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# Risk, restrictive quotas, and income smoothing

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A B S T R A C T

Income shocks due to environmental variability, climatic events 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.

## 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, 2023). However, increasing harvesting in times of need imposes an externality on other resource users by reducing resource levels and future yields (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 reduces resource stocks, 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, see also Barbier, 2010).

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 rebuild resource stocks, increase earnings and stabilize resource dynamics. This makes coping with risk easier in the long run. On the other hand, restrictive harvesting regulations reduce the ability of resource users to increase their harvesting effort in response

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[1] For fisheries, there is by now ample evidence that capping overall harvest has succeeded in reducing the risk of stock collapse (Costello et al., 2008; Isaksen and Richter, 2019). Further, there is evidence that harvest restrictions have decreased the variance in catch levels (Essington, 2010). While there is evidence that fished populations have a larger variance than unharvested population (Anderson et al., 2008), it is not clear whether fish stocks that are harvested at maximum sustainable yield levels have a higher variability than fish stocks that are harvested at open-access levels. Fishing affects the stock level, but it also alters the internal structure of the fish stock by truncating its size distribution, (Diekert, 2013), which affects resource dynamics (Rouyer et al., 2012). While the relationship between resource stock levels and their variance is a fascinating question, it is not the topic of the current paper.

to negative shocks (Béné et al., 2010; Nunan, 2014). Consequently, resource users will have to rely more on precautionary savings or other strategies for smoothing income and consumption. Alternative smoothing strategies and holding precautionary savings may be costly, insufficient, or non-existent, leading to a short-term welfare loss. In other words, in addition to considering the expected values of costs and benefits, we emphasize the higher-order moments of these distributions when evaluating policy reform.

The trade-off between restricting resource users' ability to smooth consumption on the short-term and the long-term benefits from restrictive harvest quotas is particularly relevant as more and more developing and middle-income countries strive to improve resource governance by issuing restrictive harvest quotas. In these settings, well functioning quota markets may be politically or institutionally difficult to establish and good outside labour opportunities may be rare. Hence, 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.

Here, we show that the link between restricting harvest from common pool resources, income variability and the perceived need for precautionary savings can be empirically relevant. To this end, we present results from a cross-sectional survey among Chilean artisanal fishers that we combine with official fisheries data. The artisanal fisheries in Chile offer a unique setting to study the relation between risk, restrictive quotas and income smoothing because the fisheries vary strongly 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). Our dataset contains survey answers from 433 fishers in the Coquimbo, Valparaíso and Bio-bío regions of Chile. We classify fishers' labour flexibility based on the fraction of their income generated from harvesting species with restrictive quotas. Restricted fishers expect their total fishing income for the following year to be less variable than respondents whose harvesting opportunities are not restricted. Still, restricted fishers require, on average, an additional nine weeks of expenses saved up in order to feel secure. Furthermore, we find that higher income variability is linked to a higher perceived need for savings, but only for those fishers whose harvesting opportunities are restricted. Using the data from our incentivized choice experiments, we find that these results are not due to risk-aversion or prudence preferences. Further we exploit the spatial variability in the Chilean setting and make use of propensity score matching procedures to test the robustness of our results.

In sum, our paper highlights that restricting agents from harvesting to rebuild stocks and increase welfare in the long-run, also restricts agents from using natural resources as a buffer for income risk, which has negative welfare implications in the short-run. Hence, efforts to rationalize fisheries management could be combined with policies that offer alternative consumption smoothing mechanisms (such as easier access to credit markets or insurance schemes).

## 2. Related literature

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 (Sections 2.1 and 2.2), to serve as the background for the empirical analysis.

### *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 can significantly reduce the impacts of particular shocks. Also informal risk sharing networks 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 h 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.

In absence of access to financial markets, households in developing countries often hold livestock as assets to smooth consumption (Fafchamps et al., 1998; Kazianga and Udry, 2006). While the livestock is mostly privately owned, the land on which the animals graze is often common property (Jodha, 1986; Pattanayak and Sills, 2001; Thondhlana and Muchapondwa, 2014). Income smoothing from communally owned natural resources means that 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 (Berry et al., 2019; Barbier, 2010).

In summary, the effect a negative shock has on the household's trade-off between income and leisure depends on the type of shock. A negative shock to wealth, such as an unexpected expense, is likely to increase the marginal utility of an additional unit of income and may therefore increase labour supply (Dupas et al., 2020; Nocetti and Smith, 2011). A negative shock to the effective wage rate, for example a decrease in resource abundance, could either reduce or increase labour supply. The decrease in income would increase the marginal utility of income, however it is not certain this would offset the effect of the lower wage rate. As Jayachandran (2006) shows, the labour response depends in part on the ability of the workers to respond to low wages through savings or migration. Furthermore, shocks differ in that some only affect individuals or households, while others affect communities or entire economies. This scale of the shock can determine the effectiveness of consumption smoothing mechanisms. Individual increases in labour might be effective in compensating for shocks. However, a collective response by all workers might lower the wage, or in the case of fisheries, the resource stock or price, such that income does not increase sufficiently to compensate.

### 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 depends on 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 at which marginal gains are 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 reach the break-even point. Prolonged levels of low 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. This may lead 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). 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 increased intra-annual flexibility to spread effort over time, for example, allows for reduced risk taking by fishers (Pfeiffer and Gratz, 2016) and increases the ability of the fishers to spread their income over the duration of the fishing season. Nevertheless, the individual harvest, and hence the opportunity to smooth consumption in reaction to income shocks, is restricted by the individual quota, especially when quotas are not tradable.

Given restrictive quotas, fishers may smooth consumption by diversifying their harvesting activities to other restricted or non-restricted resources. To the best of our knowledge, the only empirical studies on this topic come from the US Alaskan and West-Coast fisheries (Kasperski and Holland, 2013; Anderson et al., 2017). The authors highlight that diversification is costly when it requires the acquisition of new gears and permits. 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 (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 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 reintroduce 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 absence of a functioning market for catch shares, restrictive regulations effectively close 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. One such method are precautionary savings.

Consequently, one would expect that *restricted fishers have a higher need for precautionary savings than less restricted fishers* (conjecture 1). Furthermore, one would also expect that restricted fishers respond stronger to fluctuations in income than less restricted fishers. In other words, *the need for precautionary savings increases stronger with income variability for restricted fishers than for less restricted fishers* (conjecture 2). Testing whether these two conjectures are empirically relevant is the aim of our paper. To this end, we turn to the artisanal fisheries of Chile, which offer a particularly well-suited setting.

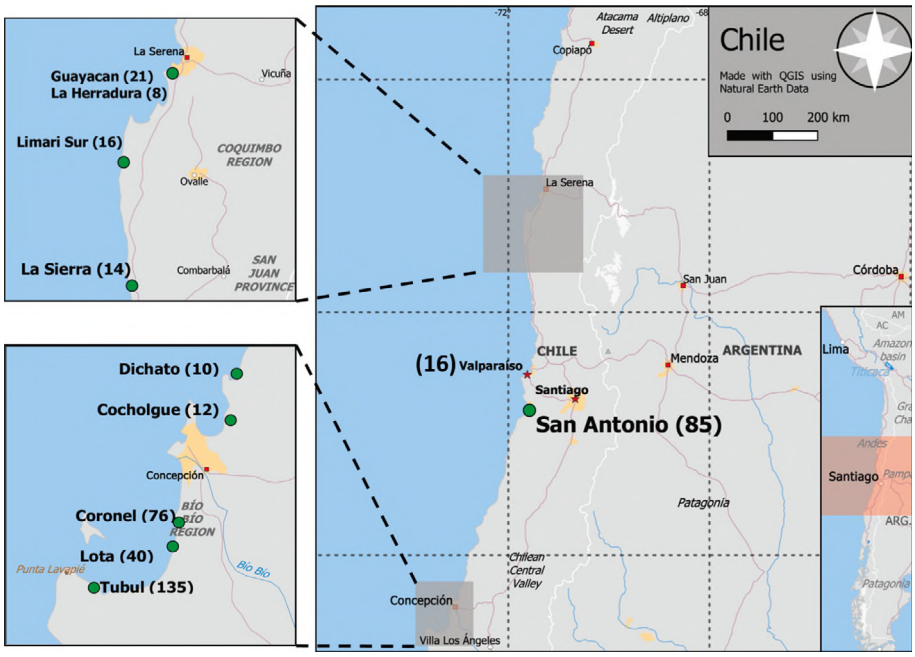



**Fig. 1.** Map of Chile with green dots indicating visited locations. The number between brackets indicates fishers sampled from that location. Most of the visited locations were either near Concepción in the Bio-bío region or near La Serena in the Coquimbo region. These areas are marked with a grey overlay and a higher resolution zoom of these areas is presented on the left.

## 3. Field setting

Chile is a middle-income country that is 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 selected fisheries in the early 2000s and this management effort was instrumental in their recovery (Gelcich et al., 2010). At the same time, a large part of Chilean marine resources remains unregulated by quotas, or existing TAC quotas are far from binding. The resulting diversity in regulatory regimes means that some fishers are restricted in how much they can harvest while others are not. This 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 (a small number of large vessels) 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, 2019).[2] 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: 18 m, hold capacity 80 $m^3$, combined gross tonnage of both vessels: 50 tons).

Artisanal fishers need to be registered in a national database and are required to hold licences for the gear they utilize and the species they land. Most economically relevant fisheries are closed to new entrants, limiting diversification possibilities and switching between fisheries. 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 fisheries, mainly Anchoveta (*Engraulis ringens*) and Araucanian herring (*Strangomera bentincki*), and for benthic fisheries associated with harvesting molluscs (such as Macha clams, *Mesodesma donacium*, and Chilean abalone, *Concholepas concholepas*) and macroalgae through diving and beach collecting, but there are also more general organizations. The fisheries organizations are also used as a contact point between fishers and the government to deal with various management and development issues. It can be difficult for unaffiliated fishers to gain membership to existing fisheries organizations as these have the right to decline new members, and can do so to prevent sharing the fishing rights that they have attained (Albers et al., 2019). For example, in 2019, the Jumbo flying squid (*Dosidicus gigas*) fishery had waiting lists of 663 vessels in the Bio-bío region and 102 vessels in the Valparaíso region.

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 (La Niña and El Niño, see Gomez et al., 2012). The most notable species affected by this are the small pelagics, Anchoveta and Araucanian herring, which accounted for about 40% of the total tonnage landed by the Chilean artisanal fishing sector. The variations in abundance of the two species between years are largely independent of the standing stock as both species are fast growing and heavily dependent on yearly, stochastic, recruitment (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 Anchoveta and Araucanian herring fisheries were 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), which has since been expanded to Jurel (*Trachurus murphyi*) and Merluza común (*Merluccius gayi gayi*). Through the RAE, qualifying fisheries organizations are able to get exclusive rights to a share of the TAC. The size of the share is based on the history of landings of the vessels that are member to the organization. Fishers that are dissatisfied with the quota distribution within the organization are able to change the membership of their vessel to another organization, bringing their quota allocation to the new organization, however this can only be done between years. The RAE regime has restricted possibilities for trading quotas during the fishing season. With

[2] 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.

the permission of their organization vessels are allowed to buy or sell quota to other organizations or industrial fishing vessels that operate in the same region. Over the years there has been dissatisfaction about the low level of the obtained quotas. In the wake of the political tensions in 2019, the Chilean government agreed to raise the TAC.[3]

The species under the RAE are not the only restricted fisheries in Chile, however these are the only species with partial quota tradability. Sixteen out of a total of 75 finfish species that where harvested in Chile between 2009 and 2019 are under a TAC system, representing 92% of total annual finfish landings during this period. For crustaceans, only three out of 22 species were managed with TACs, representing on average 45% of total annual crustacean landings between 2009 and 2017 declining to 29% in 2019. Similarly, only a small fractions of the harvested algae and molluscs species are under a TAC system. As some of the TAC quotas are not binding (and hence do not restrict fishers in how much they harvest) we have classified fishers only as being restricted when the quotas for the respective species that they harvest are actually binding (see the Appendix, Table B-1). There are concerns that fishers are able to bypass the constraints imposed by quotas by fishing illegally. A purportedly common way is that fishers would land a species with a quota, but to conceal overharvesting, they would report it as a common bycatch species of their activity. For example, Anhoveta and Araucanian herring have in the past regularly been misreported as other species, which are not quota restricted but can also be used for fish meal production, such as Mote (*Normanichthys crockeri*) or Pampanito (*Stromateus stellatus*) (Entramar, 2018).

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. Self-employed workers such as fishers have been exempt from the mandatory contributions for unemployment insurance[4] and public pensions. Since 2019, the pension scheme has gradually become mandatory for independent workers younger than 55 and 50 for men and women respectively.[5] The uptake of vessel and gear insurances is low in the artisanal fishing sector. There are several insurance providers in Chile that offer insurances for fishing vessels and gears (FAO and van Anrooy, 2022). These insurance are almost exclusively used by industrial fishing companies and not by the artisanal fishers. The uptake of formal bank accounts in Chile is relatively low for a developed country (Dupas 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, 2019). All Chilean citizens have access to free bank account at the national bank (Banco Estado), called the Cuenta Rut. This account is mainly used to receive transfers from the government. Access to credit in Chile is comparable to other upper middle income countries. However, it often comes at high interest rates, in particular for lower income workers (Cohen et al., 2022).

## 4. Empirical methods and data

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

From the survey, we obtain a standardized measure of the respondent's perceived need for precautionary savings, which we denote by $S_i$. Further, we obtain a standardized measure of the respondents expectation about the variability of next year's fishing income, $V_i$. Moreover, we gather data on the respondents' fishing activities, which we use to estimate their level of fishing income, and a number of other participant characteristics that we include in a control vector $\mathbf{X}_i$. Finally, 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.

Having these measures at hand, we test our first conjecture that restricted fishers require more precautionary savings. We then turn to our second conjecture, that restricted fishers respond stronger to an increase in income variability than unrestricted fishers. To do so, we estimate the coefficients of Eq. (1), and test whether $\beta_1$ and $\beta_3$, are significantly different from zero.

$$S_i = \beta_0 + \beta_1 R_i + \beta_2 V_i + \beta_3 (R_i \times V_i) + \mathbf{X}_i \gamma + \varepsilon_i \tag{1}$$

### 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 Bio-bío regions of Chile, see Fig. 1 for a map indicating the visited locations. Fisheries organizations 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 pelagic fish (Araucanian herring and Anchoveta), (2) squid fishers, (3) crab fishers and (4) a range of benthic gatherers, including beach collectors and divers, for both molluscs, kelp and algae. This classification is broad and we expected substantial heterogeneity within the four groups. Therefore, we elicited the set of target species and classified each fisher individually. While our sample is small relative to the population of Chilean fishers, and it does not represent the full extent of Chile's long coastline, it does reflect the diversity of artisanal fisheries in Chile, in particular with respect to their exposure to harvest restrictions.

Each session consisted of a series of incentivized preference questions and a demographic 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 h. 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 perceived need for precautionary savings

To measure the perceived need for income smoothing trough precautionary saving, $S_i$, 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. Doing so has two advantages. First, we do not need to ask respondents to state absolute levels, which may make them feel uncomfortable. Second, our relative measure implicitly controls for income (at least to the extent that income is proportional to expenses). Our question was phrased as follows:

[3] Meeting minutes of the first extraordinary session of 2019 of the Comité Científico de Pesquerías de Pequeños Pelágicos

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

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

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 respondents to state their need for precautionary savings, we measure the level of consumption smoothing which has to be done through savings, as opposed to risk sharing networks or through labour supply decisions.

Note that our question explicitly takes the respondent's household into account. Hence, it is most natural to think of the agents as being or representing a household. For simplicity, we continue to speak of "the fisher" in the text. This perspective is warranted as in fact, respondent's household income predominantly or exclusively comes from harvesting marine resources (mean = 87%, median = 100%).

### 4.3. Measuring labour flexibility

To measure participant's labour flexibility, $R_i$, we classify to what extent participants operate under restrictive regulations. This is expressed as the fraction of their fishing 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 yearly quota for said species was filled for more than 95%, and not restricted if either the quota was not met, or no quota was present. See Appendix B-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 $X_i^R$.

$R_i$ is calculated by dividing the income generated from target species with restrictive regulations by the income generated by the complete set of target species, see Eq. (2), where $\pi_{x,i,j}$ is the income from species $x$ of fisher $i$ in location $j$. That is, fishers harvesting only restricted species have a value of $R_i = 1$, whilst those harvesting only unrestricted species have a value of $R_i = 0$.

$$R_i = \frac{\sum_x^{X_i^R} \pi_{x,i,j}}{\sum_x^{X_i} \pi_{x,i,j}} \tag{2}$$

We do not have individual level data on revenue generated per target species. Therefore we use the revenue per species in 2017 and 2018 on the landing site level, which is determined using the official landing and price figures of the Chilean fisheries service (SERNAPESCA). This method comes with the assumption that the distribution of revenue between species as measured on the landing site level is representative for the individual fisher, or reflects the relative income generating opportunities available from harvesting these species. Note that illegal fishing through misreporting is captured by our measure $R_i$. A fisher that misreports a restricted species as its unrestricted substitute will reduce the degree to which the participant is classified as restricted.

### 4.4. Measuring income variability from harvesting

Our method for eliciting the expected income variability from harvesting, $V_i$, is based on a series of questions originally used in the 1995 Bank of Italy Survey of Households Income and Wealth (SHIW). The method relies on simply understandable questions which allow us to elicit the expectation of the fishers about future income and with minimal assumptions form a distribution of possible future incomes. The method has previously been applied in field settings to estimate the returns from schooling in a labour market field experiment in Uganda (Alfonsi et al., 2020) or for estimating beliefs about returns from labour and marriage markets (Attanasio and Kaufmann, 2017).

To elicit the expected variability in next year's fishing income, we ask the participants to give their maximum and minimum expected income from fishing for next year. The responses were elicited as fractions of a typical yearly fishing income. We also ask about the probability that they will earn less than a typical year.[6] 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 first two questions elicit the range of possible outcomes. The third question distributes the probability mass between the upper and lower half of the distribution. To give a likelihood to each outcome we follow Guiso et al. (2002) and Alfonsi et al. (2020), and we assume a double triangular distribution, which can be fully constructed without any additional data or assumptions.

Based on the constructed distribution we calculate the standard deviation of the expected income, which will be used as our measure of the participant's income variability $V_i$.[7]

### 4.5. Estimating individual income

We do not have a direct measure of fisher's income. During the design of the survey, we committed to not ask questions directly related to the income of the participants, as these questions were considered impolite and likely to damage the relation between the field experts and fishers. Therefore, we frame the question about respondent's perceived need for savings in relative terms (measured in weeks of usual expenses). This implicitly controls for income to the extent that the former is proportional to expenses. In addition, we chose to estimate income through the fishing activities and location of the participants. The income estimation broadly consists of three steps. First, we estimate the profit from a fishing trip on the vessel level. Second, we calculate the individual fisher's remuneration per trip through prevailing income sharing rules. Third, we determine yearly income of fishers, including for those active in multiple fisheries and vessels. The full procedure of this estimation is outlined in Appendix A-3.

[6] To increase comprehension we relate numeric percentages to verbal expressions of likelihood according to Manski (2004).

[7] 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.

### 4.6. Control variables

We control for a number of characteristics that could influence precautionary savings. The core list of control variables includes family composition, gender and education and is chosen based on a recent review of the empirical precautionary savings literature (Lugilde et al., 2018). We use age and education as proxies for health and financial literacy, respectively.

Moreover, we control for a number of variables that are specific to our setting. First, we ask respondents about their role in the fishery (whether they are crew or a boat owner), and how much they have invested in the fishery. Second, to capture non-fishing labour opportunities, we elicit whether respondents would prefer a secure job in an office or a factory, the extent to which they rely on formal or informal risk-sharing networks, and whether they reside in a small fishing cove or in a larger town or city.

In addition to these observable characteristics, participants may differ systematically with respect to their economic preferences, in particular prudence and risk aversion (for details, see Appendix A-2). Prudence is an economic preference akin to risk-aversion and, in theory, an important determinant of precautionary savings. Ceteris paribus, more prudent agents save more when faced with risk. It is possible that due to self-selection these characteristics are not balanced between groups, and a correlation of prudence and $R_i$ could bias the desired level of precautionary savings (Schaap, 2021; 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. To be able to control for such an effect, we use incentivized choice experiments to measure participant's prudence and risk aversion. Specifically, we use the lottery pairs designed by Eeckhoudt and Schlesinger (2006) and the risky-investment method (Gneezy and Potters, 1997), which has been tested extensively in lab-in-the-field settings (Charness et al., 2013).

## 5. Empirical results

We present our results in four steps. First, we show descriptive statistics of the exposure to restrictive regulation in our sample. Based on this, we compare restricted and unrestricted fishers in a second step. We show that restricted fishers perceive a higher need for precautionary savings compared to unrestricted fishers. This result holds despite the observation of a higher variability in fishing income. We also report where and how restricted and unrestricted fishers differ with respect to income and their elicited control variables. In a third step, we turn to regression models to explain the need for precautionary savings. In particular, we test our second conjecture, a positive interaction between income variability and restrictive quotas. Finally, we discuss and address potential threats to internal validity.

### 5.1. Exposure to restrictive regulation

The distribution of $R_i$ over our sample is presented in Fig. 2. 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. While we will use the continuous measure $R_i$ in the regression analysis, we classify those fishers that mostly harvest restricted species ($R_i > 0.5$) as "restricted" and those fishers that harvest mostly unrestricted species ($R_i \leq 0.5$) as "unrestricted" for the sake of the comparisons in the next subsection.

### 5.2. Differences in income, income variability and need for savings

Fig. 3 shows the group averages and 95% confidence intervals of the need for precautionary savings (on the left), income variability (in the middle) and estimated average income (on the right).

First, we compare the perceived need for precautionary savings, $S_i$, between unrestricted ($R_i \leq 0.5$) and restricted fishers ($R_i > 0.5$). The respective sample means of the two groups are 21.2 and 31.0 weeks of expenses as savings. Based on a Wilcoxon rank sum test we find that that the means of the two group differ significantly ($p < 0.001$, two-sided test). This indicates that restricted fishers perceive a need for about nine weeks of expenses worth of savings more than unrestricted fishers in order to smooth consumption.

Next, we compare the income variability and average income between the groups. As the need for precautionary savings would under certain conditions theoretically increase with income variability for individuals with prudent preferences (Kimball, 1990), it is possible that the higher need expressed by restricted fishers is caused by a higher variability in fishing income. This is not what we find. To the contrary, we find that restricted fishers have a lower income variability from harvesting than unrestricted fishers. The mean value of $V_i$ is 0.24 for unrestricted fishers and the mean value of $V_i$ is 0.15 for restricted fishers. The difference is substantial and significant (Wilcoxon rank sum test, $p = 0.009$).

Similarly, differences in average income might influence the perceived need for savings. Poorer fishers may think that high levels of savings are infeasible and therefore adjust their response downward (Dupas et al., 2018), or they may perceive a higher need for additional savings because they are closer to a subsistence threshold (Jayachandran, 2006). In line with a recent FAO report (Benítez and Nava, 2016), we find that Chilean fishers harvesting regulated resources have a substantially higher average income. We estimate that restricted fishers have an average yearly income of 16 million CLP. This is substantially higher than that of unrestricted fishers, which is 8.15 million CLP. We make no claims that the additional income is due to the regulation, as regulation and enforcement are more likely to be implemented for more profitable resources (Englander, 2019).

In sum, our findings are consistent with the conjecture that restricted agents require more precautionary savings. As mentioned, there are a several factors that may affect the need for precautionary savings and there are potentially many ways to smooth consumption. For example, having to care for children or parents substantially affects the household economy. Similarly, other household members can contribute through labour responses, either within or outside of fishing, or fishers can rely on informal or formal risk sharing networks.

In the next subsection, we therefore turn to the regression analysis where we (1) document that the correlation between the degree of restrictiveness, $R_i$, and the need for precautionary savings, $S_i$ holds when controlling for additional variables and (2) explore the interaction of $R_i$ and $V_i$, that is, whether fishers in the restricted and the unrestricted group react differently to increases in income variability.

### 5.3. Regression analysis

Table 1 contains the main empirical result of our paper. It presents the coefficient estimates of a regression model that tests whether exposure to restrictive regulations is positively correlated to the need for precautionary savings (column 1), whether the effect is mediated by the variability in fishing income (column 2), and whether there is an interaction between quota restrictions and income variability (column 3).

Table 1 presents our preferred specification where we include age, age-squared, log income and an indicator variable whether the parents live in the same household or community with the fisher ("Parents") as control variables. Further controls, such as gender, an indicator whether children live in the household, the fraction of household

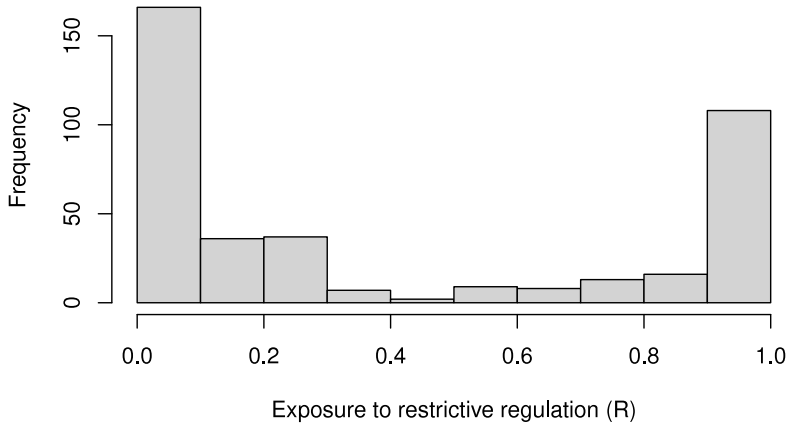



**Fig. 2.** The distribution of $R_i$, showing how restricted fishers' harvesting opportunities are.

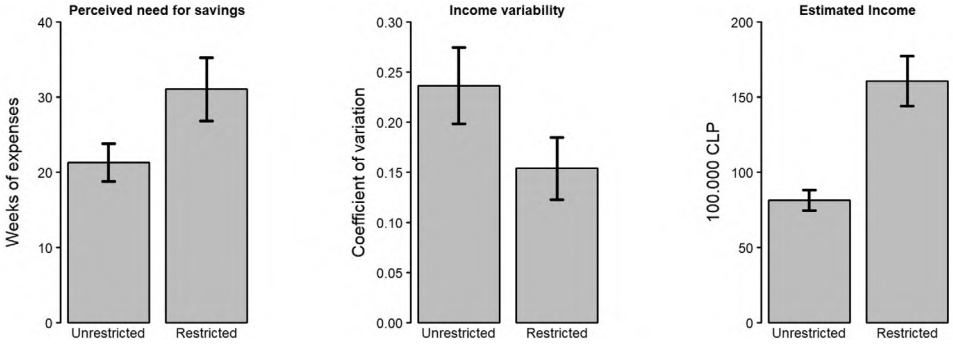



**Fig. 3.** Average need for precautionary savings $S_i$ (left panel) and average variability $V_i$ (middle panel) and average income (right panel) for the unrestricted and restricted group, respectively. Error bars show 95% CI.

**Table 1**
The table reports the OLS regression coefficients of the main regressions. From the sample of 433 observations, 25 participants did not wish to answer the savings question, 6 did not have a valid fishing portfolio, 4 are removed due to non-answers for control variables and 25 did not have a valid income distribution. Robust standard errors are clustered at the landing site level.

| | *Dependent variable:* | | |
|---|---|---|---|
| | Weeks of savings | | |
| | (1) | (2) | (3) |
| Restricted ($R_i$) | 10.00** | 10.33** | 7.32 |
| | (4.30) | (4.88) | (5.50) |
| Variability ($V_i$) | | 2.45 | −1.88 |
| | | (5.34) | (6.22) |
| Restricted×Variability | | | 18.01*** |
| | | | (6.04) |
| Age | 1.06** | 1.15*** | 1.19*** |
| | (0.43) | (0.35) | (0.34) |
| Age-Squared | −0.01** | −0.01*** | −0.01*** |
| | (0.005) | (0.004) | (0.004) |
| Parents | 7.31*** | 7.32*** | 7.61*** |
| | (1.56) | (1.75) | (1.74) |
| Log(Income) | 1.74 | 1.84 | 2.00 |
| | (1.97) | (1.93) | (1.95) |
| Constant | −13.65 | −16.43* | −17.05** |
| | (11.33) | (8.83) | (8.34) |
| Observations | 398 | 373 | 373 |
| Adjusted $R^2$ | 0.07 | 0.07 | 0.07 |

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

income that does not come from fishing, and the amount invested in the fishery all have only a negligible and non-significant influence on the regression results and were hence excluded in the model selection process. Results for model specifications that include these additional variables are presented in Table A-7 in the Appendix.

Column (1) shows 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 10.0 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 less than 2% are part of a pension system (Benítez and Nava, 2016). Our finding that fishers report that they need about 7 weeks more savings when their parents live in their household or their vicinity highlights the importance of various income smoothing mechanisms, also in middle-income countries like Chile.

In the model specification presented in column (2) of Table 1, we add the reported income variability $V_i$ as control variable. 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 1, we see that higher income variability is linked to a stronger need for precautionary savings for restricted fishermen. The effect is sizable and significant at the 1 percent level. Correspondingly, the effect of harvesting quota restricted species as such decreases and loses significance ($p = 0.183$).

### 5.4. Addressing internal validity

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 five pieces of evidence that address potential concerns about the internal validity of our results.

The first concern that we aim to address is bias that results from selective entry into either restricted or unrestricted fisheries. To this end, we 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 (1) and (2) in Table 2 show the regression results for this subsample of 272 fishers corresponding to specifications (2) and (3) in Table 1, 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. That said, our exercise cannot control for attrition based on the variable of interest (out-selection over time). However, we think selective attrition is unlikely because outside opportunities are rare and shifting target species requires new permits which are difficult and costly to obtain. Even if there were gradual selection of those initially restricted fishers into unrestricted because they value labour flexibility (more than the profitability difference between restricted and unrestricted fisheries), this would mean that our result is a lower bound estimate. The same holds when initially unrestricted fishers select into restricted fisheries because they do not value labour flexibility as strongly. In both cases gradual selection should decrease the difference in the perceived need for savings between restricted and unrestricted fisheries.

The second concern that we aim to address is that some omitted variable about the mode of production is driving the results. 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 a very different distribution of restricted and unrestricted species in their catch. Specifically, in four of the visited locations there are fishers that are active in both the largest unrestricted fishery in terms of volume (Jumbo flying squid) and the largest restricted fishery (Anchoveta and Araucanian herring). Between the locations the relative importance of the respective fisheries differs substantially. (See Figure A-4 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. Consequently, 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 and perceived need for savings holds when the mode of production remains constant. Although we are left with a relatively small sample of fishers, the results in columns (3) and (4) of Table 2 show that also in this subsample, fishers that are restricted by quotas require more savings. The interaction effect between being restricted and income variability remains positive and sizeable, however it is no longer significant in this smaller sample.

Third, we address the concern that differences in income affect the differences in perceived need for savings. As shown in Fig. 3, unrestricted fishers have a substantially lower average income compared to restricted fishers. Poorer fishers might simply perceive higher levels of savings to be infeasible and therefore give a lower estimate. While we control for income in the main regression using our imputed income measure, we use a propensity score matching procedure as an additional robustness test.

For each participant we calculate a propensity score using a logistic regression. The propensity score indicates the probability of the participant being in the restricted group based on control variables that are predictive for treatment status or the outcome variable (such as age, gender and income). As the main concern is that fishers with different income levels need different levels of savings, we partition the sample into 4 income quartiles. Then within the same income quartile unrestricted agents and restricted participants are matched such that the summed absolute difference in propensity scores between the matches is lowest. This procedure gives us a balanced but smaller sample ($n = 136$) on which we can test our hypotheses. The full procedure and balance tests are presented in Appendix A-4.

As shown in the right panel of Fig. 4, the average income for restricted an unrestricted fishers is not significantly different in the matched subsample ($p = 0.88$, two-sided t-test). The average income has dropped for the restricted group as there were no unrestricted fishers in the highest income quartile to be matched with. In the left panel we see that the difference in the perceived need for precautionary savings is still weakly significant ($p = 0.057$, Wilcoxon rank sum test). Moreover, the averages for the groups are similar in the subsample compared to the complete sample. The difference in perceived income risk between the groups is no longer significant ($p = 0.54$, two-sided t-test).

The regression results for the matched subsample are reported in columns (5) and (6) of Table 2. The restricted variable $R_i$ remains significant when income is balanced between the two groups. The effect size of the interaction effect between the restricted variable $R_i$ and income variability $V_i$ is still substantial, but no longer significant.

Then, we address the concern that the economics preferences that are important for explaining savings behaviour, might differ between

**Table 2**
OLS Regression results. Specifications (1) and (2) control for selection into restricted fisheries, by limiting the sample to those fishers that began fishing before restrictive harvesting restrictions were introduced. Specification (3) and (4) report the robustness check where the mode of production of restricted and unrestricted fishers is the same. Specifications (5) and (6) report the results from the sample balanced through propensity score matching. Standard errors are not clustered for specifications (3) and (4), as the number of clusters is too low.

| | *Dependent variable:* | | | | | |
|---|---|---|---|---|---|---|
| | Weeks of savings | | | | | |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Restricted ($R_i$) | 10.02** | 6.86 | 16.48** | 14.77* | 10.91** | 8.77* |
| | (4.04) | (4.24) | (8.29) | (8.39) | (4.59) | (4.86) |
| Variability ($V_i$) | 1.28 | −3.27 | 1.99 | −3.34 | 8.24 | 2.83 |
| | (4.20) | (5.39) | (7.66) | (13.60) | (9.24) | (12.26) |
| Restricted×Variability | | 20.99*** | | 14.40 | | 13.63 |
| | | (5.17) | | (24.03) | | (14.52) |
| Age | 1.45* | 1.40 | 2.74*** | 2.75*** | 2.54*** | 2.62*** |
| | (0.82) | (0.86) | (0.94) | (0.95) | (0.28) | (0.31) |
| Age-Squared | −0.01** | −0.01* | −0.03*** | −0.03*** | −0.03*** | −0.03*** |
| | (0.01) | (0.01) | (0.01) | (0.01) | (0.003) | (0.004) |
| Parents | 6.93*** | 6.86*** | 7.50 | 7.24 | 3.00 | 3.40 |
| | (2.03) | (2.11) | (4.99) | (5.07) | (2.80) | (2.66) |
| Log(Income) | 2.28 | 2.36 | −0.88 | −1.45 | 0.47 | 0.68 |
| | (1.86) | (1.84) | (9.16) | (9.34) | (3.12) | (3.03) |
| Constant | −55.67 | −54.47 | −41.00 | −30.61 | −42.47 | −47.47 |
| | (41.76) | (42.35) | (153.48) | (156.67) | (49.02) | (47.52) |
| Observations | 272 | 272 | 120 | 120 | 136 | 136 |
| $R^2$ | 0.07 | 0.08 | 0.15 | 0.15 | 0.08 | 0.08 |
| Adjusted $R^2$ | 0.05 | 0.05 | 0.10 | 0.10 | 0.04 | 0.03 |

* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

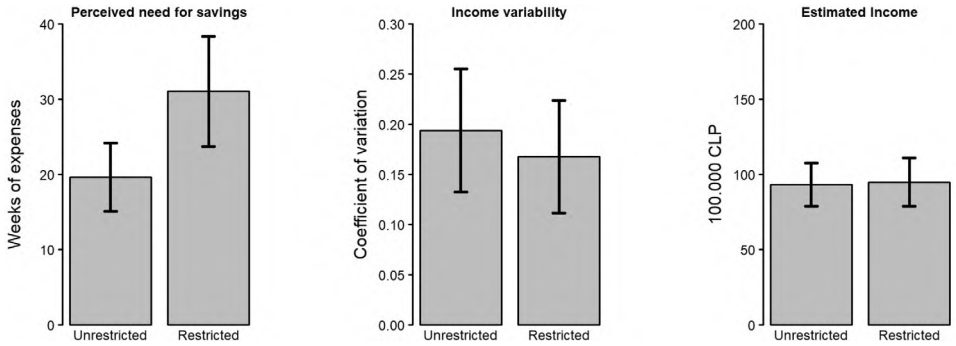



**Fig. 4.** Average need for precautionary savings $y_i$ (left panel) and average variability $V_i$ (middle panel) and average income (right panel) for the unrestricted and restricted group, respectively. Error bars show 95% CI.

the restricted and unrestricted fishers. If one group is more risk-averse or more prudent this could influence their perceived need for saving. To address this concern we show that the results are qualitatively robust to the inclusion of prudence and risk aversion as control variables. In columns (1) and (2) of Table A-7 we control for risk preferences and prudence as measured during the sessions. 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.

Lastly, we compare the alternative consumption smoothing mechanisms available to restricted and unrestricted fishers. For this we turn to the following question: "In case you need cash but have none, where would you turn to for help?". Here we make a distinction between consumption smoothing mechanisms that rely on formal networks (which includes, bank, government, fish buyer or professional organization), and informal networks (family or friends). We find that the two groups do not differ in whether they would rely formal or informal risk sharing networks.

With regard to the specific mechanisms, we find no significant difference between restricted and unrestricted fishers in the usage of banks, fish buyers, friends and family as a source of cash when in need. We do find that restricted fishers are more likely to ask either the government or their professional organization for help. The comparison is summarized in Table 3

**Table 3**
Uptake of different sources of consumption smoothing for participants.

| Network | Restricted | Unrestricted | *p*-values |
|---|---|---|---|
| Bank | 0.36 | 0.36 | 0.99 |
| Government | 0.16 | 0.06 | 0.003 |
| Fish buyer | 0.01 | 0.01 | 0.97 |
| Prof organization | 0.07 | 0.02 | 0.04 |
| Friends | 0.06 | 0.08 | 0.44 |
| Family | 0.47 | 0.54 | 0.27 |

When access to formal networks is added as a control to the main regression specification, our results remain significant and of a similar magnitude. We find that participants that use a formal network perceive a higher need for savings on average of 4 weeks, see columns (3) till (6) in Table A-7.

In sum, we can show that our results are not due to risk-aversion or prudence preferences, and hold in a sub-sample that is balanced on income, 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.

## 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 harvesting opportunities become more stable and the chance of stock collapse decreases. 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, state a higher need for precautionary savings to smooth their consumption. This results holds despite the fact that fishers in the restricted group report lower levels of income variability. Restricted fishers also tend to be richer, potentially because there is less competition and because fishers can concentrate on delivering quality rather than quantity (Abbott et al., 2010). Nevertheless, restrictive fishers are not as flexible to react to unexpected income shocks.

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. Whilst we lack direct income date, we estimate income based on official fisheries data. Our estimates are in line with a survey done by the FAO in 2015 (Benítez and Nava, 2016), who report that fishers in the restricted group have a higher average income. We find that the need for savings and estimated income are indeed positively related (Pearson's correlation coefficient = 0.14, $p < 0.01$). However, when we control for income in our regression analysis presented in Table 1, we find that the relation between the perceived need for savings and the degree to which fishers are restricted remains positive and significant ($p < 0.05$), whilst the relation between the perceived need for savings and estimated income is no longer significant. Moreover, we utilize propensity score matching to create a balanced subsample w.r.t. estimated income and other control variables. We repeat our regression analysis with this balanced subsample and we find that for this balanced sample differences in the perceived need for savings remain significant at the 5% level.

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 stabilize stock levels. 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, 2023).

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 a result, long term resource conservation objectives are sacrificed (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).

Well-functioning credit markets are therefore an important complement to resource management strategies. Jayachandran (2013), for example, highlights how payment for ecosystem services schemes may be compromised when credit-constrained agents use forests as assets that can be liquidated to meet unexpected needs. Similarly, Fenichel et al. (2019) show how better access to credit markets reduce the cost of providing ecosystem services. Noack and Costello (2022) emphasize a different interaction between credit markets and resource management. Taking a macro-economic perspective and using a unique dataset of 4,692 fish stocks, they show that more developed credit markets are linked to increased resource extraction under weak (or no) management (as it is cheaper to invest in harvesting capital), while more developed credit markets are linked to reduced resource extraction under strong management (as it is profitable to invest in the resource stock).

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., 2021). 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, 2018) 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 (IUU), which is exacerbated in the absence of sufficient income opportunities (Gallic and Cox, 2006; Axbard, 2016). Improving the capacity of fishers to smooth consumption through means other than effort supply response could have positive impact on the occurrence of IUU fishing. In Chile, SERNAPESCA estimates that in 2019, 324.000 tons of marine resources have been illegally extracted, with an estimated value of 397 million USD.[8] The presence of illegal fishing gives rise to a potential concern of a correlation between regulations and an unwillingness to disclose financial information to third parties. For this purpose all questions

[8] 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/.

regarding financial matters were phrased in relative terms. The only exception being the capital investment in fishing gear. We find that for the savings and variability questions, respectively 5.8% and 6.2% of respondent choose not answer, with no significant difference between restricted and unrestricted fishers (Chi-square test, respective $p$-values = 0.68 and 0.26). The non-response rate is higher for the investment question namely 12.2%, however again there is no difference between restricted an unrestricted fishers (Chi-square test, $p$-value = 0.20). This indicates that phrasing the questions as relative measures made fishers more willing to answer and indicates no correlation between regulations and an unwillingness to disclose information.

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 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 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 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.

## CRediT authorship contribution statement

**Robbert-Jan Schaap:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Exequiel Gonzalez-Poblete:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation. **Karin Loreto Silva Aedo:** Writing – review & editing, Writing – original draft, Validation, Resources, Project administration, Methodology. **Florian Diekert:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.


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## Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.ecolecon.2024.108319.

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