in developing countries. *Journal of Political Economy*, 114(3):538–575.

Just, D. R., Khantachavana, S. V., and Just, R. E. (2010). Empirical challenges for risk preferences and production. *Annual Review of Resource Economics*, 2(1):13–31.

Kasperski, S. and Holland, D. S. (2013). Income diversification and risk for fishermen. *Proceedings of the National Academy of Sciences*, 110(6):2076–2081.

Kimball, M. S. (1990). Precautionary saving in the small and in the large. *Econometrica*, 58(1):53–73.

Kleemann, L. and Riekhof, M.-C. (2018). Changing background risk and risk-taking - Evidence from the field. CER-ETH Economics working paper series 18/301, CER-ETH - Center of Economic Research (CER-ETH) at ETH Zurich.

Kochar, A. (1995). Explaining household vulnerability to idiosyncratic income shocks. *The American Economic Review*, 85(2):159–164.

Leal, C. P., nones, R. A. Q., and Chávez, C. (2010). What factors affect the decision making process when setting tacs?: The case of chilean fisheries. *Marine Policy*, 34(6):1183 – 1195.

Leete, L. and Bania, N. (2010). The effect of income shocks on food insufficiency. *Review of Economics of the Household*, 8(4):505–526.

Leland, H. E. (1968). Saving and uncertainty: The precautionary demand for saving. *The Quarterly Journal of Economics*, 82(3):465–473.

Lugilde, A., Bande, R., and Riveiro, D. (2018). Precautionary saving: A review of the empirical literature. *Journal of Economic Surveys*, 0(0).

Noack, F., Riekhof, M.-C., and Quaas, M. (2018). Development in a dual economy: The importance of resource-use regulation. *Journal of the Association of Environmental and Resource Economists*, 5(1):233–263.

Nocetti, D. and Smith, W. T. (2011). Precautionary saving and endogenous labor supply with and without intertemporal expected utility. *Journal of Money, Credit and Banking*, 43(7):1475–1504.

Noussair, C. N., Trautmann, S. T., and van de Kuilen, G. (2014). Higher order risk attitudes, demographics, and financial decisions. *The Review of Economic Studies*, 81(1):325–355.

Nunan, F. (2014). Wealth and welfare? can fisheries management succeed in achieving multiple objectives? a case study of lake victoria, east africa. *Fish and Fisheries*, 15(1):134–150.

OECD (2006). *Financial Support to Fisheries*.

OECD (2019). *Society at a Glance 2019*.

Okonkwo, J. U. and Quaas, M. F. (2020). Welfare effects of natural resource privatization: a dynamic analysis. *Environment and Development Economics*, page 1–21.

Panayotou, T. (1982). Management concepts for small-scale fisheries: economic and social aspects. Technical paper, FAO. FAO Fish.Tech.Pap., (228): 53 p.

Pfeiffer, L. and Gratz, T. (2016). The effect of rights-based fisheries management on risk taking and fishing safety. *Proceedings of the National Academy of Sciences*, 113(10):2615–2620.

Sandmo, A. (1970). The Effect of Uncertainty on Saving Decisions. *Review of Economic Studies*, 37(3):353–360.

SERNAPESCA (2019a). *Mujeres y Hombres en el Sector Pesquero y Acuicultor de Chile 2019*.

SERNAPESCA (2019b). Ref: Adjunta acta de la sesion extraordinaria n1 del comité científico de pesquerías de pequeños pelágicos, ano 2019. Meeting minutes, Comité Científico de Pesquerías de Pequeños Pelágicos.

Trautmann, S. T. and van de Kuilen, G. (2018). Higher order risk attitudes: A review of experimental evidence. *European Economic Review*, 103:108 – 124.

Appendix

A-1 List of harvested species

Table A-1: Table contains the name and type of regulation of all species that were harvested by our sample. The types of regulation are TAC (total-allowable catch), RAE (Regime Extracion Artesenal), OA (Open-access). All RAE fisheries are considered restricted. TAC fisheries are considered restricted if more than 95% of the quota has been used in 2018. The type of regulation and quota usage are indicated per region in the last three columns.

Scientific name	Type	Name	REG-IV	REG-V	REG-VIII	Quota %-IV	Quota %-V	Quota %- VIII
Gelidium rex	Algae	Chasca	OA	OA	OA	NA	NA	NA
Lessonia berteorana	Algae	Huiro negro	TAC	OA	OA	67%	NA	NA
Durvillaea antarctica	Algae	Cochayuyo	OA	OA	OA	NA	NA	NA
Macrocystis pyriphera	Algae	Huiro	OA	OA	OA	NA	NA	NA
Lessonia trabeculata	Algae	Huiro palo	TAC	OA	OA	99%	NA	NA
Gymnogongrus furcellatus	Algae	Liquen	OA	OA	OA	NA	NA	NA
Porphyra columbina	Algae	Luche	OA	OA	OA	NA	NA	NA
Mazzaella laminaroides	Algae	Luga cuchara	OA	OA	OA	NA	NA	NA
Sarcothalia crispata	Algae	Luga negra	OA	OA	OA	NA	NA	NA
Gigartina skottsbergii	Algae	Luga roja	OA	OA	OA	NA	NA	NA
Gracilaria chilensis	Algae	Pelillo	OA	OA	OA	NA	NA	NA
Heterocarpus reedi	Crustaceans	Camarón nailon	TAC	TAC	TAC	66%	100%	$< 1\%$
Cancer porteri	Crustaceans	Jaiba limon	OA	OA	OA	NA	NA	NA
Cancer edwardsi	Crustaceans	Jaiba marmola	OA	OA	OA	NA	NA	NA
Homalaspis plana	Crustaceans	Jaiba mora	OA	OA	OA	NA	NA	NA
Taliepus marginatus	Crustaceans	Jaiba patuda	OA	OA	OA	NA	NA	NA
Cancer setosus	Crustaceans	Jaiba peluda	OA	OA	OA	NA	NA	NA
Cancer coronatus	Crustaceans	Jaiba reina	OA	OA	OA	NA	NA	NA
Ovalipes trimaculatus	Crustaceans	Jaiba remadora	OA	OA	OA	NA	NA	NA
Cervimunida johni	Crustaceans	Langostino amarillo	TAC	OA	OA	93%	NA	NA
Pleuroncodes monodon	Crustaceans	Langostino colorado	TAC	OA	OA	89%	NA	NA

Table A-1: Continued

Scientific name	Type	Name	REG-IV	REG-V	REG-VIII	Quota %-IV	Quota %-V	Quota %- VIII
Xiphias gladius	Fish	Albacora	OA	OA	OA	NA	NA	NA
Engraulis ringens	Fish	Anchoveta	RAE	RAE	RAE	NA	NA	NA
Dissostichus eleginoides	Fish	Bacalao de profundidad	TAC	TAC	TAC	99%	78%	86%
Normanichthys	Fish	Bacaladillo	OA	OA	OA	NA	NA	NA
Cilus gilberti	Fish	Corvina	OA	OA	OA	NA	NA	NA
Genypterus maculatus	Fish	Congrio negro	OA	OA	OA	NA	NA	NA
Genypterus blacodes	Fish	Congrio dorado	OA	OA	OA	NA	NA	NA
Trachurus murphyi	Fish	Jurel	TAC	RAE	TAC	73%	NA	107%
Ethmidium maculatum	Fish	Machueuelo	OA	OA	OA	NA	NA	NA
Stromateus stellatus	Fish	Pampanito	OA	OA	OA	NA	NA	NA
Brama australis	Fish	Reineta	OA	OA	OA	NA	NA	NA
Strangomera bentincki	Fish	Sardina común	RAE	RAE	RAE	NA	NA	NA
Thyrsites atun	Fish	Sierra	OA	OA	OA	NA	NA	NA
Merluccius gayi gayi	Fish	Merluza común	RAE	RAE	RAE	NA	NA	NA
Callorhinchus callorhynchus	Fish	Pejegallo	OA	OA	OA	NA	NA	NA
Odontesthes bonariensis	Fish	Pejerrey	OA	OA	OA	NA	NA	NA
Paralabrax humeralis	Fish	Cabrilla	OA	OA	OA	NA	NA	NA
Venus antiqua	Molluscs	Almeja	OA	OA	OA	NA	NA	NA
Aulacomya ater	Molluscs	Cholga	OA	OA	OA	NA	NA	NA
Ensis macha	Molluscs	Huepo	OA	OA	OA	NA	NA	NA
Fissurella spp.	Molluscs	Lapa	OA	OA	OA	NA	NA	NA
Concholepas concholepas	Molluscs	Loco	OA	OA	OA	NA	NA	NA
Mesodesma Donacium	Molluscs	Macha	OA	OA	OA	NA	NA	NA
Tagelus dombeii	Molluscs	Navajuela	OA	OA	OA	NA	NA	NA
Mulinia Edulis	Molluscs	Taquilla	OA	OA	OA	NA	NA	NA
Trophon geversianus	Molluscs	Caracol	OA	OA	OA	NA	NA	NA
Dosidicus gigas	Molluscs	Jibia	TAC	TAC	TAC	70%	70%	70%

A-2 Supplementary Figures

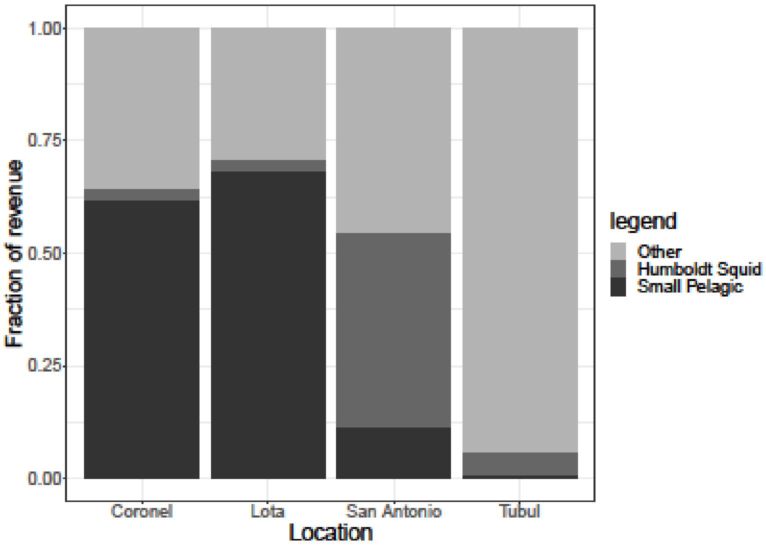

Figure A-1: The bars in the graph indicate the relative revenues generated between 2008 and 2017 by the unrestricted jibia (Humboldt squid) fishery and the restricted fishery for small pelagics (anchoveta and sardina común). The graph also includes a group for all other fisheries.

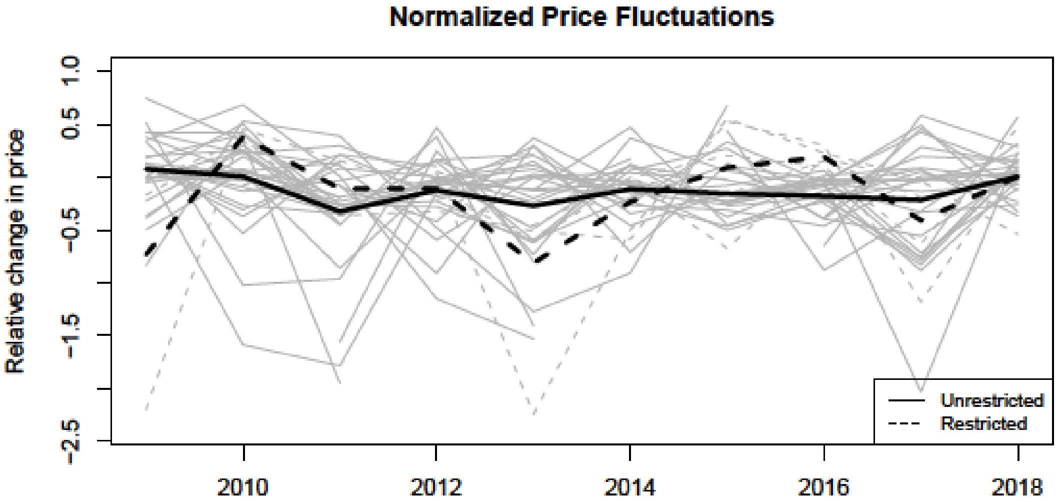

Figure A-2: Time series of relative price fluctuations for restricted species (dotted lines) and unrestricted species (solid lines). The thick lines show the development of the annual averages. Relative price fluctuations do not differ between restricted and unrestricted species ($p = 0.41$, two-sample t-test)

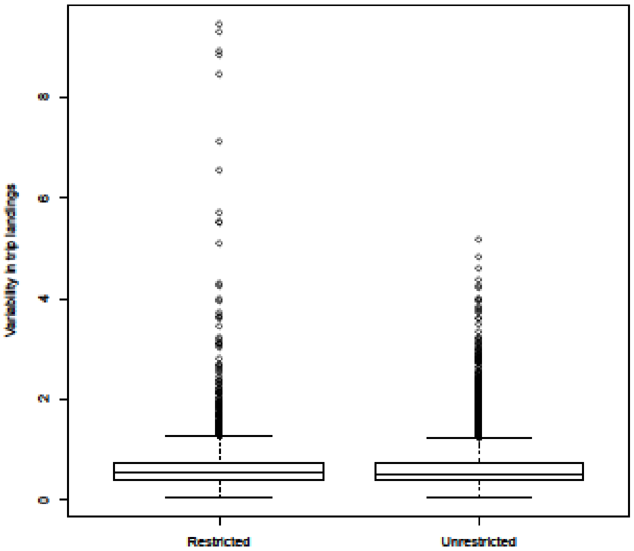

Figure A-3: Boxplot of the trip-to-trip coefficient of variation for the restricted and unrestricted fisheries. The respective averages (0.634 and 0.629) do not differ ($p = 0.59$, two-sample t-test). To arrive at the trip-to-trip coefficient of variation, we have classified each trip from the visited caletas in the years 2008-2017 as being either restricted or unrestricted. If more than 50% of the revenue comes from restricted species the trip is restricted. (90% of trips are fully restricted or unrestricted.) We then subset the fisheries data for vessel-year observations that have at least 10 restricted or unrestricted trips. This leaves 3604 and 6232 vessel-year observations for the restricted and unrestricted group respectively.

A-3 Supplementary Regression Tables

Table A-2: The table reports the OLS coefficients of specification 3 in table 2.2, with additional controls. Robust standard errors are clustered at the session level.

	Dependent variable:	
	Weeks of savings	
	(1)	(2)
Quota restrictions R_i	10.21*	7.85
	(6.10)	(6.98)
Income variability V_i	−0.37	−3.65
	(5.43)	(5.96)
Restrictions × Variability	19.05**	24.80**
	(8.96)	(11.31)
Age	1.14**	1.40***
	(0.47)	(0.49)
Age-squared	−0.01**	−0.01***
	(0.01)	(0.005)
Parentshere	9.02***	7.89***
	(2.31)	(2.91)
Gender	−0.18	−0.0004
	(3.39)	(4.39)
Children	1.40	0.44
	(4.33)	(5.02)
Non-fishing income	−1.73	−5.52
	(6.99)	(7.06)
Investment		−1.52
		(1.99)
Boat Owner		−1.03
		(3.37)
Constant	−15.43	−16.09
	(12.42)	(13.95)
Observations	370	323
R^2	0.10	0.10
Adjusted R^2	0.08	0.07

Note: $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$

Paper 3

Prudence and self-selection: Do fishers have a distaste for self-insurance?

Abstract: In this paper I present the first experimental measurement of prudence with a subject pool that is active in a high-risk occupation. Using a lab-in-the-field experiment I measure the prudence and risk-aversion of 423 Chilean small-scale fishers. The prevalence of prudence in this sample is significantly lower than that found in other populations. The key findings are that both risk-aversion and prudence (1) correlate with preferences for more secure occupations and (2) decrease strongly with tenure and age. The second finding can in part be attributed to a gradual process of out-selection of more prudent and risk-averse fishers.

Keywords: Prudence, Higher order risk preference, Self-selection, Fisheries, Natural resources, Self-insurance.

3.1 Introduction

Small-scale fishers face substantial risk for work place accidents (Pfeiffer and Gratz, 2016) and experience high levels of income variability, due to fluctuations in resource availability and prices (Anderson et al., 2017; Essington, 2010; Kasperski and Holland, 2013).[1] Initiatives aimed at insuring or reducing risk, in both the economic and health domain, can be ineffective due to the strong incentives for risky behaviour in the absence of strong property rights (Birkenbach et al., 2017). In particular in developing countries, the risky conditions combined with limited access to formal safety nets (FAO, 2019) and third-party insurances (Tietze and Anrooy, 2019; Mumford et al., 2009; Greenberg et al., 2004) can leave fishers reliant on self-insurance and informal risk-sharing networks. However it is unknown whether fishers' preference align with the high need for self-insurance. Therefore, the aim of this paper is to measure the economic preference relevant for self-insurance, *prudence*, among Chilean small-scale fishers and to analyse it determinants.

Prudence, both as an economic preference and as a general concept, is associated with careful and precautionary behaviour when exposed to risk. In economics an individual is considered to be prudent when the third derivative of the utility function is positive (Eeckhoudt and Schlesinger, 2006). The most well-known behavioural consequence of prudence is that in the presence of income risk, prudent individuals have a preference for self-insurance by accumulating precautionary savings (Leland, 1968; Sandmo, 1970; Kimball, 1990). Prudence can also imply a preference for self-protection measures (Menegatti, 2009), a distaste for downside risk, a preference for positive skewness in distributions (Ebert and Wiesen, 2011), or a preference for facing risks after gains as opposed to losses (Eeckhoudt and Schlesinger, 2006).

Economic preferences are not necessarily distributed evenly over the population. Prudent and risk-averse workers have been found to self-select into low risk occupations (Fuchs-Schündeln and Schündeln, 2005). The potential effect that occupational selection could have on self-insurance is substantial, as it creates a situation in which those who would self-insure least when exposed to risk are in the riskiest occupations and vice versa. Fuchs-Schündeln and Schündeln (2005) estimate that for their sample the observed self-insurance in the form of precautionary savings is 42% lower compared to a counter-factual situation in which self-selection would not be possible.[2] For fishers specifically, it has been established that they are generally less averse to risk than the general population (Pollnac et al., 1998; Smith and Wilen, 2005; Nguyen and Leung, 2009; Davis, 2012), however it has so far not been established that they are also less prudent.

Whilst direct measurements of risk-aversion have been common for decades (Binswanger, 1980), only a relatively recent development in experimental economics has made it accessible

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[1] The mortality rate of fishers in the United states is 30 times greater than that of the average occupation.

[2] Fuchs-Schündeln and Schündeln (2005) compare the effect of being a civil servants in West-Germany with being one in East-Germany after the German reunification. German civil servants have very high job security and predictable income, however those employed in former East-Germany could not have selected based on income risk, as there was non. After the reunification the low-risk was exogenously assigned to them. In the absence of self-selection (East-Germany) the relative difference in savings between high risk and low risk occupations is larger than when self-selection is possible (West-Germany)

to directly measure prudence (Eeckhoudt and Schlesinger, 2006).[3] Following the development by Eeckhoudt and Schlesinger (2006) an experimental literature has emerged that is concerned with measuring the prevalence of prudence and determining its demographic correlates. Since then, the majority of experiments have found that individuals are on average prudent (Trautmann and van de Kuilen, 2018), indicating that this might be a common property of the utility function. However, to the best of my knowledge, there are only two studies that do not use university students as their sample. The exceptions being Noussair et al. (2014), who test for prudence in a representative Dutch population sample and an unpublished conference paper by Joshi et al. (2017) who measure prudence in a sample of farmers in the West-Bengal region of India. Both these papers report that a substantial majority of their sample is prudent.

In this paper I present the first experimental measurement of prudence with a population exposed to high levels of risk. More specifically, using a lab-in-the-field experiment I have measured the prevalence of prudence in a heterogeneous sample of 423 Chilean small-scale fishers. I compare this measurement of prudence to previous experiments using non-student populations, and I find that as a population group fishers are substantially less prudent. Furthermore, I find that both risk-aversion and prudence have a strong negative correlation with age and tenure. The negative correlation between tenure and prudence can in part be attributed to out-selection of prudent fishers when more secure jobs are available.

The first contribution of this paper is expanding experimental measurements of prudence to a non-standard subject pool, in particular one that is exposed to high levels of risk. This measurement also gives additional insights into the demographic correlates of prudence. The second contributions is further evidence that prudent individuals are less likely to preside in high risk occupations. This possibility has been posited by Browning and Lusardi (1996) and is considered a major complication in the empirical studies of precautionary savings. Fuchs-Schündeln and Schündeln (2005) show that prudent and risk-averse individuals do select into low risk occupations, they do so by estimating the level of precautionary savings. This paper contributes by showing that selection can reduce the prevalence of prudence in high-risk occupations with prudence directly measured using an incentivized experimental measure as opposed to econometric estimations of precautionary savings.

A better understanding of the prevalence of prudence and the associated demographics can be beneficial for policy makers as it allows them to more efficiently target fishers that are likely to engage in collective or self-insurance schemes. Measures that involve self-insurance are particularly important for fishers because formal mechanisms for coping with the risk they are exposed to are frequently lacking. Small-scale fishers are in many cases self-employed which can exclude them from formal safety nets such as unemployment benefits and pensions (FAO, 2019). Furthermore, third-party insurance providers are weary of providing insurances to small-scale fishers, because of the complexity of the risks involved and the relatively low premiums which can be gathered (Tietze and Anrooy, 2019; Mumford et al., 2009). In the case that fishers are imprudent and unlikely to self-insure, it could form an argument for including them in more formal safety nets.

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[3] The method by Eeckhoudt and Schlesinger (2006) is not the first experimental method for measuring prudence, see Tarazona-Gomez (2005). However, the method is more accessible and relies on fewer assumptions on the utility function than previous methods.

The paper progresses as follows. In the next section I give a brief overview of the literature on risk-aversion and prudence. I emphasize the theorized behavioural consequences of prudence and the current state of the experimental literature. In section 3.3, I discuss the field setting. In section 3.4, I show the experimental set-up and I explain how I measure prudence. In section 3.5, I present the results and I conclude in section 3.6.

3.2 Literature review

The background literature section is structured as follows. First I give definitions for risk-aversion and prudence, and I discus how these relate to preferences over distributions. Second I discuss the theoretically predicted behavioural consequences of prudence and lastly I summarize the experimental evidence for the predicted behaviours.

3.2.1 Preferences and distributions

Under expected utility the degree risk-aversion is determined by the second derivative of the utility function. An agent is risk-averse when the second derivative of the utility function is negative and therefore the utility function concave ($U''(.) < 0$). Rothschild and Stiglitz (1970) gave a behavioural definition for risk-aversion, where they describe a risk-averse person as someone with a distaste for mean-preserving spreads. Phrased differently, risk-averse agents prefer distributions with lower variance, all other things held constant. In practice a risk-averse individual would therefore have a preference for occupations with lower variability in income (Guiso and Paiella, 2008; Bellemare and Shearer, 2010).

Risk-aversion only partially captures an individuals' risk preference. Prudence, and other higher-order risk attitudes such as temperance and edginess, have implications for choices under uncertainty and preferences for distributions (Noussair et al., 2014). Prudence is determined by the third derivative of the utility function. An agent is considered prudent when the third derivative is positive $U'''(.) > 0$, which means that the marginal utility function is convex. Prudence is associated with an aversion to downside risk and negative skewness (Deck and Schlesinger, 2010). Similar to how a risk-averse agent would prefer a distribution with lower variance, a prudent agent would prefer positively skewed distributions over negatively skewed distributions.

Figure 3.1 contains an example of downside risk and negative skewness. The graph portrays the relative success of fishing trips in the Chilean artisinal fishery for small-pelagic species. The potential success of trips is (imperfectly) censored due to the hold capacity of the vessel and there is a long left tail consisting of relatively unsuccessful trips. The distribution is negatively skewed and would therefore be unfavourable for prudent individuals. Downside risk is a common feature of fisheries, considering the possibility of resource collapse and the high risk for serious injuries.

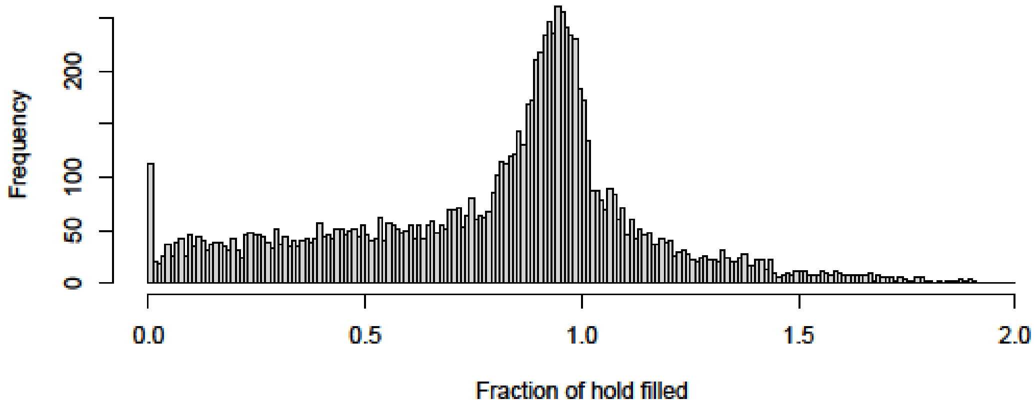

Figure 3.1: The graphs reports the landings per fishing trip as a fraction of the ships' official hold capacity. The data used are the 2018 landings of the Chilean Seine Purse fleet, that target mostly small-pelagic fish. A value of 1 would indicate that the ship was full when it returned to port. Values greater than 1 indicate that the trip landings surpassed the ships' official capacity (which might not accurately reflect the actual capacity). The distribution has a skewness of -0.27.

3.2.2 Behaviour associated with prudence

Prudence is generally not known as a preference for a certain amount or type of risk, but rather a preference for the response to the risk you face. The term prudence was coined by Kimball (1990), because the behaviour suggests *"..the propensity to prepare and forearm oneself in the face of uncertainty,.."*. The most well-known behavioural consequence of prudence, and the most studied is precautionary savings.

The convexity of the marginal utility function (prudence) increases the expected marginal utility from consumption in later periods if income is uncertain, thereby motivating the agent to lower consumption now and generate additional (precautionary) savings (Leland, 1968; Sandmo, 1970). The convexity of the marginal utility function is a necessary condition for precautionary savings. Moreover, an agent with non-prudent preferences ($U'''(.) = 0$) would not increase their savings if future income would becomes more uncertain, whilst an imprudent agent ($U'''(.) < 0$) would even decrease savings when future income becomes more uncertain. When future income is certain, prudence will not influence the optimal allocation of consumption between periods.

There are multiple motives for savings, such as preparing for a planned expense, however precautionary savings are only those savings which are motivated by uncertainty about future income (Carroll and Kimball, 2006). Whilst the majority of empirical papers confirm the existence of the precautionary motive for savings, the estimates regarding its importance for the general population vary strongly. Some studies indicate that precautionary savings are negligible and others suggest that precautionary savings account for up to 60% of the total stock of wealth (Lugilde et al., 2018). The only measurement of precautionary savings of fishers is presented in Zhou (2003), who shows that Japanese fishers (grouped with forestry, agricultural workers and the self-employed) experience greater variability and have a greater proportion of their wealth allocated for precautionary purposes. However the author does not report estimates for prudence.

Conventionally, the prevalence of prudence in a population is estimated through measurements of its behavioural consequence, precautionary savings (Lugilde et al., 2018). Precautionary savings are measured by the change in wealth holdings due to some exogenous changes in risk. However, as highlighted by Browning and Lusardi (1996) there are major complications with regard to empirically estimating precautionary savings. Primarily, finding a measure of risk that accurately captures the uncertainty as experienced by the household. This is particularly impractical within small-scale fisheries, as accurate financial data is difficult to obtain and household income risk is complicated to assess due to interactions between prices, resource abundance and government policies (Mumford et al., 2009).

The majority of research into precautionary savings also assumes that labour supply is fixed, whilst for many occupations, including fisheries, labour supply can be flexible (Hammarlund, 2018). When labour supply is fixed, the only way to generate savings is to reduce consumption, but when labour supply is flexible, the agent has two possibilities to generate savings. The agent can reduce consumption or increase current labour and allocate the excess productivity to savings. Flodén (2006) studies in more detail how labour flexibility can help to insure against wage uncertainty in a two-period model, under the assumption that agents are prudent. His main finding is that labour flexibility in most cases would increase precautionary savings and that individuals will increase their labour in the first period in preparation for future income shocks. However, when the income effect dominates the substitution effect, increasing labour supply ex-post can be used to compensate for the effect of a negative shock, which in turn reduces the need for precautionary savings (Schaap et al., 2020; Pijoan-Mas, 2006; Bodie et al., 1992). How exactly varying the degree of prudence would influence behaviour once the assumption of fixed labour supply is loosened is dependent on several assumption, such as the type of shock (wealth or wage) and whether the in income effect and substitution effect are balanced (Nocetti and Smith, 2011).

Another strand of the prudence literature is concerned with self-protection (or precautionary effort), which constitutes actions that lower the probability of a bad event occurring. Eeckhoudt and Gollier (2005) find the counter-intuitive result that prudent agents would invest less in measures of self-protection in one-period models. The intuition for this result is that the prudent individual would prefer to have the wealth, which would otherwise be spend on self protection, available to them when the bad event occurs. This result does not hold when the cost of self-protection and the bad events occur in separate periods. In a two period model, where the cost of the self-protection event occurs in a separate period the opposite result is found (Menegatti, 2009). For example a prudent individual would be more likely to buy and install safety equipment now, such that the chance of an accident in the future would be smaller.

3.2.3 Experimental evidence

Similar to the work of Rothschild and Stiglitz (1970) for risk-aversion, Eeckhoudt and Schlesinger (2006) have created a behavioural definition for prudence. They show that prudence can be considered a preference for disaggregating harms, such that a prudent individual would rather take a mean-zero risk after a gain than after a loss. They also devised a class of lottery pairs which utilize this concept to determine whether participants are prudent. Participants are given the choice of allocating an unavoidable mean-zero risk to the good outcome or a bad outcome of a lottery. In their paper, they prove that allocating the risk to the good outcome is equivalent to putting a positive sign on the third derivative of the utility function, which implies convexity of the marginal utility function and thus prudence.

The external validity of experimentally elicited prudence and the correlations with the predicted financial behaviour is still being established. The lottery pairs as designed by Eeckhoudt and Schlesinger (2006) were used in Noussair et al. (2014) to show that prudence positively correlates with the presence of savings and negatively with credit card debt. Using an alternative method based on certainty equivalents Schneider et al. (2019), find a correlation between prudence and wealth accumulation, in particular in the presence of income risk using a non-student sample in Columbia. Again using a method based on certainty equivalents, Schneider and Sutter (2019) find a marginally significant correlation between prudence and savings behaviour for German schoolchildren.

Regarding self-protection, Krieger and Mayrhofer (2017) show in a laboratory experiment with university students that participants with prudent preferences are less likely to invest in self-protection measures, confirming the theoretical predictions derived in the one-period model. Joshi et al. (2017), report that farmers with higher drought resilience are more prudent. Other experimental results regarding prudence include work by Engle-Warnick et al. (2016), who shows that portfolio preference on scale from safety to growth positively correlate with prudence. Lastly, in a laboratory experiment Ebert and Wiesen (2011) confirm that prudent participants have a preference for positively skewed lotteries.

3.3 Field setting

Globally, Chile is the 10th largest contributor to total fishery production (FAO, 2020). Chilean fisheries are separated into the industrial sector with relatively few but large vessels, and the artisinal sector. The artisinal sector is comprised of approximately 91.000 fishers and 12 700 vessels, which are up to $18m$ in length and have a maximum hold capacity of $80m^3$ (SERNAPESCA, 2019). Artisinal fishers are relatively small-scale and are only allowed to own up to two vessel with a combined gross tonnage of 50 tons. All fishers and vessels have to be registered in a national database (Registro Pesquero Artesanal) and currently new registrations are limited in fully exploited and overexploited fisheries. It is common for artisinal fishers to join fisheries organizations. These organizations form a contact point between fishers and regulators, and are necessary to attain particular quotas and territorial use rights (Castillo and Dresdner, 2012).

There exists a formal social safety net in Chile with health insurance, pensions and unemployment insurance funded through a combination of mandatory contributions and general taxes. The basic public health insurance requires a mandatory 7% contribution of workers' reported earnings, which includes self-employed workers such as fishers. Private health insurance providers are available, however uptake of private insurance is relatively low among fishers, with 88% of fishers insured through public health insurance (Yanez et al., 2018). Additionally artisinal fishers and divers are required to have a life insurance policy, insuring them against the risk of accidental death and disability.[4]

Traditionally, self-employed workers such as fishers have been exempt from the mandatory contributions for unemployment insurance[5] and public pensions. Self-employed workers have been allowed to contribute to the pension scheme on a voluntary basis. Only a minority of fishers (25%) contributes to the pension plan (Yanez et al., 2018). Those that do not contribute are only entitled to a minimal solidarity pension. It is therefore not uncommon for fishers to experience poverty in old age (CONAPACH, 2015) and work past the age of 65 (INE, 2010). In 2019, the pension scheme has become mandatory for independent workers younger than 55 and 50 for men and women respectively.[6]

Although fishers are excluded from some formal safety nets or exempt from participating, it is not uncommon for them to receive aid or direct payments on an ad-hoc basis after negative shocks. For example after the Tsunamis in 2010 and 2015, the artisinal fishing fleet experienced severe losses. The Chilean government invested in rebuilding the artisinal fisheries sector.[7] Recently, as part of a social agenda to improve fishers welfare, an unconditional direct payment of 250.000 CLP [8] was made to male fishers above 65 and female fishers older than 45.[9]

The uptake of vessel and gear insurances is low in the artisinal fishing sector. According to a review by the United Nations' Food and Agriculture Organization (FAO) regarding insurances in capture fisheries in 2008, there are several insurance providers in Chile that offer insurances for fishing vessels and gears (van Anrooy et al., 2008). These insurance are almost exclusively used by industrial fishing companies. The lack of insurance uptake in the artisinal sector is attributed mostly to the low demand from artisinal fishers. Uptake by artisinal fishers is usually only done when it is a condition for a loan required by a financial institution. To best of my knowledge it is not possible to insure fisheries income or revenues.

The uptake of formal bank accounts in Chile is relatively low for a developed country (Dupas et al., 2018; Kast et al., 2018). An estimated 73.8% of households have an account at a financial institution and 21% have saved money at a financial institution in the last year (The World Bank, 2017). In a recent research project by Dupas et al. (2018) aimed at banking the unbanked, they record only moderate uptake of bank accounts through their intervention.

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[4] The General Fisheries and Aquaculture Law 20.657 Article 50 C.

[5] The Law for Establishing Unemployment Insurance 19,728, article 2

[6] Law No. 21,133 - Amending the Rules for the Incorporation of Independent Workers into Social Protection Schemes

[7] 2010: http://www.subpesca.cl/portal/617/w3-article-93405.html,
2015: http://www.subpesca.cl/portal//617/w3-article-2839.html

[8] For reference, the monthly minimum wage in Chile is 320,000 CLP.

[9] Details of the program are specified in res.ex N 247-2019: APRUEBA BASES DE PROCEDIMIENTO PARA IMPLEMENTACION DEL "PROGRAMA DE ESTUDIO DE LOS RECURSOS PESQUEROS DISPONIBLES A NIVEL NACIONAL".

They posit that being unbanked is mostly a choice in Chile, as all Chilean citizens have access to free account, called the Cuenta Rut, at the national bank (Banco Estado).

To summarize, even though Chile is a developed country, small-scale fishers there face many of the same challenges as small-scale fishers in developing countries. In particular, Chilean fishers face restricted access to or low uptake of formal consumption smoothing mechanisms. This situation seems be changing, as recent regulations are integrating fishers into more facets of the social security systems. However, to the best of my knowledge, no policy evaluations have been conducted so far. Furthermore, a new assessment of insurances in capture fisheries by the FAO is in progress, which will indicate whether progress has been made regarding insurance uptake since 2008.

3.4 Methods and data

In order to determine the prevalence of prudence among fishers I have directly measured prudence using a lab-in-the-field experiment, details for which can be found in sections 3.4.1 and 3.4.2. The measurement for prudence has been parametrized such that comparisons are possible with previously tested non-student populations. The results regarding the prevalence of prudence and the comparisons to other populations can be found in section 3.5.1. Additionally, I estimate the demographic correlates of prudence in the sample using regression analysis, which is presented in section 3.5.2.

Next I test whether risk-averse and prudent individuals are more likely to select out of high-risk occupations such as fishing. In section 3.5.3, I first test whether risk-aversion and prudence correlate with a stated preference for a secure job, whilst controlling for participants their demographic and economic situation. Subsequently I test whether the preferences in the population of fishers have indeed changed over time due to out-selection. For this, I use spatial variability in the abundance of secure and salaried jobs to isolate the effect of selection. Because as Fuchs-Schündeln and Schündeln (2005) show, the effects of risk preference and prudence on job selection are limited when there is no possibility to choose occupations based on how secure and variable the income is. Details on how locations are classified as having scarce or abundant secure occupations are presented in section 3.4.4.

I test three predictions that would indicate occupational selection has influenced prudence and risk-aversion in the population of fishers, which I will explain using the illustrative model in Figure 3.2 and the following regression specification:

$$y_i = \beta_0 + \beta_1 T_i + \beta_2 O_i + \beta_3 (T_i \times O_i) + \mathbf{X}_i \gamma + \varepsilon_i \tag{3.1}$$

Where y_i is either the measure of prudence or risk-aversion, T_i is a measure of tenure and O_i is a dummy variable indicating either scarce (0) or abundant (1) non-fishing opportunities in the landing site of the fisher. $\mathbf{X}_i$ is the vector of demographic controls and ε_i is the error term, clustered at the landing site level[10].

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[10] It is necessary to cluster the standard errors as the treatment variable, the abundance of secure occupations, is assigned on the landing site level(Abadie et al., 2017)

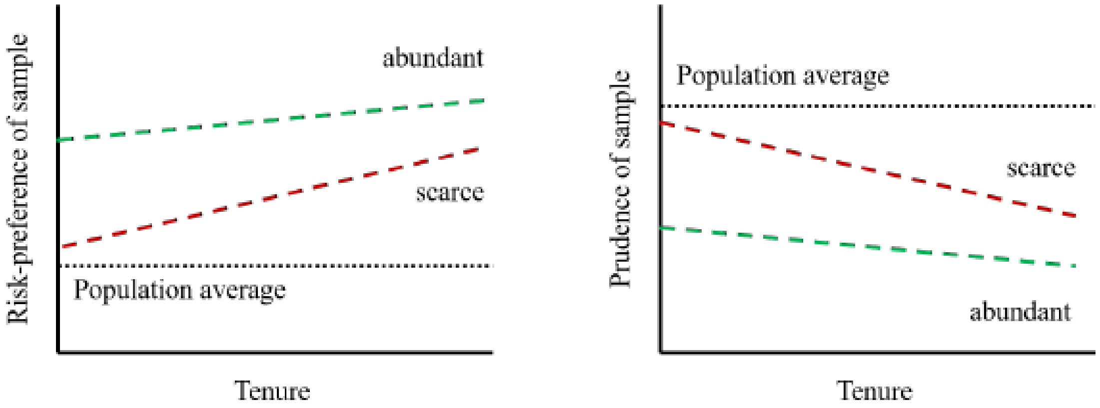

Figure 3.2: The graph illustrates how the distribution of risk preferences and prudence of a population of fishers could change over time based on the scarcity of secure jobs. When secure jobs are scarce (red line), the sample of fishers initially resembles the broader population in prudence and risk preferences. However, when risk-averse and prudent fishers prefer secure jobs and select out, those that remain fishers and attain longer tenure will be less prudent and risk-averse compared to the broader population. When secure jobs are abundant (green line) the difference in preferences between the fishers and the broader population is already substantial regardless of tenure.

The first prediction is that those who start fishing in areas with abundant opportunities for secure jobs, are less prudent and risk averse on average. To give some intuition for this prediction, consider a situation in which selection into different occupations is not possible and occupational choice would be independent of economic preferences. In this case, the risk aversion and prudence of fishers would be identical to that of the general population. Therefore the more scarce secure occupations are, the closer the preferences of fishers are to that of the average population. This would be indicated by a negative coefficient for O_i with regard to both prudence and risk-aversion. In Figure 3.2 this is indicated by the difference in preferences between the scarce and abundant situations when tenure is equal to zero.

Under the assumption that prudent and risk-averse fishers are more likely to prefer secure jobs, it would suggest that fishers with these preferences are more likely to select out of fishing when given the opportunity. When risk-averse and prudent fishers are more likely to select out, longer tenured fishers are less likely to be risk-averse and prudent compared to younger fishers. Therefore, the second predictions is that the coefficient for tenure (T_i) in equation 3.1 is negative. This correlation can however not directly be attributed to out-selection as it is possible that preferences change over time due to other processes that confound with tenure, such as a gradual desensitisation to risk (Schildberg-Hörisch, 2018).

To attribute this correlation between preferences and tenure to an out-selection process, I again use the abundance of secure occupations. As stated in prediction 1, in areas with abundant secure occupations, individuals have had the option not to become a fisher in the first place. Therefore the third predictions is that correlation between tenure and preferences should be smaller when secure options are abundant. This would be indicated by a positive coefficient for the interaction effect ($T_i \times O_i$) in equation 3.1. In Figure 3.2 this predictions is indicated by the greater steepness of the slopes in the scarce situations compared to the abundant situations.

3.4.1 Experimental sessions

Between October 29th and November 24th of 2018, we held 26 session, with a total of 423 participants in the Coquimbo, Valparaíso, Bío-bío and O'Higgins regions of Chile.[11] Experimental sessions were held in the common spaces of fisheries organisations. In the sessions prudence and risk preference were measured using incentivized tasks in a controlled lab-in-the field setting. An unrelated one-shot public goods game was also conducted during the sessions. After completing the experiments participants filled in a questionnaire regarding their demographics and fishing activities.

At the end of the session either the risk, prudence or public good experiment was randomly chosen to be paid out. The preference questions and demographic survey were answered on tablets running OpenDataKit survey software (Hartung et al., 2010). The sessions lasted between 1.5 and 2 hours and had between 8 and 22 participants. Participants were paid 10,000 Chilean pesos (CLP) for finishing the survey and could earn an additional 0 to 24,000 CLP with the incentivized preference questions. The average payout was 18,100 CLP, which is equivalent to 23,76 Euro.

Researchers of the Pontificia Universidad Católica de Valparaíso approached fisheries organisations during a round of preparatory visits in September 2018 to recruit fishers to take part in the experiment. Chilean artisinal fishers are diverse in their fishing activities and these activities are clustered in locations based on resource availability. The recruiting of fishers for this project was done in targeted way with the aim of representing a substantial range of fisheries. Selection of fishers was done based on relatively broad classifications covering the main taxonomic groups. The targeted groups were, (1) pelagic fishers targeting a combination of Anchovy, Sardine and other fish species, (2) pelagic fishers targeting the Humboldt squid, (3) benthic gatherers and divers collecting molluscs and macro algae, (4) benthic fishers targeting crustaceans. The full list of species targeted by the sample is reported in the appendix Table A-1.

There exists substantial overlap between the groups and heterogeneity within the groups. Therefore during the sessions, I record the set of target species for each participant, by asking them which species contribute significantly to their income. The list provided by the participants is compared to the official landings data for 2018 provided by the Chilean fisheries service (SERNAPESCA). In the appendix section A-2 I show that the sample is largely representative of the larger population of Chilean artisinal fishers with regard to basic demographic characteristics and that the sample is active in the majority of the fishing activities in Chile.

3.4.2 Measuring prudence

To measure prudence I present participants with 5 binary choices between lotteries in the style proposed by Eeckhoudt and Schlesinger (2006). A list of the choices is presented in Table 3.1.

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[11] A pilot session with 16 participants is excluded from the analysis due to a complication with the prudence task and 21 participants are not included as for these less than 25% of household income came from fishing.

Table 3.1: List of lotteries. The notation for the lotteries is as follows, $[H|L]$ would indicate a lottery that has outcomes H and L with equal probabilities. The lotteries for prudence have the following structure $[H + (l|h)|L]$, which indicates that the lottery $H + (l|h)$ and the outcome L occur with the same probability.

	Option A	Option B
Baseline	$9 + (4 \mid -4) \mid 6$	$9 \mid 6 + (4 \mid -4)$
Prudence + 1	$10 + (4 \mid -4) \mid 7$	$9 \mid 6 + (4 \mid -4)$
Prudence - 1	$9 + (4 \mid -4) \mid 6$	$10 \mid 7 + (4 \mid -4)$
Prudence + 2	$11 + (4 \mid -4) \mid 8$	$9 \mid 6 + (4 \mid -4)$
Prudence - 2	$9 + (4 \mid -4) \mid 6$	$11 \mid 8 + (4 \mid -4)$

Participants are presented one choice at a time. Participants do not receive feedback on the outcome of their choices until the end of the session and only one of the choices is paid out.

The choices consists of allocating a mean-zero risk to either the high or low outcome of a lottery. The mean-zero risk and lottery are two independent coin-flips, represented in Figure 3.3 by the European and Chilean coin respectively. If the first coin flip is heads the participant will receive high payout H and if it is tails they will receive low payout L. Beforehand, they are asked to put the mean-zero lottery on one of the two outcomes. We will call putting the mean-zero lottery on the low outcome, option A, and on the high outcome, option B. The mean-zero lottery is the second coin flip with payout h and l, where $l = -h$. Option A is imprudent as the possibility exists of receiving both low payouts. A participant is classified as prudent if they choose option B, as choosing this option disaggregates the possibilities of getting the bad outcomes of both the first and second coin flip.

The first choice that the participants make is between a prudent and imprudent option with the same expected outcome and standard deviation.The difference in the distribution of outcomes is that option A has a negative skew, whilst option B has a positive skew. This first lottery will be referred to as the baseline lottery. The four subsequent lotteries have differences

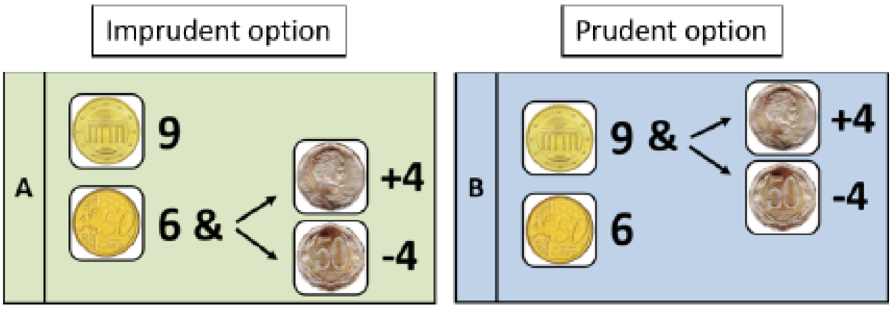

Figure 3.3: The figure shows the two options participants can choose between when measuring prudence. In both options participants have to flip a coin, they receive the good outcome of 9 points when they throw heads and the bad outcome of 6 points when they throw tails. Beforehand participants make the choice of allocating a risk to either the good outcome or the bad outcome. In the imprudent option (A) participants allocate a mean-zero risk of +4/-4 to the bad outcome of the first lottery. Meaning that they will only flip the second coin if they threw tails in the first coin-flip. When the participants choose the prudent option (B) they only flip the second coin if they threw heads in the first coin-flip.

in expected payout for choosing option A and option B. The payout for the first coin toss is increased by 1 or 2 point(s) if option A (B) is chosen. This adds an extra incentive for choosing the imprudent or prudent options respectively. The structure of the prudence lotteries allows us to determine whether participants are consistent in their choices. For example if a participant chooses the prudent option in the baseline lottery and subsequently chooses the imprudent option, when the expected value of the prudent option is comparatively larger, the participants is making choices inconsistent with regard to payout maximization.

3.4.3 Measuring risk preference

Risk preference was measured using two standard methods, which are explained in further detail below. For the sake of the analysis, the two measures of risk-preference are combined with equal weighting to form a single measure of risk-preference in order to help reduce measurement error (Schildberg-Hörisch, 2018).

The first measure is an incentivized risky investment task (Gneezy and Potters, 1997). Participants are asked to allocate 6 points between 2 projects. Project A has a sure payout of 1 for each point invested. Project B has a 50% chance of paying out 3 times the amount invested and it has a 50% chance to pay out 0. Whether project B is good or bad depends on a coin-flip by the participant at the end of the session. This particular task is relatively simple and has been used previously in lab-in-the-field settings (Gneezy et al., 2015; Charness et al., 2013).

The second measure is a survey question from the German socio-economic panel regarding the individual's self-reported propensity for risk. The question reads as follows: "Generally speaking, are you a person who is willing to take risks?".[12] Participants answer in the form of a 6-point likert scale.

3.4.4 Scarcity of secure occupations

In this section, landings sites are classified based on the extent to which non-fishing and secure occupations are available. To make this classification, I combine the municipal unemployment rate in 2018 and the answers to two survey questions.[13] In the first survey question, participants indicate whether they would prefer to have a secure job with a schedule in an office or factory. The aim of this question is to elicit whether they would select out now, if given the opportunity to have a secure job. In the second survey question participants indicate whether they started fishing because it was the 'best option' or the 'only option'. The purpose of the question is to determine whether the participant would have chosen a different occupation initially if a better option was available at the time that they started fishing.

Figure 3.4 shows that these metrics are strongly correlated. The positive correlation between the municipality level unemployment rate and the percent of fishers that want a salaried job is substantial (Pearson's correlation coefficient = 0.88). Similarly the fraction of fishers responding that fishing was their only option strongly correlates with both the unemployment rate in the municipality (Pearson's correlation coefficient = 0.78) and preferences for salaried

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[12] The Spanish translation as shown to the fishers: "En general, ¿es Usted alguién que está dispuesto a arriesgarse?"

[13] The unemployment rate is calculated using the 2018 employment survey data from the Chilean National Statistics Institute (INE). The data is publicly available and can be found at www.ine.cl

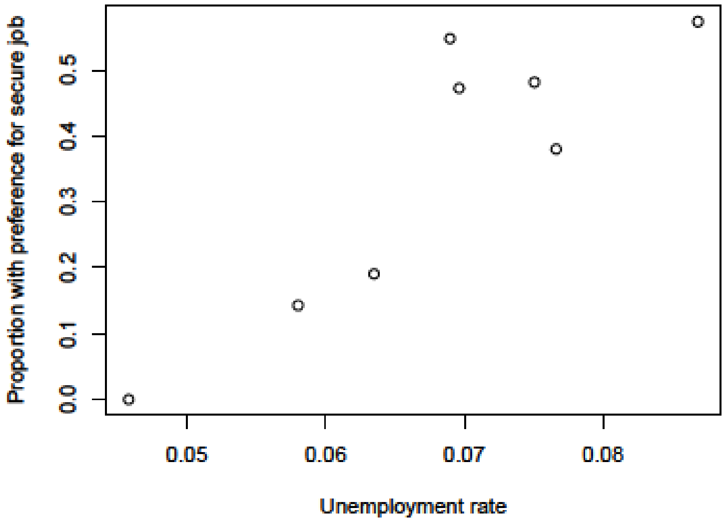

Figure 3.4: The graph shows the municipal level unemployment rate compared to the proportion of participants in that municipality with preferences for a salaried job.

jobs (Pearson's correlation coefficient = 0.92). This indicates that the level of opportunities in the landing sites relative to each other, has stayed stable over time. In Table A-3, I summarize the unemployment rate and responses to these questions per municipality.

There are 3 municipalities which contain 4 landings sites, that are below median in all three categories. These landings sites are Cochulgue caleta grande in the municipality of Tomé, Pichilemu in Pichelemu and the landing sites Caleta Limarí and Caleta La Sierra in the municipality of Ovalle. These landings sites are classified as having 'abundant' employment options. The remaining landing sites are classified as having 'scarce' employment options.

3.5 Results

I present the results in three steps. First, I present the results of the prudence lotteries and compare the prevalence of prudence of the sample to that found in previous research. Second, I present the demographic correlates for prudence. Finally, I test for the effect of self-selection on the prevalence of prudence.

3.5.1 Prevalence of prudence

Figure 3.5 shows the proportion of participants that choose the prudent option in the lotteries presented in Table 3.1. In the left graph I show the full sample, and in the right graph I show the subset of fishers that answered the comprehension question correctly and made consistent choices, meaning that they did not switch from prudent to imprudent or vice versa when the expected value of their previous choice increased.

First I test whether the sample as a whole exhibits prudent preference. For the baseline lottery I find that of the full sample, 53.7% choose the prudent option. This does not differ significantly from a random choice or 50% (two-sided binomial test, $p = 0.1446$, n =423). For the consistent subsample I find that 64.7% choose the prudent option, which is significantly different from 50% (two-sided binomial test, $p < 0.01$, n = 193).

I find that both the complete and consistent sample are more likely to choose the prudent option when the expected value increases. For the complete sample the difference is 5.9 percentage points between the baseline and the +2 lottery, and 8.9 pp between the -2 and +2 lotteries. This difference is much more pronounced for the consistent sample, where there is an 17.6 pp increase between the baseline and + 2 lottery, and a 44.6 pp difference between the -2 and +2 lotteries.[14]

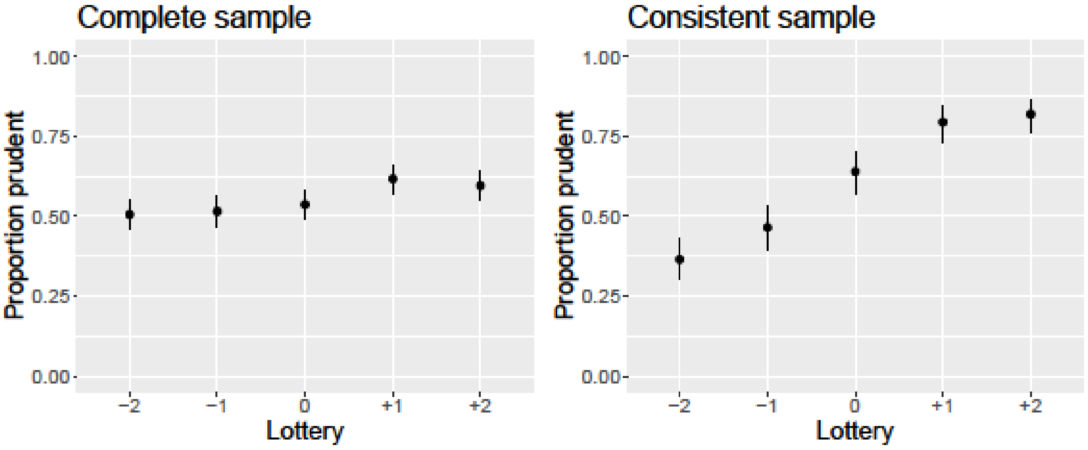

Figure 3.5: The left graph reports the fraction of the sample that choose the prudent option in each of the five prudence lotteries. The number on the x-axis reports the expected value of the prudent option compared to the imprudent option. The right graph only report the choices of those participants that did not switch more than once. The bars indicate the 95% binomial confidence intervals.

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[14] Participants that have attended high school are 24% more likely to make consistent choices (Spearman correlation coefficient 0.24 ($p < 0.01$)).

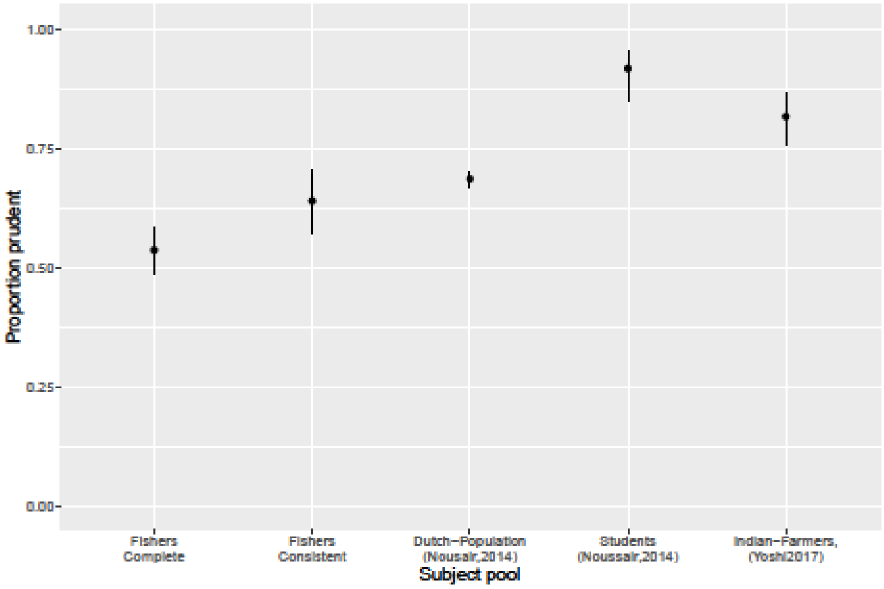

Figure 3.6: The graph compares the proportion of participants that choose the prudent option in the baseline lottery between several studies. The bars indicate the 95% confidence intervals.

Next I compare the choices in the baseline lottery to notable previous studies with samples that have used the same parameters for the lotteries. First, Noussair et al. (2014) find that in a representative Dutch population sample (LISS), the prudent option is chosen 68.6% of the time. In the same study they report the results from a laboratory experiment with university students of which 91.7% choose the prudent option. Both these samples choose the prudent option significantly more than the sample of Chilean fishers (Two-proportions z-test, $p < 0.01$). The difference between the consistent fishers and the Dutch population sample is not significant (Two-proportions z-test, p=0.16). The difference between the students and consistent fishers is significant (Two-proportions z-test, $p < 0.01$).

The only other paper measuring prudence with a non-western sample concerns a study of the higher-order risk-preference of farmers in the West Bengal region of India (Joshi et al., 2017). In this study, the prudent option is chosen 81.7% in the baseline lottery.[15]. This is significantly more than both the complete and consistent sample of Chilean fishers (Two-proportions z-test, $p < 0.01$).

In the analysis I measure prudence as the number of prudent choices that the participant has made out of the 5 possible. For the complete sample, participants on average choose the prudent option 2.78 out of 5 times. This is significantly different from 2.5 (Wilcoxon signed rank test, $p < 0.01$). The consistent sample on average made 3.1 out 5 prudent choices, this is significantly different from 2.5 (Wilcoxon signed rank test, $p < 0.01$). For the consistent sample, the number of prudent choices also indicates the switching point from imprudent to prudent and the willingness to pay for the prudent option in the baseline lottery. For example if the participant made two prudent choices (+2 and +1), it would indicate that participant

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[15] The authors only report the subsample of participants that made consistent choices in a risk preference experiment and correctly answered comprehension questions

would only choose the prudent option if he receives at least one extra point. However, when the expected value of the lotteries is equal or higher for the imprudent option (0, -1, -2), the participant prefers the imprudent option.

In order classify a participant as prudent, the participant has to prefer the prudent option in the baseline lottery and consistently when the expected value is equal or higher than that of the imprudent option, and vice versa for imprudent. Based on these criteria 125 of the 423 participants can be classified as prudent (30.3%) and 68 can be classified as imprudent (17.0%). The remaining 230 made inconsistent choices and can therefore not be classified as either being prudent or imprudent. Regarding risk-aversion, the risky-investment game can only identify participants as being either risk-averse or risk-neutral/risk-loving. The expected payout of putting points in the risky option is strictly higher than in the safe option. Therefore a participant is risk-averse unless all points are in the risky option. If all points are in the risky option, the participant is either risk-neutral or risk-loving. Based on this method I find that 87.7% of participants are risk-averse and 12.3% either risk-neutral or risk-loving.

Under certain common assumptions of the utility function such as constant relative risk aversion (CRRA), risk-aversion always implies prudence. Whilst other utility functions such as quadratic utility do not allow for prudence as the third derivative is equal to zero. The model-free measurements of prudence and risk-aversion I use do not put any constraints on the utility function. Using similar model-free specification, several papers find that prudence and risk-aversion are moderately correlated, with Spearman correlation coefficient ranging between 0.251 and 0.312 (Noussair et al., 2014; Brunette and Jacob, 2019). I however do not find a correlation between risk-aversion and prudence.[16]

3.5.2 Demographic correlates

In this section I present the demographic correlates for prudence and risk-aversion. Table 3.2 reports the OLS regression results. The first and second specification report the estimates for prudence and the third and fourth specifications report the estimates for risk-aversion. Specifications 1 and 3 report the estimates for full sample. In estimates 2 and 4, I exclude those participants that either failed the comprehension test for the relevant dependent variable or chose inconsistently in the case of prudence. The standard-errors are clustered on the level of the landing site. I report the OLS coefficients for ease of interpretation, however as the dependent variable for prudence is discrete and ordered I also report the estimates from an ordered-logistical regression to show that the found estimates are robust. The robustness check can be found in regression Table A-4 in the appendix.

Age has a strong and significant negative correlation with both prudence ($p < 0.01$) and risk-aversion ($p < 0.01$). It is unclear if the negative correlations are strictly due to ageing or if a confounding process such as out-selection or experiences drives this effect. I will addressed this in section 3.5.3. Tenure (years active as a fisher) is not included in this specification due

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[16] In contrast to my methods, Noussair et al. (2014); Brunette and Jacob (2019), measure risk-aversion and prudence using a similar format for both measures. It is possible that the lack of correlation could be due to changing methods between the elicitation tasks. Even correlations between different risk elicitations tasks are found to be limited (Schildberg-Hörisch, 2018). For example when only measuring the correlation between the experimental risk task and prudence the correlation is negative and significant (Spearman rank correlation coefficient: -0.10, $p = 0.04$), which indicates a positive correlation between prudence and risk-aversion.

Table 3.2: Table reports OLS coefficients of the demographic correlates prudence and risk-aversion. Specification (2) and (4) exclude participants that did not pass comprehension criteria for the prudence and risk experiments respectively. Robust standard errors are clustered on the level of the landing site.

	Dependent variable:			
	Prudent choices		Risk-Aversion	
	(1)	(2)	(3)	(4)
Age	-0.039^{***}	-0.056^{***}	-0.010^{**}	-0.012^{***}
	(0.006)	(0.016)	(0.004)	(0.004)
Age start fishing	0.008	0.011	0.012^{**}	0.011^{**}
	(0.008)	(0.021)	(0.006)	(0.005)
Male	0.226^{*}	0.380	0.021	0.030
	(0.126)	(0.318)	(0.096)	(0.103)
High School	0.095	-0.021	-0.146	-0.215^{*}
	(0.156)	(0.337)	(0.095)	(0.110)
Single Parent	-0.620^{**}	-1.093^{*}	-0.122	-0.028
	(0.269)	(0.582)	(0.152)	(0.192)
Spouse and Children	-0.227	-0.001	-0.243	-0.182
	(0.232)	(0.245)	(0.170)	(0.188)
Spouse, no Children	-0.071	-0.041	-0.292	-0.219
	(0.268)	(0.681)	(0.212)	(0.274)
Formal Networks	0.458^{***}	0.741^{***}	-0.044	0.0002
	(0.094)	(0.281)	(0.073)	(0.092)
Boat Owner	-0.237^{**}	-0.119	0.207^{*}	0.174
	(0.120)	(0.350)	(0.120)	(0.114)
Constant	4.218^{***}	4.549^{***}	2.292^{***}	2.346^{***}
	(0.360)	(0.914)	(0.152)	(0.166)
Observations	404	182	387	360
R^2	0.159	0.242	0.044	0.051
Adjusted R^2	0.126	0.173	0.005	0.010
Note:	$^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$			

to concerns about collinearity; the Pearson correlation coefficient for tenure and age is 0.75. However, the participants starting age is included and fishers that started fishing at a later age are more risk-averse ($p < 0.05$). Men are marginally more prudent ($p < 0.1$), however it is only significant for the complete sample. There is no significant gender effect for risk-aversion. Fishers that have finished high school are marginally less risk-averse ($p < 0.1$), however I find no significant effect for education on prudence. Single parents are less prudent compared to the base group of single and no children. Prudence has a positive correlation with the use of formal networks (banks and government) in times of need for both the complete sample ($p < 0.01$) and the consistent subsample ($p < 0.05$).

In previous research only a few demographic correlates for prudence have been observed. Most notably no significant age effect has been found previously (Trautmann and van de Kuilen, 2018), indicating that declining prudence with age is not a general process. For risk-aversion, it is commonly reported that risk-aversion even increases with age (Schildberg-Hörisch, 2018), whilst the opposite is true in this sample. Ebert and Wiesen (2014) report a marginally significant gender effect, indicating that women might be more prudent. I find that women are marginally less prudent. Most studies find that in the general population women are more risk-averse than men (Falk et al., 2018; Croson and Gneezy, 2009), however some studies that focus on individuals in occupations with high levels of risk, such as mutual fund managers, find no significant gender effect (Atkinson et al., 2003; Croson and Gneezy, 2009). This would be a possible explanation for the lack of a gender effect for risk-aversion in this sample. The strongest correlate in other research is the positive relation between education and prudence (Trautmann and van de Kuilen, 2018), which I do not find. This is however not necessarily conflicting. As compared to previous research, the overall level of education is quite low in this sample. Furthermore, those that have attained high levels of educations selected into this high risk occupation which generally does not require specific degrees. The finding that prudent individuals are more likely to prefer formal networks relates to the finding of Noussair et al. (2014), who report that prudence correlates with the usage of savings accounts and that prudent individuals are less likely to have credit card debt.

3.5.3 Selection effect

In this section, I test the prediction that risk-averse and prudent individuals are more likely to select out of small-scale fishing in favour of more secure jobs using the methods specified in section 3.4. The results are presented in two steps. First I use a logistic regression to test the assumption that risk-aversion and prudence correlate with a stated preference for a secure job. Second, I estimate the effect occupational selection has on prudence and risk-aversion in the population of fishers.

In specification 1 of Table 3.3, I show that fishers that make more prudent choices are more likely to prefer a salaried job over fishing ($p < 0.01$). The coefficient for risk-aversion is positive but not significant. The preference for a salaried job is also likely to be influenced by the profitability of the fishing activity and the current economic circumstances. Therefore, I include a fishery fixed-effect, the municipal unemployment rate, and whether the participant is a boat-owner in specification 2. When controlling for economic circumstances the positive co-

Table 3.3: Table reports logistic regression coefficients. Specification (3) excludes participants that did not pass comprehension tests for the prudence and risk experiments. Robust standard errors are clustered on the level of the landing site.

	Dependent variable:		
	Preference Salary		
	(1)	(2)	(3)
Prudent Choices	0.077***	0.075***	0.115***
	(0.022)	(0.019)	(0.038)
Risk-aversion	0.036	0.087**	0.207***
	(0.045)	(0.036)	(0.075)
Boat owner		−0.380**	−0.609*
		(0.194)	(0.322)
Unemployment		0.348**	0.480**
		(0.139)	(0.187)
Demographic controls	Yes	Yes	Yes
Fishery FE	No	Yes	Yes
Observations	375	374	160
Note:	* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$		

efficient for risk-aversion increases in size and becomes significant ($p < 0.05$). Boat owners are also less likely to prefer a salaried job ($p < 0.05$). The third specification repeats specification 2 for the consistent subsample. Both the coefficients for risk-aversion and prudence remain significant and increase in size. This confirms the assumption that prudent and risk-averse fishers are more likely to prefer secure occupations.

Next I turn to the three predictions that would indicate occupational selection has influenced prudence and risk-aversion in the sampled population of fishers. To discuss the results it is useful to restate the predictions.

The first prediction is that those who start fishing in areas with scarce opportunities for secure jobs, are more prudent and risk averse on average. Which would be indicated with a negative coefficient for the dummy variable O_i, which determines whether secure occupations are relatively scarce (0) or abundant (1). The second prediction is that fishers become less prudent and risk averse as tenure increases, because the prudent and risk-averse fishers are more likely to select out of fishing when given the opportunity. This prediction has already partly been confirmed by the negative coefficient for age in the demographics section. In this section I will utilize the tenure of the participant, measured in years active as a fisher. It is possible that a correlation between preferences and tenure is not because of out-selection, but due to another confounding process such as a gradual desensitization to risk. To attribute the effect of tenure, at least partially, to out-selection I test if this effect is weaker in areas with abundant secure occupations, which would be indicated by a positive coefficient for the interaction effect ($T_i \times O_i$). The effect would be weaker when secure occupations are abundance, because prudent individuals would have had the opportunity to not select into fishing, reducing the importance of out-selection.

In Table 3.4, the predictions are first tested for prudence in specifications 1 and 2 and

Table 3.4: Table reports OLS regression coefficients. 1 and 3 full sample, 2 and 4 sample which correctly answered the relevant comprehension questions and choose consistently. Robust standard errors are clustered on the level of the landing site.

	Dependent variable:			
	Prudent choices		Risk-aversion	
	(1)	(2)	(3)	(4)
Tenure (T_i)	-0.031^{***}	-0.046^{**}	-0.012^{**}	-0.013^{***}
	(0.006)	(0.019)	(0.005)	(0.004)
Salaried options (O_i)	-0.706^{***}	-0.886^{**}	-0.010	-0.059
	(0.264)	(0.360)	(0.222)	(0.202)
Tenure:Secure options ($T_i \times O_i$)	0.016^{**}	0.011	0.009	0.007
	(0.006)	(0.016)	(0.010)	(0.010)
Fishery FE	Yes	Yes	Yes	Yes
Demographic Controls	Yes	Yes	Yes	Yes
Observations	404	182	387	360
R^2	0.132	0.200	0.047	0.053
Adjusted R^2	0.098	0.128	0.009	0.012
Note:	$^{*} p < 0.10$; $^{**} p < 0.05$; $^{***} p < 0.01$			

then risk-aversion in specifications 3 and 4. The full sample is included in specifications 1 and 3, and then I exclude those that failed the comprehension test or choose inconsistently in specifications 2 and 4. All specifications include a fishery fixed effect and the control variables discussed in section 3.5.2. In Table A-5 in the appendix I present a robustness check with the age variable as a proxy for tenure.[17]

In line with the predictions, I find that in areas with relatively abundant secure occupations (O_i) the base level of prudence for fisher is significantly lower when tenure is equal to zero, this result hold for both the complete sample ($p < 0.01$) and the consistent subsample ($p < 0.05$). This indicates that when there are abundant secure occupations and thus alternatives to fishing, those that start fishing are less prudent. In the specifications with risk-aversion as the dependent variable, the coefficient for secure occupations is negative, however it is relatively small and not significant. Thus the first prediction does not hold for risk-aversion. In the robustness check the results for both prudence and risk aversion remain consistent.[18]

Regarding the second prediction, I find that both prudence and risk-aversion strongly decline with tenure (T_i) when secure occupations are scarce. This effect is consistently significant for both prudence and risk-aversion ($p < 0.05$). The interaction term between the abundance of secure occupations and tenure ($T_i \times O_i$) is positive and significant for prudence when the complete sample is used ($p < 0.05$). For the consistent subsample and for both specification of risk-aversion the interaction term is positive but not significant. In the robustness check where

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[17] Age and tenure are strongly correlated in this sample (Pearson's correlation coefficient = 0.75) and it is unclear whether age or the self-reported measure for tenure is the more reliable variable for the length the participant has been a fisher. For example, when comparing the answers for tenure to the participants age reveals that 38 fishers started before the age of 10 and 6 started at birth, which is implausible. However age is of course not a completely accurate proxy for tenure as some fishers start fishing late in life. Therefore I report the results from both specifications.

[18] In Table A-5, the coefficient for secure options (O_i) is marginally significant in specification (4). This can be disregarded as it estimates the effect at an age of 0, which has no economic relevance.

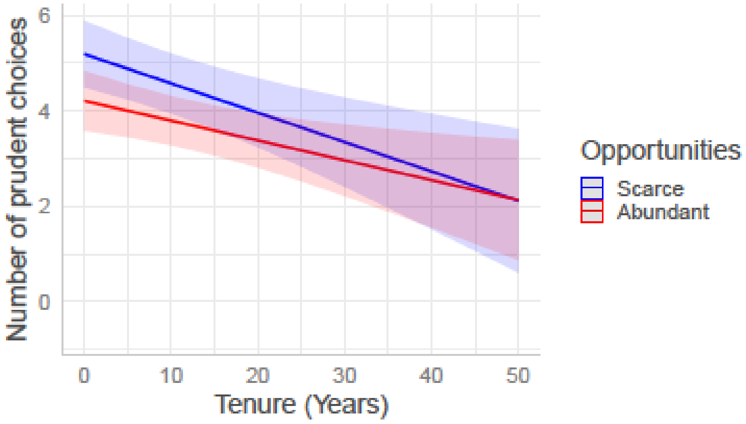

Figure 3.7: The graph illustrates the marginal effect of tenure on prudence, based on whether there are non-fishing options available in the municipality. The marginal effects are based on the OLS estimates reported in specification (1) of table 3.4. The shaded areas indicate the 95% confidence intervals for the estimates.

age is utilized as a proxy for tenure the interaction effect is consistently significant at the 5% level for both risk-aversion and prudence. The combined results indicate that the negative correlation between tenure and preferences is weaker when secure occupations are abundant. This result is quite robust for prudence, however less so for risk-aversion.

To summarize the results I use Figure 3.7, in which I plot the marginal effects of the three coefficients reported in specification (1). The graph illustrates how the difference in prudence between individuals in areas with abundant and scarce options changes as tenure increases. At tenure 0, there is a significant difference between the two situations. As tenure increases prudence decreases in both situations. When added together the tenure term and the interaction term are negative and jointly significantly different from 0 (F-test, $p < 0.05$). This means that in areas with abundant secure occupations, the negative correlation between tenure and prudence is weaker but still significant. The remaining coefficient is approximately half the size of the coefficient in areas with scarce options. Therefore, the difference is largest at low tenure and becomes smaller as tenure increase. The difference in prudence remains marginally significant until approximately 20 years spent as a fisher (F-test, $p = 0.08$). The results indicates that out-selection can at least in part explain the negative correlation between tenure and prudence.

3.6 Discussion

In this paper I measure the prevalence of prudence in a sample of Chilean small-scale fishers. Prudence, in the general sense, implies caution and preparedness when faced with risks. In the economic sense, prudence is a preference for self-insurance by accumulating precautionary savings when income is uncertain and a distaste for downside risk. Prudence and self-insurance are particularly relevant for fishers as they are generally excluded from formal safety nets and are exposed to substantial risks, both in the income and the health domain. The measurement for prudence presented in this paper is the first one done with a high risk population group. This allows for comparisons to previous measurements of prudence, with have primarily done with lower risk groups, such as western populations and students. Comparatively, I find that fishers are substantially less likely to be prudent. Furthermore, prudence strongly decreases with the tenure and age of the fishers, which can in part be explained by prudent fishers being more likely to exit fisheries in favour of more secure occupations.

One of the contribution of this paper is that it addresses a common concern in the precautionary savings literature, namely that prudent and risk-averse individuals select into safer occupations (Browning and Lusardi, 1996). Self-selection complicates assessments of precautionary savings and creates a situation in which those that take the least precautions are in the riskiest occupations. Fuchs-Schündeln and Schündeln (2005) have previously confirmed this hypothesis by estimating precautionary savings for workers when risk is either endogenous to occupational choice or exogenously assigned. In their estimations they assume a utility function with constant relative risk aversion (CRRA), under which risk-aversion and prudence can be considered synonyms. This study contributes by further testing and confirming this hypothesis whilst relaxing the assumptions on the utility function and directly measuring prudence using experiments as opposed to estimating preferences through precautionary savings.

Small-scale fishers form a vulnerable segment of the population with a limited capacity to cope with shocks (FAO, 2019). Even though Chile is a developed country, fishers there face many of the same challenges as fishers in developing countries. The combination of a variable income, health risks, a low uptake rate of insurances and limited access to the safety nets can leave fishers vulnerable to shocks (Tietze and Anrooy, 2018; van Anrooy et al., 2008). Enhancing the ability of fishers to adapt and cope with shocks can have wide-ranging social and environmental benefits. Insight into the economic preferences of fishers is informative when choosing the proper risk management option as a regulator. If it were the case that fishers are imprudent and mostly unwilling to self-insure, it would be unlikely that promoting self-insurance would be an effective tool to increase the resilience of fishers and their communities to shocks. Rather, this could form an argument for including them in mandatory formal social security systems. Whilst the results presented in this paper show that fishers are less prudent than other groups, they are still more often prudent (30.3%) than imprudent (17.0%).

Third party revenue and income insurances are currently not a viable alternative to self-insurance in fisheries. These types of insurances are commonly used by farmers to protect against bad harvests, but face significant obstacles before they can be implemented in fisheries. Most notably, strong property rights and adequate monitoring are necessary to prevent incentives for intentional overfishing in anticipation of insurance payouts (Mumford et al., 2009; Ludwig, 2002). There has been innovation on the front of fisheries insurances, as in 2019, the World Bank in cooperation with CCRIF[19] and the US state department have launched the worlds' first index insurance for fisheries in the Caribbean (Sainsbury et al., 2019). The purpose of this insurance is to protect fishers livelihoods from extreme weather events and to secure food production chains. The fishers are paid predetermined amounts after certain criteria for wind and rainfall are met. The insurance payout would reduce their incentives to fish

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[19] Caribbean Catastrophe Risk Insurance Facility

in bad weather in order to compensate for losses due to storms and restore their equipment if damaged. It is however to early to evaluate the success of this initiative.

One possible intervention to promote self-insurance can be found in Kast and Pomeranz (2018). In a field experiment with a Chilean workers they show that promoting access to savings accounts reduced consumption cutbacks due to negative income shocks by 43%, increased subjective well being and reduced the need for high interest short-term loans. Furthermore, a treatment with peer support groups was successful in increasing uptake (Kast et al., 2018). The existing infrastructure of fisheries organizations in Chile could be helpful for such an intervention, as these form natural peer groups. The results presented in this paper, suggest that a higher uptake will be achieved if the intervention is targeted at young fishers or fishers in areas with little other employment opportunities, as these are more likely to be prudent and thus value self-insurance.

References

Abadie, A., Athey, S., Imbens, G. W., and Wooldridge, J. (2017). When Should You Adjust Standard Errors for Clustering? NBER Working Papers 24003, National Bureau of Economic Research, Inc.

Anderson, S. C., Ward, E. J., Shelton, A. O., Adkison, M. D., Beaudreau, A. H., Brenner, R. E., Haynie, A. C., Shriver, J. C., Watson, J. T., and Williams, B. C. (2017). Benefits and risks of diversification for individual fishers. *Proceedings of the National Academy of Sciences*, 114(40):10797–10802.

Atkinson, S. M., Baird, S. B., and Frye, M. B. (2003). Do female mutual fund managers manage differently? *Journal of Financial Research*, 26(1):1–18.

Bellemare, C. and Shearer, B. (2010). Sorting, incentives and risk preferences: Evidence from a field experiment. *Economics Letters*, 108(3):345 – 348.

Binswanger, H. P. (1980). Attitudes Toward Risk: Experimental Measurement in Rural India. *American Journal of Agricultural Economics*, 62(3):395–407.

Birkenbach, A. M., Kaczan, D. J., and Smith, M. D. (2017). Catch shares slow the race to fish. *Nature*, 544(7649):223–226.

Bodie, Z., Merton, R. C., and Samuelson, W. F. (1992). Labor supply flexibility and portfolio choice in a life cycle model. *Journal of Economic Dynamics and Control*, 16(3):427 – 449.

Browning, M. and Lusardi, A. (1996). Household saving: Micro theories and micro facts. *Journal of Economic Literature*, 34(4):1797–1855.

Brunette, M. and Jacob, J. (2019). Risk aversion, prudence and temperance: An experiment in gain and loss. *Research in Economics*, 73(2):174 – 189.

Carroll, C. and Kimball, M. (2006). Precautionary saving and precautionary wealth. Economics working paper archive, The Johns Hopkins University,Department of Economics.

Castillo, C. and Dresdner, J. (2012). Effort optimisation in artisanal fisheries with multiple management objectives, collective quotas and heterogeneous fleets*. *Australian Journal of Agricultural and Resource Economics*, 57(1):104–122.

Charness, G., Gneezy, U., and Imas, A. (2013). Experimental methods: Eliciting risk preferences. *Journal of Economic Behavior & Organization*, 87:43 – 51.

CONAPACH (2015). *Confederación Nacional de Pescadores Artesanales de Chile (CONAPACH). 2015. Memoria CONAPACH. Diciembre 2011-Noviembre 2014.*

Croson, R. and Gneezy, U. (2009). Gender differences in preferences. *Journal of Economic Literature*, 47(2):448–74.

Davis, M. E. (2012). Perceptions of occupational risk by us commercial fishermen. *Marine Policy*, 36(1):28 – 33.

Deck, C. and Schlesinger, H. (2010). Exploring Higher Order Risk Effects. *The Review of Economic Studies*, 77(4):1403–1420.

Dupas, P., Karlan, D., Robinson, J., and Ubfal, D. (2018). Banking the unbanked? evidence from three countries. *American Economic Journal: Applied Economics*, 10(2):257–97.

Ebert, S. and Wiesen, D. (2011). Testing for prudence and skewness seeking. *Management Science*, 57(7):1334–1349.

Ebert, S. and Wiesen, D. (2014). Joint measurement of risk aversion, prudence, and temperance. *Journal of Risk and Uncertainty*, 48(3):231–252.

Eeckhoudt, L. and Gollier, C. (2005). The impact of prudence on optimal prevention. *Economic Theory*, 26(4):989–994.

Eeckhoudt, L. and Schlesinger, H. (2006). Putting risk in its proper place. *American Economic Review*, 96(1):280–289.

Engle-Warnick, J., Pulido, D., and de Montaignac, M. (2016). A Comparison of Survey and Incentivized-Based Risk Attitude Elicitation. CIRANO Working Papers 2016s-40, CIRANO.

Essington, T. E. (2010). Ecological indicators display reduced variation in north american catch share fisheries. *Proceedings of the National Academy of Sciences*, 107(2):754–759.

Falk, A., Becker, A., Dohmen, T., Enke, B., Huffman, D., and Sunde, U. (2018). Global Evidence on Economic Preferences*. *The Quarterly Journal of Economics*, 133(4):1645–1692.

FAO (2019). Social protection for small-scale fisheries in the mediterranean region- a review. Technical report, Food and Agriculture Organization of the United Nations. Rome.

FAO (2020). *The State of World Fisheries and Aquaculture 2020*. FAO.

Flodén, M. (2006). Labour supply and saving under uncertainty*. *The Economic Journal*, 116(513):721–737.

Fuchs-Schündeln, N. and Schündeln, M. (2005). Precautionary savings and self-selection: Evidence from the german reunification "experiment". *The Quarterly Journal of Economics*, 120(3):1085–1120.

Gneezy, U., Leibbrandt, A., and List, J. A. (2015). Ode to the sea: Workplace organizations and norms of cooperation. *The Economic Journal*, 126(595):1856–1883.

Gneezy, U. and Potters, J. (1997). An experiment on risk taking and evaluation periods. *The Quarterly Journal of Economics*, 112(2):631–645.

Greenberg, J. A., Herrmann, M., Geier, H., and Hamel, C. (2004). The application of farm programs to commercial fisheries: The case of crop insurance for the bristol bay commercial salmon fisheries. *Journal of Agribusiness*, (345-2016-15098):20.

Guiso, L. and Paiella, M. (2008). Risk aversion, wealth, and background risk. *Journal of the European Economic Association*, 6(6):1109–1150.

Hammarlund, C. (2018). A trip to reach the target? – the labor supply of swedish baltic cod fishermen. *Journal of Behavioral and Experimental Economics*, 75:1 – 11.

Hartung, C., Lerer, A., Anokwa, Y., Tseng, C., Brunette, W., and Borriello, G. (2010). Open data kit: Tools to build information services for developing regions. In *Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development*, ICTD '10, pages 18:1–18:12, New York, NY, USA. ACM.

INE (2010). *Primer Censo Nacional Pesquero y Acuicultor. Año Censal 2008-2009.*

Joshi, K., Ranganathan, T., and Ranjan, R. (2017). Exploring higher order risk preferences of drought affected farmers in West Bengal, India. 2017 Annual Meeting, July 30-August 1, Chicago, Illinois 258451, Agricultural and Applied Economics Association.

Kasperski, S. and Holland, D. S. (2013). Income diversification and risk for fishermen. *Proceedings of the National Academy of Sciences*, 110(6):2076–2081.

Kast, F., Meier, S., and Pomeranz, D. (2018). Saving more in groups: Field experimental evidence from chile. *Journal of Development Economics*, 133:275 – 294.

Kast, F. J. and Pomeranz, D. (2018). Savings accounts to borrow less experimental evidence from chile.

Kimball, M. S. (1990). Precautionary saving in the small and in the large. *Econometrica*, 58(1):53–73.

Krieger, M. and Mayrhofer, T. (2017). Prudence and prevention: an economic laboratory experiment. *Applied Economics Letters*, 24(1):19–24.

Leland, H. E. (1968). Saving and uncertainty: The precautionary demand for saving. *The Quarterly Journal of Economics*, 82(3):465–473.

Ludwig, D. (2002). A quantitative precautionary approach. *Bulletin of Marine Science*, 70:485–497.

Lugilde, A., Bande, R., and Riveiro, D. (2018). Precautionary saving: A review of the empirical literature. *Journal of Economic Surveys*, 0(0).

Menegatti, M. (2009). Optimal prevention and prudence in a two-period model. *Mathematical Social Sciences*, 58(3):393 – 397.

Mumford, J. D., Leach, A. W., Levontin, P., and Kell, L. T. (2009). Insurance mechanisms to mediate economic risks in marine fisheries. *ICES Journal of Marine Science*, 66(5):950–959.

Nguyen, Q. and Leung, P. (2009). Do Fishermen Have Different Attitudes Toward Risk? An Application of Prospect Theory to the Study of Vietnamese Fishermen. *Journal of Agricultural and Resource Economics*, 34(3):1–21.

Nocetti, D. and Smith, W. T. (2011). Precautionary saving and endogenous labor supply with and without intertemporal expected utility. *Journal of Money, Credit and Banking*, 43(7):1475–1504.

Noussair, C. N., Trautmann, S. T., and van de Kuilen, G. (2014). Higher order risk attitudes, demographics, and financial decisions. *The Review of Economic Studies*, 81(1):325–355.

Pfeiffer, L. and Gratz, T. (2016). The effect of rights-based fisheries management on risk taking and fishing safety. *Proceedings of the National Academy of Sciences*, 113(10):2615–2620.

Pijoan-Mas, J. (2006). Precautionary savings or working longer hours? *Review of Economic Dynamics*, 9(2):326 – 352.

Pollnac, R., Poggie, J. J., and Cabral, S. L. (1998). Thresholds of danger: Perceived risk in a new england fishery. *Human Organization*, 57(1):53–59.

Rothschild, M. and Stiglitz, J. E. (1970). Increasing risk: I. a definition. *Journal of Economic Theory*, 2(3):225 – 243.

Sainsbury, N. C., Turner, R. A., Townhill, B. L., Mangi, S. C., and Pinnegar, J. K. (2019). The challenges of extending climate risk insurance to fisheries. *Nature Climate Change*, 9(12):896–897.

Sandmo, A. (1970). The Effect of Uncertainty on Saving Decisions. *Review of Economic Studies*, 37(3):353–360.

Schaap, R., Diekert, F., Gonzalez Poblete, E., and Silva, K. (2020). Risk, restrictive regulations and income smoothing.

Schildberg-Hörisch, H. (2018). Are risk preferences stable? *Journal of Economic Perspectives*, 32(2):135–54.

Schneider, S. O., Ibanez, M., and Riener, G. (2019). Measuring utility – an application to higher order risk and saving in bogota.

Schneider, S. O. and Sutter, M. (2019). Higher order risk preferences: New experimental measures, determinants and related field behavior.

SERNAPESCA (2019). *Mujeres y Hombres en el Sector Pesquero y Acuicultor de Chile 2019.*

Smith, M. D. and Wilen, J. E. (2005). Heterogeneous and correlated risk preferences in commercial fishermen: The perfect storm dilemma. *Journal of Risk and Uncertainty*, 31(1):53–71.

Tarazona-Gomez, M. (2005). Are individuals prudent? an experimental approach using lottery choices.

The World Bank (2017). Dataset - global financial development. `https://databank.worldbank.org/source/global-financial-development`.

Tietze, U. and Anrooy, R. (2018). Assessment of insurance needs and opportunities in the caribbean fisheries sector. Technical report, Food and Agriculture Organization of the United Nations. FAO Fisheries and Aquaculture Circular No. 1175. Rome, FAO. 62 pp.

Tietze, U. and Anrooy, R. (2019). Guidelines for increasing access of small-scale fisheries to insurance services in asia. a handbook for insurance and fisheries stakeholders. Technical paper, FAO.

Trautmann, S. T. and van de Kuilen, G. (2018). Higher order risk attitudes: A review of experimental evidence. *European Economic Review*, 103:108 – 124.

van Anrooy, R., Ahmad, I. U., , Hart, T., Hotta, M., Ping, Y., Yang, W., Shipton, T., Benoit, C., Ruchismita, R., Upare, S., and Siar, S. V. (2008). *Review of the current state of world capture fisheries insurance*. FAO.

Yanez, S. D., Jopia, C. T., Parrao, M. B., and Ortega, N. V. (2018). Proyecto intercensal: seguimiento censo pesquero yacuicultor, año 2016. Technical report, Centro de Estudios de Sistemas Sociales.

Zhou, Y. (2003). Precautionary saving and earnings uncertainty in Japan: A household-level analysis. *Journal of the Japanese and International Economies*, 17(2):192–212.

Appendix

A-1 List of harvested species

Table A-1: Table contains the name and type of regulation of all species that were harvested by the surveyed sample. The first three columns identify the species. The fourth column indicates how many of the surveyed fishers target the species. The last two columns indicate the total tons landed in Chile in 2018, and the % this is of the total Chilean artisinal landings.

Scientific name	Type	Name	Targeted #	Tons Landed (2018)	% total landings (2018)
Gelidium rex	Algae	Chasca	21	174	0.01%
Lessonia berteorana	Algae	Huiro negro	36	67241	5.5%
Durvillaea antarctica	Algae	Cochayuyo	98	11458	0.95%
Macrocystis pyriphera	Algae	Huiro	56	32877	2.71%
Lessonia trabeculata	Algae	Huiro palo	49	40261	3.3%
Gymnogongrus furcellatus	Algae	Liquen	0	1045	0.09%
Porphyra columbina	Algae	Luche	86	235	0.02%
Mazzaella laminaroides	Algae	Luga cuchara	62	1558	0.13%
Sarcothalia crispata	Algae	Luga negra	69	25348	2.1%
Gigartina skottsbergii	Algae	Luga roja	45	18069	1.5%
Gracilaria chilensis	Algae	Pelillo	122	37724	3.1%
Heterocarpus reedi	Crustaceans	Camarón nailon	11	1032	0.09%
Cancer porteri	Crustaceans	Jaiba limon	95	2812	0.23%
Cancer edwardsi	Crustaceans	Jaiba marmola	65	5760	0.48%
Homalaspis plana	Crustaceans	Jaiba mora	89	110	0.09%
Taliepus marginatus	Crustaceans	Jaiba patuda	0	19	0.002%
Cancer setosus	Crustaceans	Jaiba peluda	114	264	0.02%
Cancer coronatus	Crustaceans	Jaiba reina	78	100	0.008%
Ovalipes trimaculatus	Crustaceans	Jaiba remadora	96	193	0.02%
Cervimunida johni	Crustaceans	Langostino amarillo	14	856	0.07%
Pleuroncodes monodon	Crustaceans	Langostino colorado	16	1154	0.1%

Table A-1: Continued

Scientific name	Type	Name	Targeted #	Tons Landed (2018)	% total landings (2018)
Xiphias gladius	Fish	Albacora	15	4617	0.38%
Engraulis ringens	Fish	Anchoveta	148	300427	24.8%
Dissostichus eleginoides	Fish	Bacalao de profundidad	18	1540	0.13%
Normanichthys	Fish	Bacaladillo	24	15263	1.3%
Cilus gilberti	Fish	Corvina	77	677	0.06%
Genypterus maculatus	Fish	Congrio negro	13	303	0.03%
Genypterus blacodes	Fish	Congrio dorado	13	576	0.05%
Trachurus murphyi	Fish	Jurel	134	25168	2.1%
Ethmidium maculatum	Fish	Machueuelo	43	5053	0.42%
Stromateus stellatus	Fish	Pampanito	17	1091	0.09%
Brama australis	Fish	Reineta	93	25292	2.1%
Strangomera bentincki	Fish	Sardina común	184	335296	27.7%
Thyrsites atun	Fish	Sierra	84	3176	0.26%
Merluccius gayi gayi	Fish	Merluza común	159	8273	0.68%
Callorhinchus callorhynchus	Fish	Pejegallo	1	615	0.05%
Odontesthes bonariensis	Fish	Pejerrey	1	314	0.03%
Paralabrax humeralis	Fish	Cabrilla	1	16	0.001%
Venus antiqua	Molluscs	Almeja	59	12114	1%
Aulacomya ater	Molluscs	Cholga	48	6472	0.54%
Ensis macha	Molluscs	Huepo	56	1809	0.15 %
Fissurella spp.	Molluscs	Lapa negra	65	440	0.04%
Concholepas concholepas	Molluscs	Loco	49	2469	0.20%
Mesodesma Donacium	Molluscs	Macha	59	2366	0.19
Tagelus dombeii	Molluscs	Navajuela	76	5399	0.44%
Mulinia Edulis	Molluscs	Taquilla	56	1236	0.10%
Trophon geversianus	Molluscs	Caracol	36	118	0.01%
Dosidicus gigas	Molluscs	Jibia	277	109296	9.04%

A-2 Comparison to population

To determine to what extent the sample is representative of Chilean fishers with regard to demographics, I compare the sample averages to the population averages as reported by a recent census of Chilean small-scale fishers (Yanez et al., 2018). The summary statistics of the participants and population averages are presented in Table A-2. Of the participants 21% is female, this is only slightly above the population average of 19% (binomial test, p = 0.23]). Female fishers are mostly active as beach gathers or as divers collecting algae and clam species. In the sample 80% of female fishers is active in one of these two fisheries, with the remaining 20% distributed over the remaining fisheries. The census only has data on age and tenure in the Los Lagos region of Chile. The averages they find correspond to our sample, with average age being 49 and an average tenure of 28 years. According to the 2016 census, for 62% of fishers the highest attained level is primary education, for 31% this is secondary education. This is comparable to this sample, where 46% report that they only attended primary education and 37% attained some secondary education. 27% of participant indicate to be registered as vessel owner compared to only 10% of the total fishers population. This either indicates that vessel owners are overrepresented in the sample, or that only large vessel owners ($> 15m$) are obligated to register themselves formally.

For the remaining variables there is no census information. 83% has children and 78% has a spouse. When asked what percentage of their household income comes from fishing the majority (62%) indicate that it is 100%, with the mean for the sample being 83.9%. When asked where the participant would turn of in need of cash 40.8% indicates that they would go to a formal institution (banks or government), 40.2% indicate that they would turn to informal networks (friends, family, professional organisation or fish buyer). Of the remainder, 14.9% would use both formal and informal networks and 2.8% would use neither.

	Sample	Population	*p*-value
Age	48.21 (12.49)	49*	0.101
Tenure	27.68 (14.06)	28*	0.39
Gender (Female = 1)	0.21	0.19	0.22
Boat Owner	0.27	0.10	< 0.01

Table A-2: The table contains the summary statistics from the participants. P-values result from t-tests (age and tenure), binomial-tests (gender and boat owner). Population averages for age and tenure are from the Los Lagos region.

Coverage of marine resources

In the appendix Figure A-1, I graphically illustrate the data from Table A-1 which contains the species targeted by the participants. In the figure I order the species by the number of times they are targeted on the x-axis. On the y-axis I show the fraction of total Chilean artisinal landings, that is represented by the target species target by at least this number of the participants. For example as highlighted in the graph, the most targeted species, Humboldt squid is targeted by 293 participants and represents approximately 9% of total landings. There are 187 participants that target sardina común. Combined sardina común and Humboldt squid represent 36.7% of landings. The data per species can be found in Table A-1

In the graph I show that a set representing 70% of the total landings in Chile is targeted by at least a 98 participants. When expanding the set of species to cover 90% of landings, each species in this set is targeted by at least 36 participants. This indicates that the major fishing activities in Chile are represented in our sample.

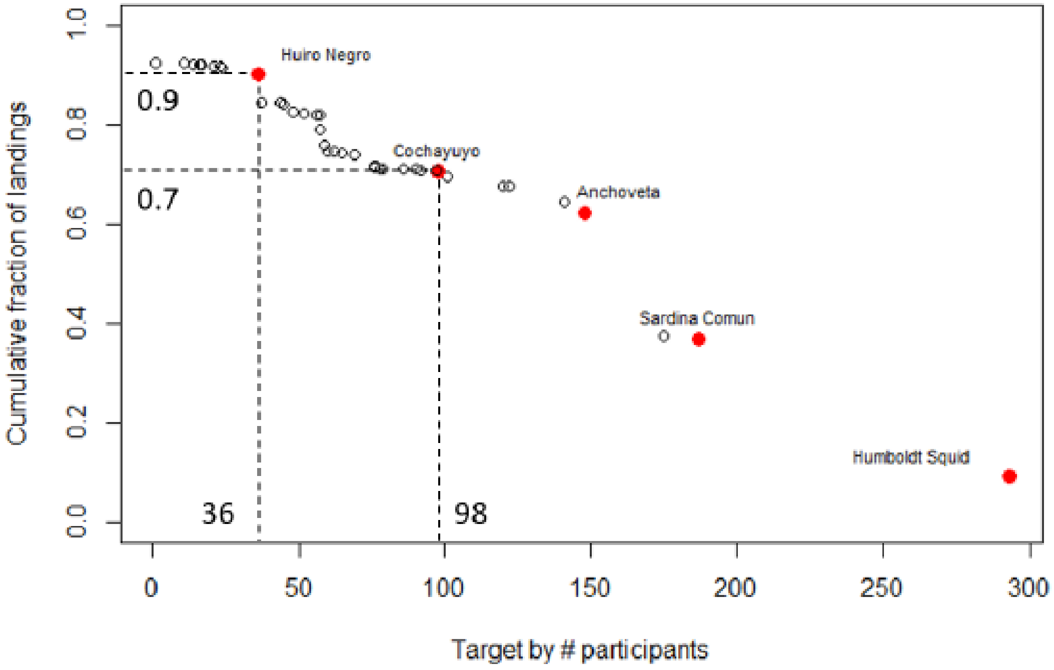

Figure A-1

A-3 Complementary tables

Table A-3: Data per municipality on the Unemployment rate, the percentage of participants that would prefer a secure job and percentage of those that started fishing because it was their only option. Unemployment rate on the municipality level is calculated using data from the Chilean national institute of statistics (cite data set).

Municipality	Preference secure job (%)	Unemployment (%)	Only Option (%)
Arauco	54.76	6.90	65.32
Coquimbo	48.15	7.51	55.56
Coronel	57.33	8.68	53.33
Lota	47.22	6.96	48.72
Ovalle	14.29	5.80	29.17
Pichilemu	0.00	4.58	9.09
San Antonio	37.97	7.66	42.17
Tome	19.05	6.35	42.86

Table A-4: Table reports the coefficients from an ordered logistic regression using the specifications 1 and 2 from Table 3.2. Robust standard errors are clustered at the landing site level.

	Dependent variable:	
	Prudent choices	
	(1)	(2)
Age	-0.051^{***}	-0.061^{***}
	(0.009)	(0.021)
Age start fishing	0.009	0.008
	(0.010)	(0.024)
Gender	0.200	0.310
	(0.168)	(0.372)
High School	0.175	0.035
	(0.200)	(0.428)
Single Parent	-0.901^{**}	-1.298^{**}
	(0.359)	(0.608)
Spouse and Children	-0.348	-0.012
	(0.363)	(0.354)
Spouse, no Children	-0.100	0.136
	(0.347)	(0.911)
Formal Networks	0.587^{***}	0.828^{**}
	(0.122)	(0.328)
Boat Owner	-0.293^{**}	-0.220
	(0.149)	(0.392)
Observations	404	182
Note:	$^{*}p<0.10$; $^{**}p<0.05$; $^{***}p<0.01$	

Table A-5: Robustness check of regression presented in Table 3.4, using age as the variable for tenure. Table reports OLS regression coefficients. Specifications 1 and 3 include the full sample. Specifications 2 and 4 the sub-sample which correctly answered the relevant comprehension questions and choose consistently. Robust standard errors are clustered on the level of the landing site.

	Dependent variable:			
	Prudent choices		Risk-aversion	
	(1)	(2)	(3)	(4)
Age (T_i)	-0.043^{***}	-0.063^{***}	-0.012^{***}	-0.014^{***}
	(0.006)	(0.018)	(0.004)	(0.004)
Secure options (O_i)	-1.324^{**}	-1.862^{***}	-0.463	-0.542^{*}
	(0.538)	(0.711)	(0.358)	(0.308)
Age:Secure options ($T_I \times O_i$)	0.023^{**}	0.031^{**}	0.015^{**}	0.015^{**}
	(0.009)	(0.015)	(0.007)	(0.006)
Demographic controls	Yes	Yes	Yes	Yes
Fishery FE	Yes	Yes	Yes	Yes
Observations	404	182	387	360
R^2	0.163	0.245	0.049	0.056
Adjusted R^2	0.128	0.172	0.008	0.012
Note:		$^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$		

Paper 4

Does nature shape risk- and social preferences? Evidence from Chile, Norway, and Tanzania

In collaboration with Florian Diekert.

Abstract: We combine survey data and administrative data from selected fisheries in Chile, Norway, and Tanzania to study whether exposure to a more risky and a more social work environment has an effect on risk- and social preferences. Our approach bridges a gap between existing case-study evidence and global estimates from historical data. While we do not find strong evidence for endogenous social preferences, we do find evidence for endogenous risk preferences, especially in Chile, where the differences in risk exposure are most pronounced. A one standard deviation increase in risk exposure is associated with a 0.08 standard deviations increase in risk tolerance globally and 0.16 standard deviations for Chile specifically. Making use of the fact that we have repeated observations from some fishermen, we make a first pass at disentangling selection from adaptation (cultural learning) as potential mechanisms that make preferences endogenous. For Chile, we find suggestive evidence for an adaptation process within fishermen, while for Tanzania, the data speaks more towards a selection process that changes the composition of the population in line with risk exposure.

Keywords: Prudence, Higher order Risk preference, Self-selection, Fisheries, Natural resources, Self-insurance.

4.1 Introduction

There is ample evidence of large heterogeneity in economic preferences (von Gaudecker et al., 2011; Dohmen et al., 2011; Vieider et al., 2015; Falk et al., 2018). Certainly, not all of it is random. The work of Becker et al. (2020), for example, shows that differences in risk aversion are correlated with the time that elapsed since different populations separated. The longer respective groups have shared common ancestors, the closer are their risk preferences. This suggests that one of the key economic traits may have a genetic component. While economic preferences have – for a long time – been regarded as fixed and stable (Stigler and Becker, 1977), the view that preferences are in fact endogenous is becoming more and more established (Bowles, 1998; Schildberg-Hörisch, 2018; Cappelen et al., 2020).

Here, we add to this literature by investigating the effect of the *natural* environment on agents' risk and social preferences.[1] Specifically, we present data from fisheries in Chile, Norway, and Lake Victoria in Tanzania, combining results from incentivized experiments with administrative data. In each country, we compare economic preferences from fishermen that target different species and hence face different levels of risk (low versus high) and organize production differently (small versus large crews).

Several studies link heterogeneity in economic preferences to the natural environment. Galor and Özak (2016), for example, argue that pre-industrial agro-climatic characteristics that yield a higher return on investment cause lower discount rates through "a process of selection, adaptation, and learning". Similarly, Buggle (2020) argues that nature has an indirect long-run impact on culture through the mode of production in pre-industrial agriculture. Societies that jointly practiced irrigation in the ancestral past hold more collectivistic, rather than individualistic, norms today.[2] Buggle and Durante (2017) examine the direct effect of climatic risk (inter-annual variability in growing conditions) in the ancestral past on levels of generalized trust today. They find that societies where farmers benefited more from mutual insurance are more likely to have inclusive political institutions early on. A reinforcing feedback loop between social preferences and institutions then means that these societies still display higher levels of trust (as measured by the World Value Survey) and have more inclusive political institutions today.

Studies that investigate long-term changes in preferences as a reaction to differing natural environments focus on developments that are encoded in (or transmitted by) institutions. Several studies complement this approach by presenting case-specific evidence for the mal-

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[1] In contrast to risk preferences, there is no generally accepted definition of "social preferences" in the economic literature. Cooper and Kagel (2016) speak of "other regarding preferences" to highlight the fact that social preferences (in contrast to risk preferences) extend the neo-classical model of a rational agent to include the actions or utility of others. Here, we say that agent i has stronger social preferences than another agent j, if i's utility is more sensitive to the action or utility of other agents than j's utility. At this point, we do not take a concrete stance on how exactly the actions or utility of others affect the agent's utility.

[2] There is a large literature documenting the long-run effect of the mode of production on current outcomes. For example, Alesina et al. (2013) famously document the relationship between labour intensive shifting cultivation or capital intensive plough cultivation and gender roles. Another example is Bentzen et al. (2017) who document a relationship between irrigation practices in the past and autocratic rule today. The difference of this literature to the studies discussed in the main text is that the latter focus more directly on the underlying economic preferences rather than on concrete manifestations.

leability of preferences over the life-cycle of individuals.[3] In a seminal contribution, Gneezy et al. (2016) argue that the way how production is organized has an effect on social-preferences through adaptation. They compare fishermen from a lake in Brazil that work on their own with fishermen that fish close by at the sea and work in groups. Fishermen at sea are shown to be more pro-social than the fishermen at the lake. Di Falco et al. (2019) combine household data with stated time preferences that are elicited at two points in time to estimate the effect of weather. Controlling for wealth and other effects, Di Falco et al. find that households that are exposed to more rainfall are more forward looking. Olbrich et al. (2011) find that Namibian farmers who are less risk averse occupy riskier farms (consistent with self-selection). Interestingly, farmers who grew up on their own farms are more risk-averse if they had been exposed to higher risks at young ages. Finally, Nguyen (2011) relies on low labour mobility in rural Vietnam to argue for a nurturing effect of occupational choice, according to which fishermen are less risk averse than farmers.

This paper aims to bridge the gap between existing case-study evidence and global estimates from historical data. We combine survey data and administrative data from selected fisheries in Chile, Norway, and Tanzania, and importantly, we use the panel structure in parts of our data to make a first pass at disentangling selection from adaptation (cultural learning) as potential mechanisms that make preferences endogenous.

Fisheries are an ideal setting to study whether exposure to a more risky and a more social work environment has an effect on risk- and social preferences. Arguably, fishing is the last occupation where production is truly close to our ancestral past as hunters/gatherers. Much the same forces apply today as in our evolutionary past. Moreover, fisheries rely directly on the natural environment, both in that the (variable) resource stock is a necessary input to production, but also in the sense that natural forces such as weather and waves determine production possibilities.

Fisheries are found in all regions of the world and across all levels of development. Sustainably managing these socio-ecological systems is of vital importance for food, income, and livelihood around the world. According to the FAO (2020), fish provided about 3.3 billion people with almost 20 percent of their average animal protein intake. Globally, around 60 million people are engaged in the primary sector of fisheries and aquaculture. Key threats to sustainable management are weak governance, incentives to overuse common pool resources and a tight coupling of ecosystems (Smith et al., 2010).

Better understanding how exposure to different natural environments may affect outcomes through shaping agent's risk- and social preferences could allow policy makers to design targeted interventions. For example, government support should reduce the vulnerability of fishermen without creating incentives to simply catch more fish more effectively (Sumaila et al., 2019). Similarly, policies to monitor and enforce harvest regulations should amplify and not destroy pre-existing community structures (Ostrom et al., 2007).

Both risk- and social preferences play a key role in determining economic outcomes in fisheries. Risk preferences fundamentally capture the mean-variance trade-off of choices under

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[3] Note that this differs from the literature that studies the short-term malleability of preferences. Several studies, for example, attempt to estimate the effect of natural disasters such as hurricanes, earthquakes, or mudslides on risk preferences, finding both positive (Eckel et al., 2009; Kahsay and Osberghaus, 2018) and negative effects (Willinger et al., 2013; Cameron and Shah, 2015).

uncertainty. As such, they are important in predicting production decisions in the short term (such as where and when to fish) and in the long term (such as how much to invest in gear and vessel), but also decisions on issues such as compliance with rules and regulations. These decisions, in turn, have important ramifications for sustainable management. Compliance is obviously central for management policies to take effect, but fishermen owning capital often have vested interests to influence policies in direction of a short-run return on investment. Harvest quotas that are too lenient, or non-compliance with strict quotas can both jeopardize the long-term stability of the socio-ecological system.

Not only risk preferences, but also social preferences determine outcomes. They do so at two levels: At the macro level, fishermen have to solve the social dilemma of using a common pool resource. While it would be socially optimal if every fisherman (or every fishing crew) would scale its own harvest in proportion to the productivity of the resource stock, each individual fisherman (or fishing crew) has strong incentives to harvest more: The gains are private but the costs are public. At the micro level, fishermen face cooperation problems when working in crews. When all row out to reach the fishing grounds or all have to lean in to haul the net, each individual has an incentive to free-ride on the effort of the other crew members. Although social preferences certainly play a central role in overcoming free-riding incentives, it is not unambiguously clear how the micro- and the macro-level interact to determine long-term socio-ecological outcomes. On the one hand, there may be cases where stronger in-group cooperation leads to stronger out-group competition and where in-group cooperation can hence be detrimental to sustainable management. On the other hand, one can think that there is a common characteristic that underlies both cooperation at the micro and at the macro level, or one can think that pro-social preferences that are learned at the micro level extend to collaboration at the macro level.

In other words, if one suspects that there could be a role for nature in shaping risk- and social preferences, then fisheries are a good place to detect it because risk- and social preferences matter directly for economic success and long-term outcomes, and because nature has such a direct impact on production. To structure our study of fishermen' risk- and social preferences in different natural and institutional contexts, it is useful to spell out how we think about the potential causal impact of the natural environment on risk- and social preferences. We do so in the next section, deriving testable hypotheses. Section 4.3 then presents the data and methods that we use to test these hypotheses and section 4.4 presents the results. Section 4.5 concludes.

4.2 Theoretical framework

In the following, we first spell out how risk- and social preferences affect socio-ecological outcomes in fisheries, to then zoom in on a submodel that explains how these preferences could be endogenous to the environment. What we have in mind is a dynamic model where an agent chooses how much effort to allocate to fishing. The central ingredient of the model is that the natural environment pre-determines the mode of production (the use of active or passive gear, working in a team or alone etc.), as well as the variance of harvest.

To be more specific, fishing effort is a necessary input to production, which together with the resource stock determines output (harvest). Output is increasing in both inputs, but production is stochastic: Either the size of the resource stock or productivity (or both) are not known when the agent decides the amount effort that he or she allocates to fishing. For example, the yearly recruitment of the Norwegian Spring-Spawning herring stock, supporting one of the most valuable fisheries in the world, fluctuates up to fourfold from one year to the next. Similarly, the trip level data from this fishery shows that for the average vessel the standard deviation in trip revenues approaches the mean (the coefficient of variation in trip revenues is 0.79). In other fisheries, exogenous fluctuations are less pronounced. In the Chilean benthic fishery for clams and macro algae, for example, the revenue from fishing trips is much less variable, with a coefficient of variation in trip revenues of 0.46. The natural environment determines the variance in stock fluctuations. From theoretical models, we know that, for a given level of risk aversion, it is optimal to allocate less effort to fishing the riskier a fishery (Reed, 1979; Kapaun and Quaas, 2013).

In many real-world fisheries, agents cannot freely harvest as much as they want. Rather, there are formal or informal constraints on what can be harvested. These constraints can be formal regulations, such as of Individual Tradeable Quotas (ITQs), or they can be informal rules that regulate how much extraction is acceptable, depending on the institutional context (Copeland and Taylor, 2009). Either way, actual harvest will be measured against the prescribed (formal or informal) norm only if the agent is monitored and detected. Detection is uncertain, and we would hence expect to see agents that are more risk averse to engage less in over-harvesting (and hence allocate less effort to fishing for a given level of risk aversion).

In addition to risk preferences, also social preferences play a role here. Specifically, one can think that the utility loss induced by the penalty depends on the social preferences of the agent who is caught over-harvesting. For example, a fisherman that cares more about the opinion of others will have greater incentives to keep within the prescribed norm of what is acceptable to harvest. The literature indeed highlights the central role of social preferences to explain compliance behaviour in fisheries (Kuperan and Sutinen, 1998; Eggert and Lokina, 2010; Dresdner et al., 2015).

That said, social preferences can matter in determining outcomes, even when the institutional context is not spelled out in the model. The first reason is when the fishery in question is small in the sense that the harvest decision of one agent has noticeable negative consequences for what other agents can harvest. In that case, agents with stronger social preferences would harvest less in order to allow others harvesting, too. The second reason why social preferences can matter in determining outcomes is that fishing is often a team exercise. In many cases fishermen do not work alone, but they work in crews that row, sail, or steam to the fishing grounds together, that haul the net together, that share profits etc. In such cases, harvest is a function of team effort. Agents with stronger social preferences are more likely to contribute to the public good of team effort, and would hence be expected to harvest more. The natural environment determines both whether a given fishery is large or small,[4] and whether a given fishery is best harvested alone, in small teams, or in large teams.

Assuming specific relations and functional forms capturing these mechanisms, it is possible to take risk- and social preferences as given and fixed and predict socio-ecological outcomes. The welfare consequences if agents were a little more risk averse or a little less pro-social could then be evaluated by comparative statics. This is not what we do here. Instead, we aim to replace the given and fixed preferences with a submodel of endogenous preference formation.

Our submodel of endogenous preference formation relies on two processes: selection and adaptation. Both processes imply that a natural environment that is more risky leads to more risk tolerant fishermen, and that a natural environment that favours working in (larger) teams leads to more pro-social fishermen.

To model selection, we simply add a stage of an irreversible occupational choice before the agent chooses his or her fishing effort. That is, agents choose whether they should become a fisherman in the first place (or do some other, unspecified, job), and only if they have chosen to be fisherman, they choose how much effort to allocate to fishing.[5] In choosing his or her occupation, the agent evaluates the outside option against the expected utility from fishing. The agent's risk- and social preferences will obviously matter for this evaluation. More risk tolerant agents are more likely to choose fishing in a more volatile fishery that is riskier than the outside job and more pro-social agents are more likely to choose fishing in a fishery where fishermen work in crews.

Selection happens at the beginning of an occupational career, but it may also operate gradually over the course of an agent's life cycle. Many fishing communities around the world are in remote or peripheral areas and good outside options may be rare. Even if there were no other options than to go fishing at the beginning of an agent's career, outside options may materialize at a later point in time. For example, the discovery of oil in North Sea opened up massive job opportunities and many fishermen along the coast decided to join the Norwegian "oil adventure". Of course, this may also happen the other way around: Many farmers along the shores of Lake Victoria became fishermen during the export boom of the Nile Perch fishery. One could capture such processes by assuming that the value of the outside option is a random variable that takes higher or lower values in different periods. Such a process of variable outside options would then lead to gradual selection, and we should observe that in the population of active fishermen, the link between the natural environment (determining the volatility and mode of production) and risk- and social preferences becomes stronger with time.

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[4] For a given set of technology, the productivity and spatial dispersion pattern of the resource stock will determine whether the harvest decision of one agent have a contemporaneous or inter-temporal effect on the production possibility set of another agent.

[5] Alternatively, one can think that the choice of effort implicitly captures selection (such that the opportunity cost of effort are measured in terms of the wage rate of the outside option, as in Copeland and Taylor, 2009) but we think that modelling occupational choice explicitly adds conceptual clarity.

Adaptation could work through the simple fact that agents may get used to their environment (desensitization). It is not immediately obvious how this process of adaptation should be modelled. Certainly, agents do not "choose their preferences" such as an one may choose to buy two apples instead of one orange in a supermarket. However, agents may choose to brave a risky situation, and having done so may leave a mark on their future evaluation of risky prospects. In other words, desensitization could operate through a form of "experiential learning".[6]

Adaptation could also work through some type of "cultural learning". There may be peer pressure to act bravely or cooperatively. Alternatively, agents may choose to listen to the reasons of others that highlight the virtue of cooperation, or they may choose to deliberate on their own, read Kant or religious scriptures, and afterwards change their opinion on the value of being pro-social.

As for gradual selection, adaptation through experiential or cultural learning would mean that the link between the natural environment gets stronger over time. Hence, we should observe a positive correlation of risk-preferences and tenure in volatile fisheries and a positive correlation of social preferences and tenure in fisheries that rely on team work to a larger extent. The difference with gradual selection is that adaptation is a process that works at the level of the individual. In other words, while gradual selection can lead to a drift in the average risk- and social-preferences in the population of fishermen, gradual selection is fully consistent with innate and stable preferences at the individual level. Adaptation, in contrast, necessitates preferences that are malleable at the individual level.

Gneezy et al. (2016) present evidence that the way how production is organized has an effect on social-preferences through adaptation. They compare fishermen from a lake in Brazil that work on their own with fishermen that fish close by at the sea and work in groups. Fishermen at sea are shown to be more pro-social than the fishermen at the lake. Importantly, their findings are robust to controlling for selection, and they do not find differences in the pro-sociality of women that do not fish in these two societies. Similarly, Leibbrandt et al. (2013), using data from the same setting, show that the lake fishermen that work alone are more competitive than the fishermen that fish in groups at the sea. Because this difference is increasing with tenure, Leibbrandt et al. (2013) argue that the competitive attitude is not innate but learned at the workplace.

Jang and Lynham (2015) compare Nile perch fishermen with Dagaa fishermen at Lake Victoria and document significant differences in pro-social behaviour across these two groups. Again, they find that the difference between the two groups is stronger for more experienced fishermen (captains), suggesting that pro-social preferences that are linked to the way different fish species are caught are malleable at the individual level.

A third example comes from Norway, where Vea (2009) compares cod fishing communities with herring fishing communities in the 19th and 20th century. He argues that herring fishermen from the West Coast of Norway are more entrepreneurial and risk-tolerant than cod fishermen from Northern Norway and that a difference in mentality can be traced back to the fact that the predominant herring fishery in the west is volatile and has been risky (as herring

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[6] Indeed, "a smooth sea never made a skilled sailor" (F.D. Roosevelt).

are caught offshore), while the predominant cod fishery in the north is relatively stable (the annual spawning migrations bring the resource close to shore and into the fjords).

In short, based on these case-studies the empirical evidence from global and historical datasets, there is reason to believe that more exposure to more risk or more social workplace organization leaves a mark on risk- or social preferences. We should hence observe the following:

Hypothesis 1: Endogenous risk preferences Fishermen are more risk tolerant in a more risky fishery

Hypothesis 2: Endogenous social preferences Fishermen are more pro-social in a more collectivistic fishery

As discussed above, both adaptation and selection could be processes that lead to endogenous preferences at the population level. We test the following two hypotheses:

Hypothesis 3: Selection We see a stronger link between the natural environment (determining the volatility and mode of production) and risk- and social preferences for those fishermen that opted into the fishery, or when many outside options exist.

Hypothesis 4: Adaptation The link between the natural environment and risk- and social preferences increases with tenure.

Accounting for endogenous preferences in a model where socio-ecological outcomes depend on risk- and social preferences could lead to different predictions than when preferences are taken to be fixed. On the one hand, there could be a reinforcing feedback loop between risk preferences and the volatility of the resource stock, where risky choices amplify resource variability, which again attracts more risk tolerant agents or makes agents more risk tolerant. On the other hand, there could be a dampening feedback loop where cooperative production modes lead to more cooperative fisheries management, which again attracts more pro-social agents or makes agents more pro-social. While the endogeneity of preferences is plausible, it is an empirical question whether the link between the natural environment and preferences is detectable and strong enough to qualitatively affect outcomes.

4.3 Methods and data

In this paper, we collate the data collected in five field surveys and one online survey (N=2126) to address the empirical question whether there is a detectable link between the natural environment and economic preferences. Specifically, the data comes from three countries, based on findings in the previous literature.

In Norway, we compare fishermen from Northern Norway that are active in the demersal fishery (with cod as the main target species) to fishermen from Western Norway targeting pelagic species such as herring. In line with Vea (2009), the demersal (cod) fishery is classified as stable and individualistic, and the pelagic (herring) fishery as risky and collectivistic. [7] In Chile, we compare benthic to pelagic fishermen, where the former are classified as stable and individualistic, and the latter as risky and collectivistic (Yanez et al., 2001; Gelcich et al., 2010). Finally, for Tanzania, our classification is based on Eggert and Lokina (2010) and Jang and Lynham (2015), with the local fishery for Lake Victoria Dagaa accordingly being the more stable fishery than the export oriented Nile-Perch fishery. The Dagaa fishery is accordingly classified as the more collectivistic fishery.

Together, these six fisheries span the range from basic artisanal to highly industrialized industries, from open-access to well-developed institutional systems and from the tropics to the polar regions, see Table 4.1 for an overview.

Table 4.1: Classification of fisheries in the three field settings

Country	Fishery	Risk exposure	Social organization
Chile	Benthic	Low	Individualistic
	Pelagic	High	Collectivistic
Tanzania	LV Dagaa	Low	Collectivistic
	LV Nile Perch	High	Individualistic
Norway	Demersal	Low	Individualistic
	Pelagic	High	Collectivistic

These literature-based classifications encompass many different dimensions of risk exposure and social organization. We complement these measures by a data-based approach that focusses on the observable variability of trip revenue and on crew size as specific components of risk- and social exposure. (We describe the construction of these exposure measures in detail in section 4.3.3.) Harnessing the power of the large sample, we standardize the measures of risk- and social preferences to test for differences in preferences across all six fisheries. After testing whether a link between preferences and exposure can be detected in the pooled sample, we repeat the same econometric exercise for each field site separately, investigating whether there are country specific differences.

Equations (4.1) and (4.2) outline our generic statistical model. Here, RP_i refers to the risk preference of agent i (measured so that a higher value means more risk tolerance or less risk aversion) and RE_i refers to her risk exposure (also measured positively, *i.e.* a higher value

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[7] Large trawling vessels for cod are grouped under the pelagic fisheries.

means exposure to more risk). The regression for social preferences, which relates the social preferences of the participant SP_i to her social exposure SE_i, is parallel to the one for risk preferences and not shown here. As age has been found to be an important determinant of economic preferences (Schildberg-Hörisch, 2018), we include it as an additional control in regression (4.1).

$$RP_i = \alpha + \beta_1 RE_i + \beta_2 Age_i + \varepsilon_i \tag{4.1}$$

Linking the regression model to the hypotheses discussed in the previous section, we see that hypothesis 1 is confirmed when the coefficient β_1 in equation (4.1) is positive and significant. In parallel, hypothesis 2 is confirmed when the coefficient on social exposure is positive and significant in the respective regression on social preferences.

$$RP_i = \alpha + \beta_1 RE_i + \beta_2 Sel_i + \beta_3 (Sel_i \times RE_i) + \beta_4 Ten_i + \beta_5 (Ten_i \times RE_i) + \varepsilon_i \tag{4.2}$$

Regression (4.2), in turn, allows a first pass at testing hypotheses 3 and 4. Provided that we do find a significant relationship between exposure and preferences, a positive coefficient on the interaction term between the indicator for having selected into the fishery, Sel_i, and a more risky fishery speaks towards a mechanism that is based on selection. A positive coefficient for the effect of selection on its own (β_2 in equation 4.2) means that those fishermen that have actively chosen be fishermen are more risk tolerant, and a positive effect on the interaction term means that this effect is particularly strong for the more risky fishery. A positive coefficient on tenure (Ten_i) and on the interaction of tenure and risk exposure could speak to either gradual (out-)selection, or adaptation. It means that risk tolerance is higher for participants with longer tenure (and especially so in the high risk fishery), which could be either due to the fact that fishermen with low risk tolerance find other jobs over time (the composition of the population changes over time), or due to desensitization/cultural learning at the level of the individual fishermen (and an unchanging composition of the population). We do not include Age_i in regression (4.2) because it is strongly correlated with tenure.

To further disentangle the processes of gradual selection and adaptation, we make use of the fact that there are several participants that we observe repeatedly. We can thus build a panel dataset and check whether there have been changes of risk preferences within fishermen, and whether these changes differ between low risk and high risk fisheries. Moreover, we compare the sample of repeated observations with the sample of participants that we do not see again. If the former sample is more risk tolerant (or more pro-social) than the latter, especially in more risky or more collectivist fisheries, this would be strong evidence for a process based on gradual (out-)selection.

Figure 4.1: Map of field sites, showing the landing sites in which we held workshops in Chile and Tanzania. For Norway, municipalities with at least 10 respondents are shown. To avoid clutter some adjacent landing sites have been merged on the map. For a full overview of landings sites and the sample size per site, see Table A-6

4.3.1 Field setting and sampling procedure

In this subsection, we briefly present the field setting and our sampling procedure in Chile, Norway, and Tanzania (see Figure 4.1).

The Lake Victoria region of Tanzania plays a crucial role for the local and regional economy. The lake's fisheries support, directly and indirectly, the livelihood and protein availability for more than four million people and its annual economic contribution to the region is estimated to be about 250 million Euro. The sustainability of the Lake Victoria fishery is threatened by climate change, pollution, population pressure, and overfishing. Solving this collective action problem is particularly acute at Lake Victoria since laws and regulations set in place to protect the lake from being overfished are poorly monitored and enforced.

Between 2017 and 2020 we conducted three field surveys in Tanzania in close collaboration with the Tanzanian Fisheries Research Institute (TAFIRI). We visited the same communities, aiming at a sample size between five and six hundred participants in each wave. In total, 1494 individual fishermen participated in the three surveys. One objective of the second field survey was to re-sample fishermen from the first survey wave. We achieved a re-sampling rate of about 50%. In the third field survey, 84 fishermen had participated in one of the two previous surveys and 41 fishermen participated in all three surveys.

In contrast to the inland fisheries in Tanzania, the fisheries in Chile take place at the sea. The coastal waters of Chile are host to a productive and diverse marine ecosystem. The upwelling caused by the Humboldt current brings nutrient rich waters to the surface. This nutrient availability allows for rapid plankton growth, which serves as the primary source of food for many marketable fish species (Gomez et al., 2012). The productivity of this ecosystem supports Chile's status as a top ten exporter of fish and fish products (FAO, 2020). However due to natural variability and overfishing, the total catches have fluctuated sharply over the last 10 years. Artisanal fishing vessels, smaller than 18 meters, do the majority of fishing in Chile.

In an effort to increase resource sustainability, artisanal fishermen have been granted exclusive fishing rights (for pelagic fisheries) and territorial use rights (for benthic fisheries, see Castilla, 2010). The Chilean government distributes these fishing rights to small-scale fisheries organizations, which are founded and managed by the artisanal fishermen (Chávez Estrada et al., 2017). The organizations are responsible for the sustainable exploitation of their resources. However, cooperation between fishermen within these organizations is necessary to manage these new fishing opportunities successfully. In addition to these rights-based fisheries, a number of species continue to be harvested under de-facto open-access regimes.

Fishermen in Chile were approached through fisheries organizations by researchers of the Pontificia Universidad Católica de Valparaíso during a round of preparatory visits preceding the field surveys. When there was interest from a fishery organization to participate the contact person of this organization was asked to invite participants for the session. If a minimum number of twelve fishermen agreed to participate, a workshop was scheduled. We did not have the objective of re-sampling fishermen between the first and second field survey in Chile, but as we largely visited the same communities, we have 77 fishermen that participated in both field surveys.

In both Chile and Tanzania, the survey was held in workshop-style sessions in community centres or directly at the landing site. Each session of these field surveys consisted of a series of incentivized preference questions and a demographics survey, the specific preferences questions differed between field surveys. At the end of the sessions one of the preference questions was randomly chosen to be paid out. The preference questions and demographic survey were answered on tablets running either Otree (Chen et al., 2016) or OpenDataKit survey software (Hartung et al., 2010). The sessions lasted between 1.5 and 2 hours. Compensation for participating in the survey was equivalent to a day's wage on average (about 5000 TZS in Tanzania and about 18000 CLP in Chile).

In Norway, it was not possible to give Norwegian fishermen incentives in the order of a day's earning. Moreover, the Norwegian survey was carried out online, due to the thin and dispersed settlement structure along the Norwegian coast. To be sure that participants are sufficiently motivated in this setting, we have slotted the incentivized preference elicitation at the very end of the survey, and asked participants to actively opt-in to answering additional questions where they could earn money (on average about 150 NOK).

The survey was online in September and October of 2019 (using a survey platform provided by the University of Oslo, *Nettskjema*). We invited respondents to participate through e-mails sent from the Norwegian sales organizations. All ex-vessel sales of fish in Norway must go through one of six sales organizations, which are mandated by law. This means that all fishermen are associated with at least one of these sales organization, and indeed more than 5% of all Norwegian fishermen participated in the survey.

Norwegian fisheries are among the most valuable fisheries in the world. Annually, about 2.5 million tons of fish, equivalent to a value of 2 billion Euro, are harvested from a largely industrialized, highly modern, fleet. Two dominant groups can be distinguished: Those boats that harvest pelagic species such as Herring and Mackerel, and those that harvest demersal species such as cod and haddock. Especially the latter fleet consists to a large part of relatively small vessels that fish close to the coast.

In all six surveys, participants were required to answer one or more comprehension questions (the exact number of questions differing between measures) before answering the incentivized preference questions. Participants that failed to successfully answer all comprehension questions are excluded from the analysis.

4.3.2 Measuring risk- and social preferences

Risk preferences

We elicited risk preferences using an incentivized lottery-choice task. The incentivized lottery-choice task is based on the "Gneezy-Potters method" (Gneezy and Potters, 1997): The participant receives 6 ECU (experimental currency units) and is asked how much to invest in project A and how much to invest in project B. While she obtains 1 ECU for every ECU invested in project A, the outcome of project B is uncertain: with probability $1 - p$, the participant will receive nothing from this investment and with probability p, she will receive k times what she has invested. Say the participant invests x ECU in project B. Her expected payout is then $6 - (1 - pk)x$. A risk-neutral (or risk loving) participant would thus invest all 6 ECU in the risky project if and only if $pk > 1$. As it is standard with this experiment, we select $p = 0.5$ and $k = 3$. Whether project B pays off will then be determined randomly by a coin-flip at the end of session (to not contaminate other choices). The "Gneezy-Potters" method has been used widely and is often chosen in field contexts due to its simplicity and robustness (for a review of different risk elicitation methods see Charness et al., 2013 or Crosetto and Filippin, 2016). We used the same setup and illustrations in all three countries.

Social preferences

In the first field survey to Tanzania and both field surveys in Chile we measured social preferences of the participants using a simple one-shot public goods game. Participants chose how many of six ECU to allocate to a private account (yielding one ECU per ECU in the account) and how many to allocate to a group account that they shared with two other, randomly and anonymously assigned participant (three others in the first Tanzania field survey). The ECU in the group account were doubled and shared equally among all three members, regardless of their actual contribution to the group account. Contributing to the group account reduces the payout of the individual, as she only receives 0.5 ECU for every ECU that she contributes. However, each participant contributing the full endowment is optimal for the group, as the group as a whole receives 2 ECU for every ECU that is contributed. Contributing more to the group account therefore indicates stronger social preferences.

In the second and third field survey in Tanzania we used a 3-player repeated prisoners dilemma to elicit social preferences. Participants can choose between cooperating and defecting. Similar to the public goods game, by cooperating the participant increases the overall payout of the group, at the cost of their individual payout and vice versa for defecting. Social preferences are in this case measured the number of times that the participant cooperated over all rounds.

To measure the social preferences of the Norwegian participants, we gave participants the ability to donate their earnings from participating in the survey to a charity, the Norwegian Society for Sea Rescue. Our measure of social preferences from Norway is hence a binary variable, indicating whether participants have donated their earnings or kept it to themselves.

Standardization

To ensure comparability between field surveys, the measures for risk preferences and social preference are standardized by transforming them to z-scores.[8] The z-scores are calculated by subtracting the field survey specific mean from each observation and dividing the result by the field survey specific standard deviation. The sign of each measure is oriented such that a stronger preference for risk or a stronger social preference is indicated by a higher score. The measures will have a mean of 0 and standard deviation of 1. The field survey specific z-scoring introduces an implicit field survey specific fixed effect, and transforms the absolute preference measure to a ranking relative to the other participants in the field survey. A value of 0 for the z-scored preference measure implies that the participant has the mean preference

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[8] See e.g. Kling et al. (2007) for a seminal application of z-scores.

for that field survey, a value of 1 implies that they are 1 standard deviation above the field survey mean.

The prisoner's dilemma games in the second and third Tanzania field survey, and the risk preference measure in the third Tanzania field survey featured different treatments. We calculate the z-scores for these measures in these cases for each treatment separately, and thus introduce an implicit treatment fixed effect.

4.3.3 Measuring exposure, tenure, and selection

In addition to the ex-ante classification based on the literature (see Table 4.1), we collect high frequency administrative data of actual variation in landings to estimate the risk exposure of our participants. Specifically, we determine the within year variability of trip revenues for a vessel in the relevant fisheries using landing tickets data. We express variability as the coefficient of variation (CoV) in trip revenue. In Chile we calculate the variability of several benthic and pelagic fisheries. As the surveyed Chilean fishermen are concentrated in fishing villages, we determine variability for each fishery on the level of the landing site. In Norway we determine variability for the major gear types used in the demersal and pelagic fisheries. In Tanzania, administrative landings ticket data is not available and we therefore develop a self-reported measure. The methods used to determine variability are explained in detail in the Appendix (A-3).

For social exposure, we use the size of the crew as our additional data-based measure. Presumably, working in larger crews requires more cooperative effort to function properly. In Tanzania and Chile crew size is self reported by the fishermen during the survey. In Norway we elicit the length of the vessel and the type of fishery during the survey and base ourselves on the averages reported by the Norwegian Directorate of Fisheries to calculate the corresponding crew size.[9]

In other words, we have two sets of main explanatory variables. One is based on ex-ante classification taken from previous studies and the related literature, while the other is based on administrative or self-reported data. The former measure allows us to capture broader aspects of risk and social exposure caused by differences in the natural environment (such as health risk, different weather conditions, different production methods, different ownership structures or payment methods), but the variation in these measures is limited to the fishery level. The latter measure, in contrast, allows us to have near individual variation in risk- and social exposure, but these measures are more narrowly defined as revenue risk and crew size.

The set of additional control variables consists of age, tenure and whether the participant has selected into becoming a fisher. Age is elicited as an integer, however to make it comparable between field surveys, we calculate the z-score for the participant with respect to the other observations in the same country. The age variable therefore indicates the relatively age of a fisher within each country.

To measure tenure, we asked fishermen how long they have been active in their current fishery. They could choose between the following options: (1) this year only, (2) two to four

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[9] `https://www.fiskeridir.no/content/download/13020/169296/version/39/file/tidsserie-arbeidsinnsats-sysselsetting.xlsx`

years, (3) five to ten years, and (4) eleven or more years. For the first field surveys in Tanzania and Chile, the question was not formulated in a way that asked specifically about their current fishery, and we have not elicited whether they switched target species, such that we utilize their overall tenure as a fisher in these cases. Parallel to age, the tenure variable is z-scored.

Lastly, we construct a dummy variable to classify if a participant has or has not selected into the specific fishery in which they are active now. We classify the participant as having selected into the fishery if one of the following three conditions is true. (1) The participant indicates that fishing was their best option (as opposed to the only option or a family tradition), (2) the participant has moved and lastly, (3) the participant has at some point changed their fishing activity. In Norway the first two conditions are not available, in this case we classify fishermen as having selected into the fishery when their parents were not fishermen.

4.4 Results

The results are structured in the following manner. First we show how the ex-ante classifications for risk exposure and social exposure relate to the data-based measures. Second, we test whether exposure to risky and collectivistic fisheries correlates with preferences on an aggregate level, and what the role is of selection and tenure. Third, we repeat the analysis on a country level. Lastly, we use the repeated observations to disentangle to what extent exposure and selection are driving the results.

4.4.1 Differences in risk and social exposure across fisheries

In this section we show how the ex-ante classifications of fisheries compare to the constructed data-based measures. The comparisons are summarized using boxplots in Figure 4.2. The top-left plot shows how the risk classification relates to the coefficient of variation in trip revenues. The top-right plot shows the same comparison, however now the coefficient of variability is standardized to a z-score within the country. The bottom-left plot shows the relation between the classification for social exposure and crew size. The bottom-right plot shows the crew size standardized within the country as a z-score.

The ex-ante classification of differences in exposure to a risky natural environment aligns well with the data-based measure for Chile. Based on the analysis of the landings ticket data, we find that vessels active in pelagic fisheries on average have a larger coefficient of variation in trip revenues (from now on variability) compared to vessels active in the benthic fisheries. The difference is substantial, the average vessel active in the pelagic fisheries has a variability of 0.769 (+/- 0.01; 95% CI) compared to 0.461 (+/- 0.01; 95% CI) for vessels active in benthic fisheries. The values assigned to the participants are significantly higher in the pelagic fishery compared to the benthic fishery (t-test, $p < 0.01$).

For Norway, we only find a small difference in variability when comparing vessel in the demersal fishery (0.75) and the pelagic fishery (0.79). However, the differences are more pronounced after separating the different gear types. We find that within the demersal fishery, vessel using trawls (0.95 +/- 0.03; 95% CI) have a higher variability compared to conventional gears (0.74 +/- 0.004 95% CI). Similarly within the Pelagic fishery, vessels using trawls (0.79

+/- 0.04; 95% CI) and nets (0.83 +/- 0.02; 95% CI) have a higher variability than those using conventional gears (0.64 +/- 0.03; 95% CI).

For Tanzania, finally, we cannot confirm the ex-ante classification. In fact, the data-based variability in the local Dagaa fishery is higher (0.26) than in the export oriented Nile Perch fishery (0.23). The difference is however smaller than in the other field settings and not significant (t-test, p=0.102).

Regarding social exposure, we find that the average crew size is larger in all fisheries that are classified as more collectivistic. This difference between the individualistic and collectivistic fishery is largest in Norway. The mean reported crew sizes are 4.2 and 15.8 for the demersal and pelagic fisheries respectively, this difference is highly significant (t-test, $p < 0.01$). The median crew size in the demersal fisheries is only 1.5, whilst the median in the pelagic fisheries is 14.92. The relative difference is smaller in Chile, with the mean reported crew sizes of 3.49 and 7.2 for the benthic and pelagic fisheries respectively. This difference is again highly significant (t-test, $p < 0.01$). The benthic vessels generally have much smaller crews, and are rarely with more than five fishermen. There are some pelagic vessel with smaller crews (3 to 5), but the majority are substantially larger (9 to 13). The median crew size is 3 in the benthic fisheries and 8 fishermen in the pelagic fishery. We find the smallest difference in Tanzania, where the

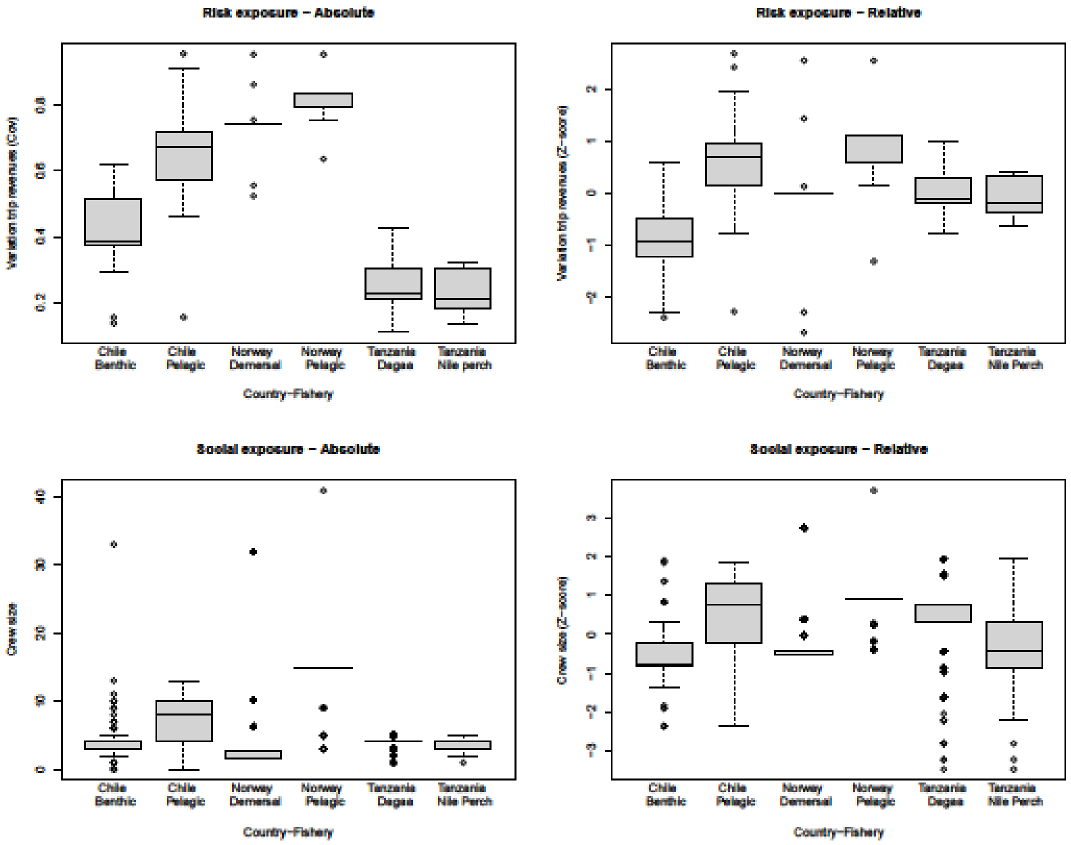

Figure 4.2: Comparison of ex-ante classification and data-based measures of risk- and social exposure

mean reported crew of a Nile perch vessel is 3.4, whilst for a Dagaa vessel the mean is 3.9. This difference is also significant (t-test, $p<0.01$).

4.4.2 Risk and social exposure is related to preferences – pooled and country-specific evidence

Table 4.2 presents the main result of this paper. The estimates from the linear regression model (equation 4.1) on the pooled sample from all field survey shows that there is a significant positive relationship between the ex-ante classification of more risky fisheries (RC) and risk preferences (risk tolerance) of the participants (Column 1). This positive relationship is confirmed when using the data-based measure of risk exposure, RE (Column 2). We find that one standard deviation increase in risk exposure is associated with a 0.08 standard deviations increase in risk tolerance. That is, exposure to a more risky natural environment is related to more risk tolerance.

For social preferences, we similarly find a strong relationship between the ex-ante classification of fisheries as more individualistic versus more collectivistic and social preferences. For the data-based measure (crew size), however, we find no such effect. One reason that we do not find such an effect could be that crew size is not a good proxy for the underlying exposure to an individualistic or collectivistic work environment. Nevertheless, Table 4.2 establishes that there is at least suggestive evidence that exposure to a more collectivistic work environment is related to more social preferences. In contrast to risk preferences, we find that age is significantly correlated with stronger social preferences, both in the regression that uses the ex-ante classification, and in the regression that uses the data-based measure.

Before we delve deeper into the question whether these relationship between the natural environment and preferences could be caused by a process of selection or a process of adaptation, we discuss the country-specific results of the regression model given by equation (4.1). The corresponding tables, Table A-1 for Chile, Table A-2 for Tanzanian, and Table A-3 for Norway are placed in the Appendix.

For Chile, we find that the effect of risk exposure, both when captured by the ex-ante classification (RC) and when proxied by the exposure to trip-based revenue volatility (RE), is strongest. Here, a one standard deviation increase in risk exposure is associated with a 0.21 standard deviations (RC) or 0.16 standard deviations (RE) increase in risk tolerance, respectively. For country specific regressions for Tanzania and Norway, in contrast, we do not detect a statistically significant effect of risk exposure on risk preferences.

Turning to social preferences, we see that social preferences are related to a more collectivistic workplace organization (SC) and a larger crew size (SE) in Chile. For Tanzania, we find no effect, and for Norway, we find an effect based on the ex-ante classification of workplace organization (SC), but not based on crew size (SE). Again, age has a significant positive effect on social preferences in all countries except Chile, and no effect on risk preferences.

The regression estimates from the model spelled out in equation (4.1) can tell whether there is an overall correlation between exposure and preferences, but does not shed light on the underlying process. Therefore, we formulate the regression model given by equation (4.2), where we include an indicator variable for whether respondents have selected into fishing,

Table 4.2: Main results, pooled data. OLS estimates of risk- and social exposure on preferences, standard errors clustered at the landing site level in parentheses.

	Dependent variable:							
	Risk Preference				Social Preference			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RC/SC	0.10* (0.05)		0.05 (0.09)		0.13*** (0.05)		0.12 (0.08)	
RE/SE		0.08** (0.03)		−0.01 (0.05)		0.02 (0.02)		0.04 (0.03)
Age	0.04 (0.02)	0.03 (0.02)			0.09*** (0.02)	0.09*** (0.02)		
Tenure			0.04 (0.03)	0.04* (0.02)			0.06** (0.03)	0.05** (0.02)
Selection			0.15** (0.07)	0.18*** (0.05)			0.02 (0.06)	0.05 (0.05)
RC/SC:Tenure			−0.01 (0.04)				−0.04 (0.04)	
RC/SC:Selection			0.04 (0.10)				0.01 (0.09)	
RE/SE:Tenure				0.04 (0.03)				0.03 (0.02)
RE/SE:Selection				0.13** (0.06)				−0.03 (0.04)
Constant	−0.03 (0.04)	0.03 (0.03)	−0.12** (0.06)	−0.10** (0.05)	−0.06* (0.03)	−0.005 (0.03)	−0.08* (0.05)	−0.05 (0.04)
Observations	2,188	1,945	2,162	1,923	2,411	2,452	2,390	2,439
Adjusted R^2	0.003	0.004	0.01	0.01	0.01	0.01	0.01	0.002
Note:					$^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$			

and a variable that measures their tenure in the fishery. Positive coefficient estimates for these terms indicate that being a fisher as such (as opposed to a, say, carpenter) is related to risk or social preferences. Including interaction terms, then, can tell us whether exposure to a more risky or more collectivistic environment has an additional effect on preferences.

Column (3) and (7) in Table 4.2 show the regression results of this model for the ex-ante classification of risk- and social exposure, respectively. Column (4) and (8) show the regression results for the data-based measures of exposure.

Looking at the results for risk preferences first, we see that for both the ex-ante-classification (RC), and the data-based measure (RE), selection is a significant variable. For the data-based measure, also the interaction effect with risk exposure is significant (which is not the case for the ex-ante measure). That is, being a fisher as such is related to more risk tolerance, and, based on the data-based measure, having selected into a more risky fishery has an additional effect on risk tolerance. For the data-based measure, we additionally find an effect of tenure: being a fisher for a longer time is related to more risk tolerance.

For social preferences, the only effect that we can detect in the model given by equation (4.2) is an overall effect of tenure. Those respondents that are fishermen for longer are more pro-social, with no detectable differences between fisheries. However, as tenure is closely correlated with age, this variable may simply pick up the age effect that we found in specifications shown in column (5) and (6) of Table 4.2.

Overall, the regression of the model given by equation (4.2) does not give us an unequivocal picture of what might be the underlying process leading to the correlation of exposure and preferences. While we do not find evidence for either selection or adaptation with respect to social preferences, we find some evidence for both selection and adaptation when looking at risk preferences. However, the respective coefficients are not estimated very precisely, and when we turn to the country-specific regressions (Table A-1 to Table A-3), none of the coefficients is significant at conventional levels.

Dropping the interaction terms (Table A-4 and Table A-5 in the Appendix), we see that selection into fishing as such (as opposed to choosing some other occupation) has a significant effect on economic preferences in Tanzania and in Norway. We find that in both countries, those that have selected to become fishermen are less risk averse, compared to those participants that have not actively selected into fishing (for example, because fishing was a family tradition, or the only option available). In Chile, there is no such effect of selection. For social preferences, we again find a significant effect of selection when we drop the interaction terms, this time for all countries. Interestingly, while the effect is positive (meaning those that have actively chosen to be a fisher are more pro-social) in Chile and Tanzania, the effect is negative in Norway.

In the next section, we present a first pass at distinguishing selection from adaptation by exploiting the panel structure in part of our data.

4.4.3 Distinguishing selection from adaptation

In this section, we make use of the fact that we have revisited some of the communities several times. In addition to testing for the effect of *selecting into* a fishery as in specifications (3)-(4) and (7)-(8) in Table 4.2 above, we can also test whether less risk tolerant respondents have gradually *selected out* of the fishery. To do so, we can compare those respondents that we observe twice, with those that we observed only during the first field survey, and could have, but did not observe during the second field survey. This obviously only provides a lower bound estimate because a fisher that is not observed again in subsequent rounds of data collection might have selected out of fishing and started a different occupation, but he might also be unavailable for other reasons (such as visiting relatives, or being too drunk to participate).[10]

In addition to this lower bound estimate of whether gradual out-selection may be relevant channel that gives rise to the phenomenon of endogenous preferences, we can look at within participant changes in risk and social preferences. In fact, this provides the strongest test of an adaptation hypothesis. Provided the method to elicit risk preferences is reliable, a positive change in risk tolerance in the risky fishery and negative change in the stable fishery is strongly suggestive evidence that an adaptation process takes place within the individual.

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[10] In Chile the sampled organizations and locations in the second field survey were different than the first field survey and we have therefore taken care to exclude participants that could not have been re-sampled and limit the analysis to a subsample of fisheries organizations that were revisited. The analysis of potential out-selection is not possible for the Norwegian sample, as there is only one data collection round.

Unfortunately, because this test can only be conducted when the elicitation procedure is the same, and we hence have to rely on a relatively small sample here.[11].

Out-Selection

Table 4.3 presents the results from a logistic regression where all resampled participants are assigned a value of 1 and all participants that we could, but did not resample are assigned a value of 0. The explanatory variables are the participants' social preferences and risk preferences as measured in the first field survey. A positive coefficient would indicate that an individual with stronger social or risk preferences is more likely to be re-sampled, and thus less likely to select out of fishing. To estimate whether this effect is stronger in riskier or more collectivistic fisheries, we interact the preferences with the ex-ante classification of exposure.[12]

Specifications (1) and (2), for Chile and Tanzania respectively, show that fishermen that have been re-sampled, do not significantly differ from those that have not been re-sampled with regard to their risk preference, regardless of risk exposure. In specification (3) we show that this is also the case with regard to social preferences for Chilean fishermen. In specification (4), we find that Tanzanian fishermen that were re-sampled during the second field survey have weaker social preferences, this finding does not depend on whether participants are active in the Dagaa fishery, which is classified as being more collectivistic, or in the Nile Perch fishery.

While we find no effect for age or having selected into fishing in Chile, we do find significant effects for these variables in Tanzania. Older fishermen are more likely to be resampled here, and those that have actively chosen to become fishermen are less likely to be resampled. The latter finding is particularly noteworthy as it confirms that our selection variable indeed measures the degree of transience in the sampled population. The main point to take away from this exercise however, is that gradual out-selection does not seem to be the main mechanism causing the observed correlation between exposure and preferences. Below, we study the changes in risk- and social preferences within an individual.

Within participant changes

In Table 4.4, we look at the participants that were observed in both Chilean field surveys and in the first and second field survey at Lake Victoria. In this analysis the dependent variable is the difference in risk-preference and social preference between the first and the second field survey. A positive value indicates that the participant has become more risk tolerant (or pro-social) after the first field survey and a negative value indicates that the participant has become more risk-averse (or less pro-social). We use the two measures for risk exposure as explanatory variables. In specifications (1) and (3) we use the ex-ante classification (*RC*) and in specifications (2) and (4) we use the data-based measure (*RE*), in specification (5) we use the ex-ante classification (*SC*) and specification (6) we use the data-based measure (*SE*).

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[11] We have 77 observations from Chile and 210 observations for risk preferences from Tanzania, where the risk preference elicitation procedure in the first and the second field survey is the same, but there are treatment specific differences in the third field survey. Similarly, the social preference elicitation procedure in Tanzania changed across field surveys

[12] Results are robust to using the data-based measures of exposure.

Table 4.3: Logistic regression coefficients, comparing re-sampled to non-resampled fishermen, standard errors clustered at the session level in parentheses.

	Dependent variable:			
	Resampled			
	Risk preference		Social preference	
	(Chile)	(Tanzania)	(Chile)	(Tanzania)
RC/SC	0.17	0.30***	0.17	−0.30**
	(0.32)	(0.12)	(0.30)	(0.12)
RP/SP	−0.12	−0.03	−0.06	−0.17**
	(0.13)	(0.09)	(0.09)	(0.08)
Sel	0.02	−0.29**	0.03	−0.28**
	(0.10)	(0.12)	(0.10)	(0.12)
Age	0.0001	0.01**	0.001	0.02***
	(0.01)	(0.01)	(0.01)	(0.01)
RC/SC:RP/SP	0.10	−0.01	−0.05	0.09
	(0.19)	(0.12)	(0.14)	(0.11)
Constant	−0.90	−0.75***	−0.94	−0.50**
	(0.62)	(0.23)	(0.59)	(0.23)
Observations	349	505	349	505
Log Likelihood	−183.18	−334.48	−182.95	−331.82
Akaike Inf. Crit.	378.35	680.96	377.90	675.63
Note:	* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$			

Table 4.4: Table reports OLS estimates. Standard errors are clustered on the experimental session level.

	Dependent variable:					
	Δ Risk preference				Δ Social preference	
	Chile		Tanzania		Chile	
	(1)	(2)	(3)	(4)	(5)	(6)
RC/SC	0.74*		0.04		−0.72	
	(0.43)		(0.46)		(0.49)	
RE/SE		0.32*		0.53		−0.01
		(0.17)		(0.64)		(0.26)
Constant	−0.25	0.15	−0.70*	−0.52*	0.75**	0.33
	(0.30)	(0.22)	(0.41)	(0.28)	(0.34)	(0.26)
Observations	77	72	210	183	77	69
Adjusted R^2	0.02	0.01	−0.005	−0.001	0.01	−0.01
Note:	* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$					

We first focus on the risk preferences in Chile, specification (1) and (2). We find that the risk preference of Chilean fishermen active in the risky fisheries increased between field surveys, whilst that of fishermen active in the stable fisheries remained stable, which is indicated by the constant. This increase is significant at the 9.2% level for the ex-ante classification (*RC*) and at the 6.8% level for the data-based measure (*RE*). Although this analysis could only be conducted on a small subsample of the data, it provides a strong indication for cultural learning or adaptation. Over time, those fishermen in the more risky fishery become more risk tolerant, while the fishermen in the less risky fishery become less risk tolerant, or do not change their risk preferences. Figure 4.3 illustrates this effect in a "difference-in-difference" plot.

Turning to the data from Tanzania, we see that participants have become more risk averse over time. However, while the coefficient on both the ex-ante classification measure SC and the data-based measure SE is positive, it is not significant. Hence, there is no evidence that fishermen in the more stable fishery become relatively more risk averse than fishermen in the fishery that is classified to be exposed to more risk. Given the negligible differences in actual risk exposure that we have detected in section 4.4.1, the fact that we do not find different responses to risk exposure is of course not very surprising. Results are illustrated in the left panel of Figure 4.4.

We now repeat the analysis for social preferences in Chile, shown in specifications (5) and (6). The dependent variable is the difference in social-preference between the first and the second field survey. A positive value indicates that the participant has a stronger social preference in the first field survey compared to the second field survey, and a negative value indicates that the participant's social preference has become weaker. We use the two measures for social exposure as explanatory variables. In specification (5) we use the ex-ante classification (*SC*)

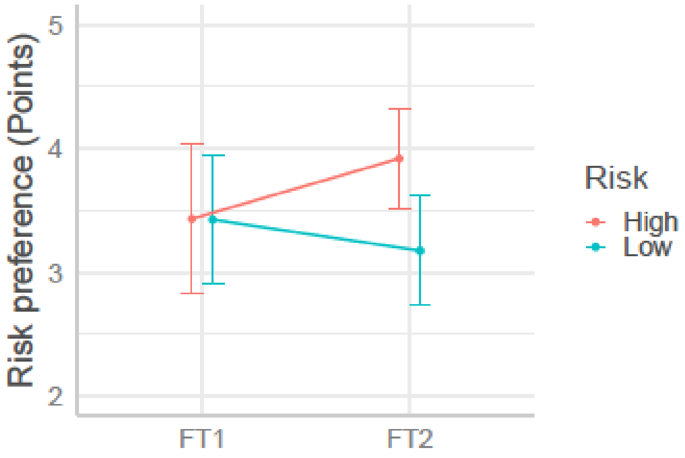
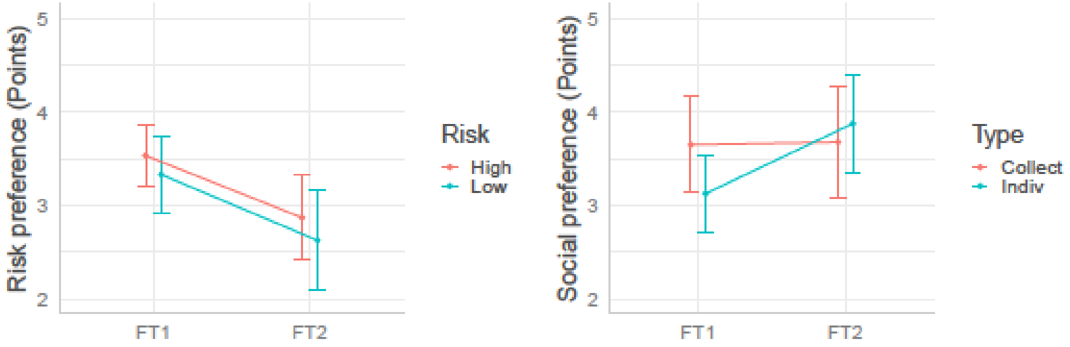


Figure 4.3: Difference in differences for risk preferences of the Chilean fishermen in high risk (pelagic) and low risk (benthic) fisheries. The graphs plot the group averages and 95% confidence interval for the first and the second field survey.

and in specification (6) we use crew size (*SE*). We find that the constant in specifications (5) is positive and significant ($p < 0.03$), indicating that the participants in the benthic fisheries have become more pro-social between the field-surveys. Participants in the collective fisheries have unchanged social preferences (F-test, *p*-value = 0.97). The results are illustrated in the right panel of Figure 4.4.



(a) Risk Preferences Tanzania

(b) Social Preferences Chile

Figure 4.4: Left panel: Difference in differences for risk preferences of the Tanzanian fishermen in Nile Perch fishery (classified as high risk) and Dagaa fishery (classified as low risk). Right panel: Difference in differences for social preferences of the Chilean fishermen in high risk (pelagic) and low risk (benthic) fisheries. The graphs plot the group averages and 95% confidence interval for the first and the second field survey.

4.5 Discussion

The natural environment has a direct effect on production in fisheries. On the one hand, the resource stock is an input and fluctuations in abundance and availability determine how much can be produced. On the other hand, the characteristics of the target species, such as size, preferred habitats, or schooling behaviour, determine the mode of production. For example, species that form schools far from shore are maybe best harvested in larger teams, using purse seines, and require relatively large and robust boats for steaming to the catch locations in rough weather, whereas for other species, the primary targets are large individuals that ambush their prey in shallow waters, and these species may well be harvested by individuals or small teams, using handlines or gillnets.

This paper studies the first link of an *indirect* effect that the natural environment may have in fisheries. The natural environment may shape fishermen's risk- and social preferences, and these will in turn affect socio-economic outcomes in fisheries. To test whether exposure to more risk, and exposure to more social workplace organization is indeed related to risk- and social preferences, we collate data from six surveys conducted in three countries. Specifically, in each country, we contrast a fishery that has been classified as high risk and/or collectivistic with a fishery that has been classified as low risk and/or individualistic in the literature. We find that the ex-ante classification based on the literature aligns well with our data-based measure of risk exposure in Chile, but less so in Norway and Tanzania. In Chile, the coefficient of variation of trip revenues in the stable benthic fishery is 0,46 while for the more volatile pelagic fishery the coefficient of variation is 0.77. For Norway's pelagic fishery, this value is 0.79, and for the coastal demersal fishery, which is classified as less risky, the coefficient of variation is 0.75. In Tanzania, we actually found that the Nile Perch fishery is somewhat less risky (but not significantly so) than the Dagaa fishery, contrary to our expectation. For social exposure, which we proxied by crew size, we found that the ex-ante classification is accurate in all three countries.

Pooling the data from all fisheries, using standardized values of risk- and social preferences and explanatory variables, we find that more risk exposure is indeed related to more risk tolerance. This holds both for the broad ex-ante classifications that may capture different aspects of risk exposure more holistically, and the data-based measure of risk exposure, which more narrowly, but also more precisely, captures variation in revenues. For social preferences, we find that participants from fisheries that are classified as being more collectivistic have stronger social preferences, but we find no significant relationship for crew size and social preferences.

One reason for the lack of a clear relationship between social preferences and crew size corresponding to the documented relationship between social preferences and the ex-ante classification could be that crew size does not adequately capture the distinction between an individualistic and collectivistic workplace culture. Another reason could be that our procedure for measuring social preference is worse than the procedure for measuring risk preferences. For the latter, we have consistently used the Gneezy and Potters (1997) method, while for measuring social preferences, we have used a public goods game in Chile and the first Tanzanian field survey, a prisoner's dilemma experiment in the second and third Tanzanian field survey and a donation experiment in the Norwegian online survey. What is interesting to note is that age is related to more social preferences, but not related to risk preferences in our sample of fishermen, which stands in contrast with the consistent finding that risk preferences decrease with age in the general population (Schildberg-Hörisch, 2018; Falk et al., 2018).

Turning to the country specific differences, we find that the link between risk exposure and risk preferences is strongest in Chile. In fact, the relationship between risk exposure and risk preferences is not significant at the country level for Tanzania and Norway. The latter result is maybe not surprising, given the almost negligible difference in risk exposure. What we do find for Norway and Tanzania, is that selection into fishing in general is an important predictor of risk and social preferences, but we find no differential degree of selection. This result accords well with the development of the fishing sector in the three countries. In Chile, outside opportunities are rare, and many communities are rather isolated. In most communities, however, there is the option to either participate in the pelagic or in the demersal fisheries. Once in a given fishery (and member in the relevant fisheries union), it is uncommon to switch between fisheries. The situation regarding outside options is similar in Tanzania, with two important differences: First, capital investments and skills are much less fishery specific, making the boundary between the different fisheries more fluid. Second, both the Dagaa and the Nile Perch fishery has recently experienced a boom, so that many farmers have decided to become fishermen and migrate to the Lake. In Norway, settlement patterns are more stable and the fisheries are also more localized. Relatively large fishery specific investments preclude switching between fisheries. All these factors speak for finding a difference in risk preference across the more and less risky fishery in Norway. Next to the fact that there is very little variation in the explanatory variable, good outside opportunities are plentiful in Norway. This fact may accentuate the difference between fishing and not fishing, and blur the difference between fishing demersal or pelagic species.

In sum, our study bridges an important gap in the literature on endogenous preferences. Combining the virtues of case-study detail with a global scope, we find convincing evidence that there where there are the pronounced differences in risk exposure, fishermen in more risky fisheries are also more risk tolerant. Our analysis suggests that this could indeed be a causal effect, driven by both selection and adaptation. First, we find that fishermen that select into fishing are on average more risk tolerant than those that fish because it was a family tradition, or that did not have any outside opportunities. Second, for a small subset of our data, namely those Chilean fishermen that we have observed twice (hence ruling out selection), we find that risk tolerance increases between field surveys for those fishermen that are in the risky fishery, but not for those fishermen that are in the more stable benthic fishery.

Exploring the robustness of this finding is but one of several avenues for further research that our study opens. On the one hand, there are several important theoretical questions that arise: How does adaptation work? What role do social processes such as peer pressure or preferences to conform with the actions of others play, in contrast to more psychological processes such as desensitization and learning? What distinguishes a process of adaptation from a process of selection, and if there are differences in these processes, do they translate into socio-ecological outcomes? On the other hand, there are several relevant practical implications: What is the consequence of a link between resource risk and risk preferences for monitoring and enforcement or capital investments? Would a link between exposure and resource risk turn into a positive feedback loop, supporting or threatening sustainable management? Should policy makers take endogenous preferences into account when designing welfare programs for fishermen?

References

Alesina, A., Giuliano, P., and Nunn, N. (2013). On the origins of gender roles: Women and the plough. *Quarterly Journal of Economics*, 128(2):469–530.

Becker, A., Enke, B., and Falk, A. (2020). Ancient origins of the global variation in economic preferences. *AEA Papers and Proceedings*, 110:319–23.

Bentzen, J. S., Kaarsen, N., and Wingender, A. M. (2017). Irrigation and autocracy. *Journal of the European Economic Association*, 15(1):1–53.

Bowles, S. (1998). Endogenous preferences: The cultural consequences of markets and other economic institutions. *Journal of Economic Literature*, 36(1):75–111.

Buggle, J. and Durante, R. (2017). Climate Risk, Cooperation, and the Co-Evolution of Culture and Institutions. CEPR Discussion Papers 12380, C.E.P.R. Discussion Papers.

Buggle, J. C. (2020). Growing collectivism: irrigation, group conformity and technological divergence. *Journal of Economic Growth*, 25(2):147–193.

Cameron, L. and Shah, M. (2015). Risk-taking behavior in the wake of natural disasters. *Journal of Human Resources*, 50(2):484–515.

Cappelen, A., List, J., Samek, A., and Tungodden, B. (2020). The effect of early-childhood education on social preferences. *Journal of Political Economy*, 128(7):2739–2758.

Castilla, J. (2010). Fisheries in chile: small pelagics, management, rights, and sea zoning. *Bulletin of Marine Science*, 86:221–234.

Charness, G., Gneezy, U., and Imas, A. (2013). Experimental methods: Eliciting risk preferences. *Journal of Economic Behavior & Organization*, 87:43 – 51.

Chen, D. L., Schonger, M., and Wickens, C. (2016). otree—an open-source platform for laboratory, online, and field experiments. *Journal of Behavioral and Experimental Finance*, 9:88 – 97.

Chávez Estrada, G., Quiroga, M., and Cid, J. (2017). The effect of collective rights-based management on technical efficiency: The case of chile's common sardine and anchovy fishery. *Marine Resource Economics*, 33:000–000.

Cooper, D. J. and Kagel, J. H. (2016). Other-regarding preferences. In Kagel, J. H. and Roth, A. E., editors, *The Handbook of Experimental Economics, Volume 2*, pages 217–289. Princeton University Press.

Copeland, B. R. and Taylor, M. S. (2009). Trade, tragedy, and the commons. *American Economic Review*, 99(3):725–49.

Crosetto, P. and Filippin, A. (2016). A theoretical and experimental appraisal of four risk elicitation methods. *Experimental Economics*, 19(3):613–641.

Di Falco, S., Berck, P., Bezabih, M., and Köhlin, G. (2019). Rain and impatience: Evidence from rural Ethiopia. *Journal of Economic Behavior & Organization*, 160(C):40–51.

Dohmen, T., Falk, A., Huffman, D., Sunde, U., Schupp, J., and Wagner, G. G. (2011). Individual risk attitudes: Measurement, determinants and behavioral consequences. *Journal of the European Economic Association*, 9(3):522–550.

Dresdner, J., Chávez, C., and Barriga, O. (2015). Compliance in artisanal fisheries: Do morality, legitimacy, and peer effects matter? *Marine Resource Economics*, 30(4):349–370.

Eckel, C. C., El-Gamal, M. A., and Wilson, R. K. (2009). Risk loving after the storm: A bayesian-network study of hurricane katrina evacuees. *Journal of Economic Behavior & Organization*, 69(2):110–124.

Eggert, H. and Lokina, R. B. (2010). Regulatory compliance in Lake Victoria fisheries. *Environment and Development Economics*, 15(02):197–217.

Falk, A., Becker, A., Dohmen, T., Enke, B., Huffman, D., and Sunde, U. (2018). Global Evidence on Economic Preferences. *The Quarterly Journal of Economics*, 133(4):1645–1692.

FAO (2020). The State of World Fisheries and Aquaculture. Technical report, Food and Agricultural Organization (FAO), Rome.

Galor, O. and Özak, Ö. (2016). The agricultural origins of time preference. *American Economic Review*, 106(10):3064–3103.

Gelcich, S., Hughes, T. P., Olsson, P., Folke, C., Defeo, O., Fernández, M., Foale, S., Gunderson, L. H., Rodríguez-Sickert, C., Scheffer, M., et al. (2010). Navigating transformations in governance of chilean marine coastal resources. *Proceedings of the National Academy of Sciences*, 107(39):16794–16799.

Gneezy, U., Leibbrandt, A., and List, J. A. (2016). Ode to the sea: Workplace organizations and norms of cooperation. *The Economic Journal*, 126(595):1856–1883.

Gneezy, U. and Potters, J. (1997). An experiment on risk taking and evaluation periods. *The Quarterly Journal of Economics*, 112(2):631–645.

Gomez, F., Montecinos, A., Hormazabal, S., A, C. L., Correa-Ramirez, M., and Chavez, F. P. (2012). Impact of spring upwelling variability off southern-central chile on common sardine (strangomera bentincki) recruitment. *Fisheries Oceanography*, 21(6):405–414.

Guiso, L., Jappelli, T., and Pistaferri, L. (2002). An empirical analysis of earnings and employment risk. *Journal of Business & Economic Statistics*, 20(2):241–253.

Hartung, C., Lerer, A., Anokwa, Y., Tseng, C., Brunette, W., and Borriello, G. (2010). Open data kit: Tools to build information services for developing regions. In *Proceedings of the 4th ACM/IEEE International Conference on Information and Communication Technologies and Development*, ICTD '10, pages 18:1–18:12, New York, NY, USA. ACM.

Jang, C. and Lynham, J. (2015). Where do social preferences come from? *Economics Letters*, 137:25 – 28.

Kahsay, G. A. and Osberghaus, D. (2018). Storm damage and risk preferences: Panel evidence from germany. *Environmental and Resource Economics*, 71(1):301–318.

Kapaun, U. and Quaas, M. F. (2013). Does the optimal size of a fish stock increase with environmental uncertainties? *Environmental and Resource Economics*, 54(2):293–310.

Kling, J. R., Liebman, J. B., and Katz, L. F. (2007). Experimental analysis of neighborhood effects. *Econometrica*, 75(1):83–119.

Kuperan, K. and Sutinen, J. G. (1998). Blue water crime: Deterrence, legitimacy, and compliance in fisheries. *Law & Society Review*, 32(2):309–338.

Leibbrandt, A., Gneezy, U., and List, J. A. (2013). Rise and fall of competitiveness in individualistic and collectivistic societies. *Proceedings of the National Academy of Sciences*, 110(23):9305–9308.

Nguyen, Q. (2011). Does nurture matter: Theory and experimental investigation on the effect of working environment on risk and time preferences. *Journal of Risk and Uncertainty*, 43(3):245–270.

Olbrich, R., Quaas, M. F., Haensler, A., and Baumgärtner, S. (2011). Risk preferences under heterogeneous environmental risk. Working Paper Series in Economics 208, University of Lüneburg, Lüneburg.

Ostrom, E., Janssen, M. A., and Anderies, J. M. (2007). Going beyond panaceas. *Proceedings of the National Academy of Sciences*, 104(39):15176–15178.

Reed, W. J. (1979). Optimal escapement levels in stochastic and deterministic harvesting models. *Journal of Environmental Economics and Management*, 6(4):350–363.

Schildberg-Hörisch, H. (2018). Are risk preferences stable? *Journal of Economic Perspectives*, 32(2):135–54.

Smith, M. D., Roheim, C. A., Crowder, L. B., Halpern, B. S., Turnipseed, M., Anderson, J. L., Asche, F., Bourillon, L., Guttormsen, A. G., Khan, A., Liguori, L. A., McNevin, A., O'Connor, M. I., Squires, D., Tyedmers, P., Brownstein, C., Carden, K., Klinger, D. H., Sagarin, R., and Selkoe, K. A. (2010). Sustainability and global seafood. *Science*, 327(5967):784–786.

Stigler, G. J. and Becker, G. S. (1977). De gustibus non est disputandum. *The American Economic Review*, 67(2):76–90.

Sumaila, U. R., Villasante, S., and Le Manach, F. (2019). Fisheries subsidies wreck ecosystems, don't bring them back. *Nature*.

Vea, J. (2009). *To kulturer: en sammenlignende undersøkelse av det vestnorske og det nordnorske kystsamfunnet: med hovedvekt på det 19. og 20. Århundret*. Høyskoleforlag, Kristiansand.

Vieider, F. M., Lefebvre, M., Bouchouicha, R., Chmura, T., Hakimov, R., Krawczyk, M., and Martinsson, P. (2015). Common components of risk and uncertainty attitudes across contexts and domains: Evidence from 30 countries. *Journal of the European Economic Association*, 13(3):421–452.

von Gaudecker, H.-M., van Soest, A., and Wengstrom, E. (2011). Heterogeneity in risky choice behavior in a broad population. *American Economic Review*, 101(2):664–94.

Willinger, M., Bchir, M. A., and Heitz, C. (2013). Risk and time preferences under the threat of background risk: a case-study of lahars risk in central Java. Working Papers 13-08, LAMETA, Universtiy of Montpellier.

Yanez, E., Barbieri, M., Silva, C., Nieto, K., and Espindola, F. (2001). Climate variability and pelagic fisheries in northern chile. *Progress in Oceanography*, 49(1):581 – 596. Pacific climate variability and marine ecosystem impacts.

Appendix

A-1 Country specific regression results

Table A-1: Country-specific results, Chile. OLS estimates of risk- and social exposure on preferences, standard errors clustered at the landing site level in parentheses.

	Dependent variable:							
	Risk preference				Social preference			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RC/SC	0.21^{**}		0.22		0.24^{**}		0.31^{*}	
	(0.09)		(0.14)		(0.10)		(0.17)	
RE/SE		0.16^{***}		0.07		0.11^{**}		0.15^{*}
		(0.05)		(0.08)		(0.05)		(0.08)
Age	0.06	0.05			0.01	0.03		
	(0.04)	(0.04)			(0.05)	(0.04)		
Tenure			0.04	0.05^{*}			-0.01	-0.01
			(0.05)	(0.03)			(0.06)	(0.03)
Selection			0.10	0.08			0.18	0.19^{**}
			(0.13)	(0.09)			(0.16)	(0.09)
RC/SC:Tenure			0.03				0.02	
			(0.06)				(0.07)	
RC/SC:Selection			-0.04				-0.06	
			(0.16)				(0.19)	
RE/SE:Tenure				0.03				-0.04
				(0.04)				(0.04)
RE/SE:Selection				0.10				-0.04
				(0.09)				(0.08)
Constant	-0.05	0.07	-0.12	0.01	-0.13^{*}	0.01	-0.29^{**}	-0.12
	(0.07)	(0.05)	(0.10)	(0.08)	(0.07)	(0.05)	(0.14)	(0.09)
Observations	749	639	738	630	803	726	793	727
Adjusted R^2	0.01	0.03	0.01	0.02	0.01	0.01	0.01	0.01

Note: $^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$

Table A-2: Country-specific results, Tanzania. OLS estimates of risk- and social exposure on preferences, standard errors clustered at the landing site level in parentheses.

	Dependent variable:							
	Risk Preference				Social Preference			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RC/SC	0.08		0.10		0.07		0.12	
	(0.09)		(0.15)		(0.06)		(0.11)	
RE/SE		0.06		0.11		−0.02		0.003
		(0.11)		(0.20)		(0.03)		(0.05)
Age	0.02	0.01			0.08**	0.07**		
	(0.04)	(0.04)			(0.03)	(0.03)		
Tenure			0.03	0.03			0.10***	0.06**
			(0.05)	(0.04)			(0.04)	(0.03)
Selection			0.22**	0.21***			0.15*	0.12*
			(0.11)	(0.08)			(0.08)	(0.06)
RC/SC:Tenure			−0.02				−0.10*	
			(0.07)				(0.05)	
RC/SC:Selection			−0.04				−0.09	
			(0.16)				(0.13)	
RE/SE:Tenure				0.06				0.04
				(0.11)				(0.03)
RE/SE:Selection				−0.09				−0.04
				(0.24)				(0.07)
Constant	−0.05	0.004	−0.20*	−0.14*	−0.04	−0.02	−0.14***	−0.12**
	(0.08)	(0.05)	(0.12)	(0.07)	(0.04)	(0.03)	(0.05)	(0.05)
Observations	977	864	962	851	1,155	1,273	1,144	1,259
Adjusted R^2	−0.0003	−0.002	0.01	0.01	0.01	0.004	0.01	0.004

Note: $^{*}p<0.10$; $^{**}p<0.05$; $^{***}p<0.01$

Table A-3: Country-specific results, Norway. OLS estimates of risk- and social exposure on preferences, standard errors clustered at the landing site level in parentheses.

	Dependent variable:							
	Risk Preference				Social Preference			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
RC/SC	-0.11		-0.25		0.19^{*}		0.01	
	(0.15)		(0.19)		(0.11)		(0.16)	
RE/SE		-0.03		-0.10		0.03		-0.03
		(0.05)		(0.07)		(0.04)		(0.07)
Age	0.03	0.02			0.23^{***}	0.22^{***}		
	(0.05)	(0.04)			(0.04)	(0.04)		
Tenure			0.07	0.06			0.03	0.06
			(0.06)	(0.06)			(0.06)	(0.05)
Selection			0.16	0.24^{**}			-0.33^{***}	-0.33^{***}
			(0.12)	(0.09)			(0.12)	(0.09)
RC/SC:Ten			-0.02				0.10	
			(0.14)				(0.13)	
RC/SC:Sel			0.34				-0.02	
			(0.21)				(0.24)	
RE/SE:Ten				0.06				0.08
				(0.06)				(0.05)
RE/SE:Sel				0.15				-0.07
				(0.11)				(0.10)
Constant	0.03	-0.001	-0.06	-0.14^{*}	-0.02	0.02	0.18^{**}	0.17^{**}
	(0.06)	(0.06)	(0.09)	(0.08)	(0.05)	(0.05)	(0.09)	(0.07)
Observations	462	442	462	442	453	453	453	453
Adjusted R^2	-0.001	-0.004	0.01	0.01	0.05	0.04	0.03	0.04
Note:						$^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$		

Table A-4: Country-specific OLS estimates, excluding the interaction terms. Standard errors, clustered on the experimental session level, in parantheses.

	Dependent variable:					
	Risk Preference					
	Chile		Tanzania		Norway	
	(1)	(2)	(3)	(4)	(5)	(6)
RC	0.10^{**}		0.03		-0.05	
	(0.05)		(0.04)		(0.06)	
RE		0.14^{***}		0.05		-0.04
		(0.05)		(0.11)		(0.05)
Tenure	0.06^{**}	0.06^{**}	0.02	0.03	0.09^{*}	0.09^{*}
	(0.03)	(0.03)	(0.03)	(0.04)	(0.05)	(0.05)
Selection	0.03	0.03	0.18^{***}	0.19^{**}	0.21^{**}	0.22^{**}
	(0.07)	(0.08)	(0.07)	(0.07)	(0.09)	(0.09)
Constant	0.04	0.05	-0.11^{*}	-0.11	-0.08	-0.09
	(0.06)	(0.06)	(0.06)	(0.07)	(0.06)	(0.07)
Observations	738	630	962	851	462	442
Adjusted R^2	0.01	0.02	0.01	0.01	0.01	0.01
Note:			$^{*}p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$			

Table A-5: Country-specific OLS estimates, excluding the interaction terms. Standard errors, clustered on the experimental session level, in parantheses.

	Dependent variable:					
	Social Preference					
	Chile		Tanzania		Norway	
	(1)	(2)	(3)	(4)	(5)	(6)
SC	0.13***		0.03		0.02	
	(0.05)		(0.03)		(0.04)	
SE		0.11**		−0.02		−0.05
		(0.05)		(0.03)		(0.04)
Tenure	−0.03	−0.02	0.06**	0.05**	0.06	0.07*
	(0.04)	(0.04)	(0.03)	(0.03)	(0.04)	(0.04)
Selection	0.15**	0.17**	0.13**	0.13**	−0.28***	−0.29***
	(0.08)	(0.08)	(0.06)	(0.06)	(0.09)	(0.09)
Constant	−0.10	−0.09	−0.10**	−0.11**	0.12*	0.13**
	(0.07)	(0.07)	(0.05)	(0.05)	(0.06)	(0.06)
Observations	793	727	1,144	1,259	453	453
Adjusted R^2	0.02	0.02	0.01	0.005	0.02	0.02

Note: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

A-2 Visited locations

Table A-6 shows the visited locations. In Tanzania, each session had 20 participants in round 1, 21 participants in round 2, and 18 participants in round 3. In Chile, the number of participants per session varied. Participants in Norway, where we conducted an online survey, came from all around the coast, with municipalities out of which more than participants come in our sample being highlighted in Figure 4.1.

Table A-6: The table summarizes the sample size at the each location visited during the field surveys.

Tanzania				Chile		
Location	Round 1	Round 2	Round 3	Location	Round 1	Round 2
Bezi	40	21	36	Cocholgue	0	14
Bugabu	20	21	18	Coquimbo	11	0
Bugula	40	42	36	Coronel	67	77
Chabula	40	42	36	Dichato	15	10
Guta	40	42	36	Guayacan	0	22
Igabilo	0	0	36	La Herradura	0	8
Kabangaja	20	21	18	La Sierra	0	15
Kahunda	40	42	36	Laguna Verde	12	0
Kakete	0	0	18	Limari	0	16
Kakukuru	40	42	36	Los Vilos	13	0
Kanga	0	42	36	Lota	35	41
Kanyala	20	21	18	Penuelas	34	0
Kayenze Ndogo	20	21	0	Punta Lavapie	5	0
Kibuyi	40	42	36	San Antonio	61	87
Kijiweni	40	42	36	Tubul	98	142
Kobongo	20	21	0	Tumbes	17	0
Luchelele	20	0	0	Valparaiso	0	16
Makoko	40	42	36			
Nubembe	0	0	36			
Mwembeni	0	0	36			
Nafuba Island	20	21	18			
Namasabo	20	21	18			
Nyarusya	0	21	0			
Senga	0	0	36			
Shinembo	20	21	18			

A-3 Details on the procedure to measure risk exposure

We calculate the coefficient of variability in trip revenues in the following manner using administrative landings tickets data. Let $h_{i,t,k,x}$ be the tons of species x landed by ship i on trip k in year t active in fishery c. Subsequently let the $P_{x,t}$ be the ex-vessel price of species x during year t. We then get $y_{c,i,k}$ as the revenue of ship i on trip k in year t, active in fishery c, by multiplying the vectors of harvest and price.

$$y_{c,i,t,k} = \sum_{x=1}^{X} h_{c,i,t,k,x} P_{x,t}$$

Subsequently, let $\bar{y}_{c,i,t}$ be the average trip revenue and $\sigma(y_{c,i,t})$ the standard deviation in trip revenues of vessel i in year t active in fishery c. Each vessel-year observation has to contain at least 10 trips in the same fishery to be included in the dataset. We calculate the CoV in trip revenues for ship i in year t as follows

$$CV_{c,i,t} = \frac{\sigma(y_{c,i,t})}{\bar{y}_{c,i,t}}$$

The variable $CV_{c,i,t}$ indicates the variability of trip revenues for ship i in year t active in fishery c. We calculate the average variation in trip income for fishery c by averaging the CoV of all ships active in fishery c ($N_{c,t}$ is the number of vessel-year observations):

$$CV_c = \frac{1}{N_{c,t}} \sum_{t=t_{min}}^{t_{max}} \sum_{i=1}^{i=N_c} CV_{c,i}$$

Chile

The Chilean landings tickets and price data are recorded by the Chilean national fisheries service (SERNAPESCA)[13]. The landing tickets data contains the record of 1,043,702 fishing trips of 9000 vessels between 2007 and 2017. Of these trips 192,589 were in benthic fisheries and 806,110 in pelagic fisheries.

For the first field survey we are only able to determine if fishermen are active in the benthic or pelagic fishery. For the second field survey we are able to assign fishermen to more specific fisheries that exist within the benthic and pelagic fisheries. In this case, pelagic fishermen are divided into those specifically targeting anchoveta and sardina común, those targeting Humboldt Squid, and into those targeting other fish species. Benthic fishermen are divided into crab fishermen and algae/mollusc gatherers.

Norway

The Norwegian landing tickets data is published yearly by the Norwegian directorate for fisheries[14] and contains information of species, tonnage and revenue for each fishing trip. We use the data from 2011 till 2018, which includes a total of 1,698,888 landing events, of which 1,314,177 were in demersal fisheries[15] and 59357 in pelagic fisheries. The demersal fishery contain the species groups cod and flatfish, whilst the pelagic fishery is limited to the species group pelagic fish which contains species such as sardine and herring. The demersal and

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[13] Landing tickets data was granted after a request. Price data is publicly available at (sernapesca.cl), missing observations for prices were replaced with nearest observation

[14] https://www.fiskeridir.no/Tall-og-analyse/AApne-data/AApne-datasett/Fangstdata-seddel-koblet-med-fartoeydata

[15] Included are 151222 demersal trips using trawls.

pelagic fisheries are further subdivided based on the gear type, with the following options: net, trawl and conventional.

Tanzania

For Tanzania we estimate the variability of the fisheries using a set of 5 survey questions. These questions allows us to construct a distribution of possible levels of earnings from fishing trips. The method is an extension of a method originally used in the 1995 Bank of Italy Survey of Households Income and Wealth (SHIW) to elicit income variability of households Guiso et al. (2002). The questions are phrased as follows:

1. What is the minimum amount that you have earned from a single fishing trip during your last 20 fishing trips? (Y_{min})
2. What is the maximum amount that you have earned from a single fishing trip during your last 20 fishing trips? (Y_{max})
3. From how many of the last 20 fishing trips did you earn less than ($\frac{Y_{max}+Y_{min}}{2}$) ($z$)
4. From how many of the last 20 fishing trips did you earn less than ($\frac{Y_{max}+Y_{min}}{4}$) ($q$)
5. From how many of the last 20 fishing trips did you earn less than ($\frac{Y_{max}+Y_{min}}{4/3}$) ($x$)

The first two questions elicit the maximum (Y_{max}) and minimum income (Y_{min}) that the participant has earned from his previous 20 fishing trips.[16] These two questions give us the range of possible outcomes for a fishing trip.

With the last 3 questions we give each possible outcome a probability. The first question elicits the chance that a fishing trip is more or less successful than the midpoint of the previously determined minimum and maximum, indicated by z. Subsequently we assess the number of trips that would generate the lowest 25% (q) and highest 25% (x) of possible outcomes respectively. We assign probabilities by assuming a particular structure to the distribution. Which is a uniform distribution split in 4 parts. The probability density function is given by

$$f(Y) = \begin{cases} \frac{Q}{Y_{Q_1}-Y_{min}} & if \quad Y \in [Y_{min}, Y_{Q_1}) \\ \frac{Z-Q}{Y_{med}-Y_{Q_1}} & if \quad Y \in [Y_{Q_1}, Y_{med}) \\ \frac{1-Z-X}{Y_{Q_3}-Y_{med}} & if \quad Y \in [Y_{med}, Y_{Q_3}) \\ \frac{X}{Y_{Max}-Y_{Q_3}} & if \quad Y \in [Y_{Q_3}, Y_{Max}] \end{cases} \tag{4.3}$$

Based on this distribution we calculate the variance in trip revenues

$$Var(Y_i) = \int_{Y_{min}}^{Y_{max}} (Y - Y_{med})^2 f(y) dy \tag{4.4}$$

Then we calculate the coefficient of variation in trip revenues,

$$CoV_i = \frac{\sqrt{Var(Y_i)}}{E(Y_i)} \tag{4.5}$$

To reduce outliers and individuals biases we assign individuals the average variability for their fishery (Dagaa or Nile Perch) at their landing site. The measure was conducted during the third field survey, participants from the first and second field survey are also assigned the value for their fishery if available.

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[16] Participants are asked to answer questions (Y_{min}) and (Y_{max}) using an input field that has a range of 0 to 500, which indicates how many thousand TZS they would earn. This means that the range of possibilities is bounded by 0 and 500.000 TZS per trip.