Risk, restrictive quotas, and income smoothing[†]

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Abstract

Income shocks due to climate change or overexploitation can result in severe hardships for natural resource users which 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. (116 words)

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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 resources users to increase their harvesting effort in response to negative shocks (Béné et al., 2010; Nunan, 2014). As a consequence, resources 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

[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).

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 resources 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 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 availabilty 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 beause their portfolio weights differ due differences in resource availability. Finally, we make us of the fact 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 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 2.1 and 2.2), to serve as the background for the conceptual framework that we develop to frame the empirical analysis (section 2.3).

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 empricial literature that shows how labour flexibility can be used to reduce the impact of negative shocks for individuals. Dupas et al. (2019), 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. She 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 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 modeled 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 (2004) 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 function 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.

2.3 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:

$$y = x - \pi(\mathrm{e}) + \varepsilon \tag{1}$$

For simplicity, we consider that ε is the only random variable. It captures all risk that 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 $f(\mathrm{e})$ as well as a random component ε such that $\pi(\mathrm{e}) = f(\mathrm{e}) - \varepsilon$. 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 (1) is a budget-balance condition that could result from a more complete inter-temporal 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,

[2]Such an assumption is well in line with models where agents have to cover basic needs, e.g. (Kleemann

$\varepsilon < 0$, 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 1 illustrates the effort allocation by a restricted and an unrestricted agent in response to a negative shock.

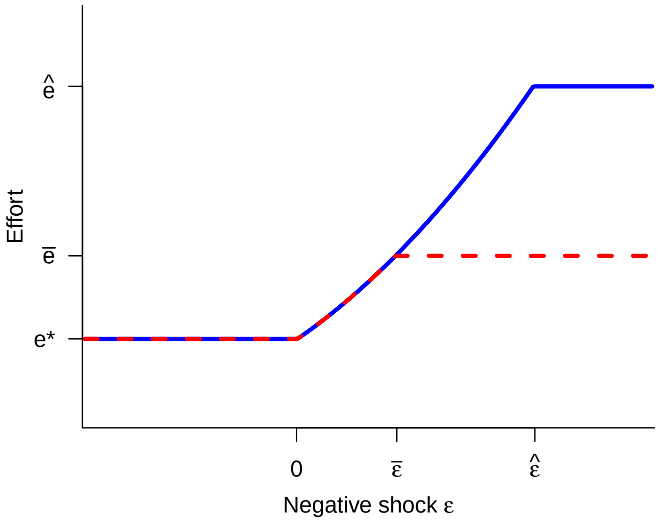

Figure 1: The graph illustrates how effort allocation (e) changes in response to a negative shock ε. The blue solid line indicates the level of effort that the unrestricted agent exerts. The restricted agent (red dashed line) follows the same path, but can only increase effort till $\bar{e}$, corresponding 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 ê.

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 income than unrestricted agents. Conversely, unrestricted agenst 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, restricted 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 ê in Figure 1).

Third, the budget-balance condition, equation (1), highlights that more risk (in terms of a mean-preserving spread of ε) translates to an increased need for savings y, especially

and Riekhof, 2018), and with the empirical observations from flexible labour supply, e.g. (Dupas et al., 2019)

[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.

[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 unresctricted agent, but the restricted agent has to choose $\bar{e}$ given ε^{neg}, while the unrrestricted agent can

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 $\mathrm{e} \leq \bar{\mathrm{e}}$ becomes binding and in which the agent has to turn to precautionary savings to cover expenses. For 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 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:* $\mathrm{var}[\pi^{R=1}] < \mathrm{var}[\pi^{R=0}]$
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 as 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]

choose $\mathrm{e} > \bar{\mathrm{e}}$, we have:

$$\mathrm{var}[\pi^{R=1}] < \mathrm{var}[\pi^{R=0}]$$
$$\Leftrightarrow$$
$$\frac{1}{2}\pi(\mathrm{e}^*)^2 + \frac{1}{2}\pi(\bar{\mathrm{e}})^2 - \left(\frac{1}{2}\pi(\mathrm{e}^*) + \frac{1}{2}\pi(\bar{\mathrm{e}})\right)^2 < \frac{1}{2}\pi(\mathrm{e}^*)^2 + \frac{1}{2}\pi(\mathrm{e})^2 - \left(\frac{1}{2}\pi(\mathrm{e}^*) + \frac{1}{2}\pi(\mathrm{e})\right)^2$$
$$\Leftrightarrow$$
$$\frac{1}{2}\left(\pi(\bar{\mathrm{e}})^2 - \pi(\mathrm{e})^2\right) < \frac{1}{4}\left((\pi(\bar{\mathrm{e}}) + \pi(\mathrm{e}^*))^2 - (\pi(\mathrm{e}) + \pi(\mathrm{e}^*))^2\right)$$
$$\Leftrightarrow$$
$$2\pi(\mathrm{e}^*) < \pi(\bar{\mathrm{e}}) + \pi(\mathrm{e})$$

[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.

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.

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.

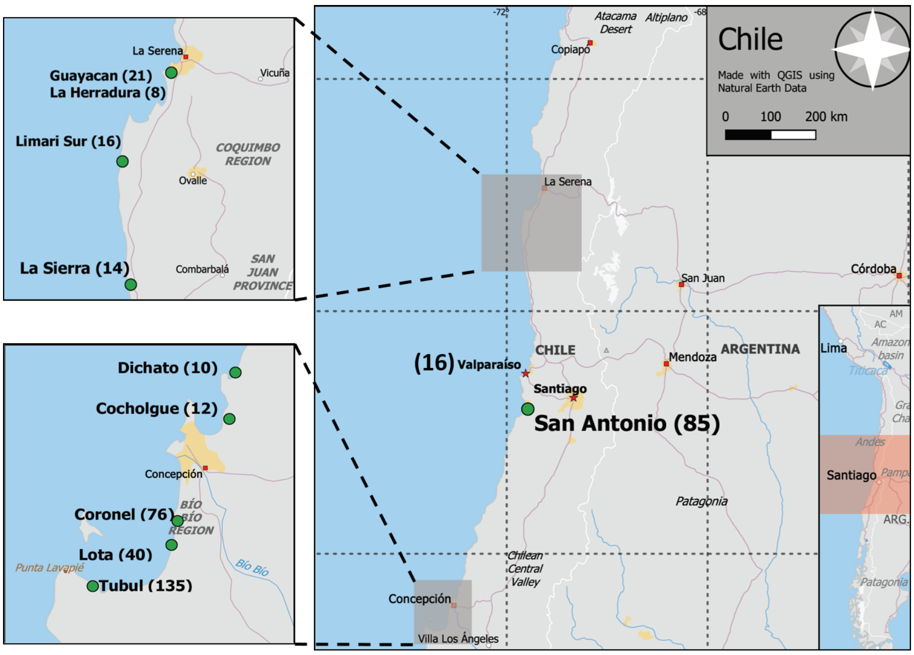

Figure 2: Map of Chile with green dots indicating visited locations. The number between brackets indicates fishers sampled from that location. Most of the visited locations were either near Concepción in the Bío-bío region or near La Serena in the Coquimbo region. These areas are marked with a grey overlay and a higher resolution zoom of these areas is presented on the left.

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 organization, 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 pelagics 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).

[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.

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 fisher's 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≤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:

$$y_i = \beta_0 + \beta_1 R_i + \beta_2 V_i + \beta_3 (R_i \times V_i) + \mathbf{X}_i \gamma + \varepsilon_i \tag{2}$$

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) 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-ample 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.

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 for a map indicating the visited locations[7]. Fisheries organisations were approached 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 both 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.

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 rea-*

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

[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?"

sons. 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.

4.3 Measuring labour flexibility

To measure participant's 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 (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].

$$R_i = \frac{\sum_x^{X_i^R} \pi_{x,i,j}}{\sum_x^{X_i} \pi_{x,i,j}} \tag{3}$$

The distribution of R_i over our sample is presented in Figure 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

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

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.

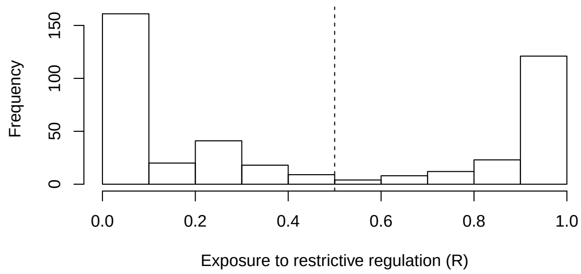

Figure 3: The distribution of R_i, showing how restricted fishers' harvesting opportunities are.

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 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 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]

[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., 2017)

[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 respondents' answer to the first question, Y_{max} is the respondents' 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.

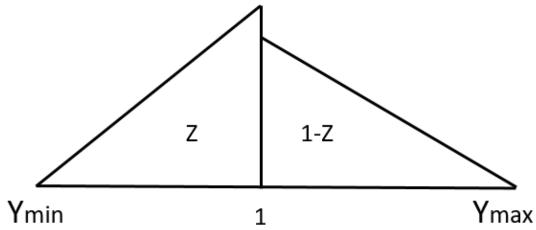

Figure 4: Depiction of the double triangular income distribution, where Y_{min} is the minimum expected income from harvesting, Y_{max} is the maximum expected income from harvesting, and z is the subjective probability for earning less than a typical year. We assume that the density of the distribution is highest at a typical yearly income and normalize this value to 1.

4.5 Control variables

We present the socio-economic characteristics of our participants split between the restricted and unrestricted groups in Table 1. The presented variables will be used as controls in later 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. A specific control for financial literacy is missing in our analysis.

Table 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).

	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

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]

[13]The two more remote locations were Caleta La Sierra and Caleta Limari, both are small fishing

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 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.

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 agents' 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

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

to choose between allocating a mean-zero risk to either the good or bad outcome of another lottery, see figure 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.

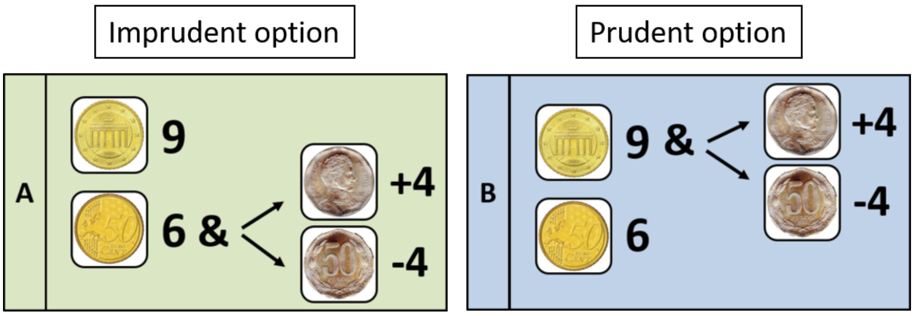

Figure 5: The figure shows the two options participants can choose between when measuring prudence. In both options participants have to flip a coin, they receive the good outcome of 9 points when they throw heads and the bad outcome of 6 points when they throw tails. Beforehand participants make the 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.

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 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 5) or the good outcome (option B in Figure 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.

As an additional robustness control, we measure participant's 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).

[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.

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.

5.1 Differences in income variability and need for savings

Figure 6 shows the group averages and 95% confidence intervals of income variability (on the left) and the need for precautionary savings (on the right).

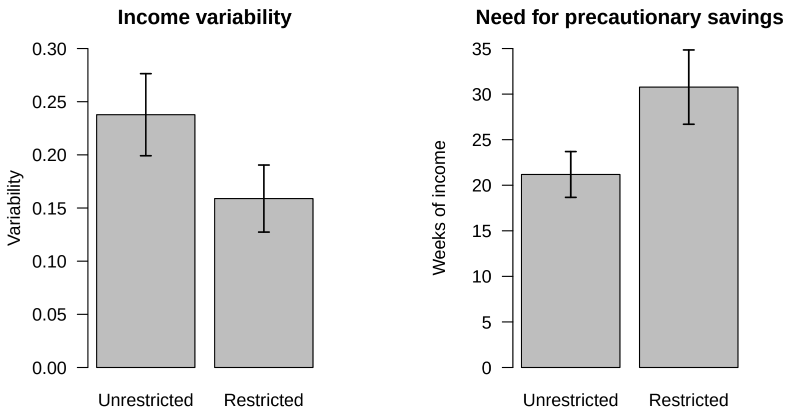

Figure 6: Average variability V_i (left panel) and the average need for precautionary savings for the unrestricted and restricted group, respectively. Error bars show 95% CI.

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 adaptions 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.

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)

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

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.

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

Table 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.

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

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 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, 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, 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.

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 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 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).

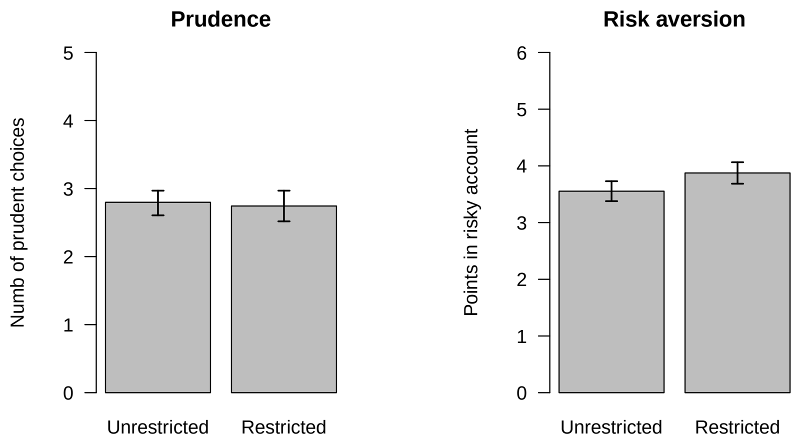

Figure 7: Average level of prudence and risk aversion for unrestricted and restricted group, respectively. Error bars show 95% CI.

In Table 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

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

(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 column (4) of Table 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 3 show the regression results for this subsample of 276 fishers corresponding to specifications (2) and (3) in Table 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.

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

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 reserve" (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 results 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 individuals 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 agents 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 livable 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 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 regula-

[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/)

tions? 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 ensure 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 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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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

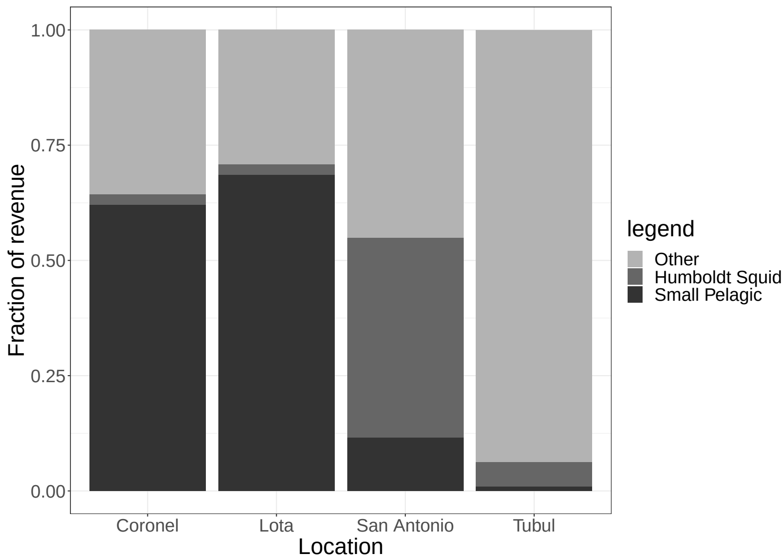

Figure A-1: The bars in the graph indicate the relative revenues generated between 2008 and 2017 by the unrestricted Jibia (Humboldt Squid) fishery and the restricted fishery for small pelagics (Anchoveta and Sardina Común). The graph also includes a group for all other fisheries.

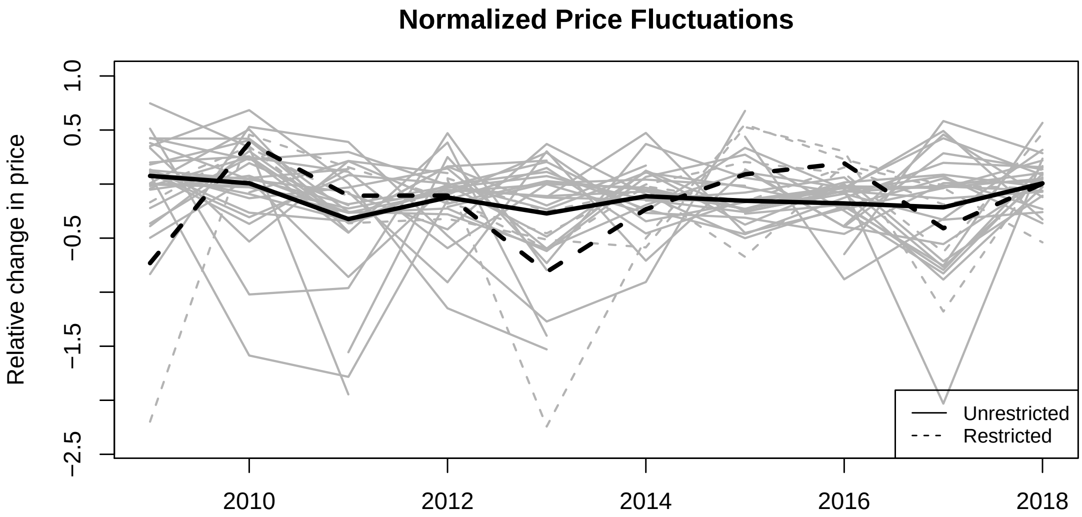

Figure A-2: Time series of relative price fluctuations for restricted species (dotted lines) and unrestricted species (solid lines). The thick lines show the development of the annual averages. Relative price fluctuations do not differ between restricted and unrestricted species ($p = 0.41$, two-sample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

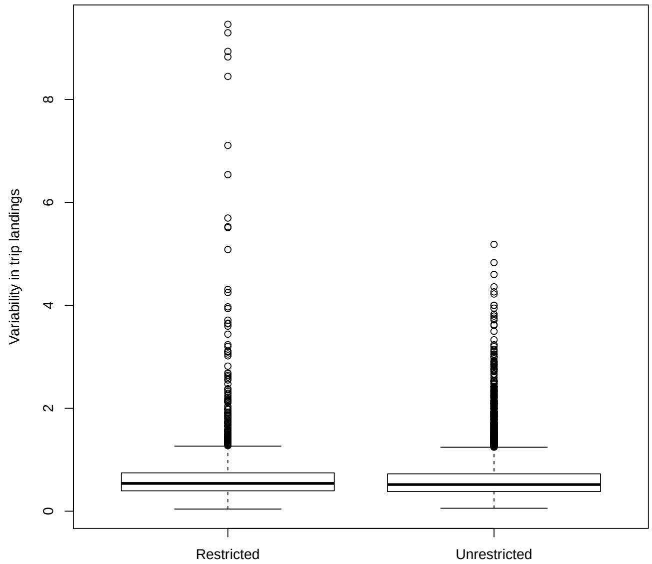

Figure A-3: Boxplot of the trip-to-trip coefficient of variation for the restricted and unrestricted fisheries. The respective averages (0.634 and 0.629) do not differ ($p = 0.59$, two-sample t-test). To arrive at the trip-to-trip coefficient of variation, we have classified each trip from the visited 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, 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: * $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$