Risk, restrictive quotas, and income smoothing[*]

Robbert-Jan Schaap[1], Exequiel Gonzalez-Poblete[2], Karin Loreto Silva Aedo[2], and Florian Diekert[1,3]

[1]Alfred Weber Institute for Economics, Heidelberg University
[2]Pontifical Catholic University of Valparaíso, School of Marine Sciences
[3]CEES, Department of Biosciences, University of Oslo

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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

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

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 across fisheries. By implication, resource users are less able to buffer negative income shocks.

Here, we develop a theoretical model that highlights the long-term/short-term trade-off in the variability domain, and we provide direct evidence for the empirical link between restrictive quotas, income variability and the need for precautionary savings. Specifically, we present results from a survey among Chilean artisanal fishers that we combine with official fisheries data.

The artisanal fisheries in Chile offer a unique setting to study these questions because the fisheries vary strongly in the spatial availability of different commercial species and in the degree to which harvesting is restricted. Chile is a middle-income country that shares elements of developed economies with modern industries and relatively well functioning governance institutions as well as elements of developing economies with low uptake of formal savings accounts (Dupas et al., 2018) and limited social security expenditure (OECD, 2019; Benítez and Nava, 2016). Hence, understanding the trade-off from imposing restrictive regulations on harvesting is relevant in Chile in its own right, but it is also of interest for natural resource management in other regions of the world.

Our dataset contains survey answers 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, and find that the restricted fishers consider their income from fishing to be less variable compared to the respondents whose harvesting opportunities are less restricted. 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. Exploiting the spatial variability in the Chilean setting, we show that the results hold in a sub-sample of fishers that concentrate on the same portfolio of species, but are differently restricted because their portfolio weights differ due differences in resource availability. Finally, we make use of the fact that some of our respondents have a long tenure in their fishery. Hence, we can rule out selection effects by conducting our analysis on a sub-sample of fishers that have started fishing at a time when there were no restrictions on any species.

2 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 (section 2.1 and 2.2), to serve as the background for the theoretical model (section 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 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 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. 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). 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.

3 Theoretical Model

In this section we develop a model to study precautionary savings behaviour and to evaluate the welfare effects of restricting labour flexibility in the context of natural resource harvesting. To this end, we combine elements from Flodén (2006), who studies the effect of labour flexibility on savings under standard consumption preferences with elements from Jayachandran (2006) who studies the effect of a minimum consumption level on savings decisions when labour supply is flexible.

The model is constructed as a two-period savings problem for a representative agent that faces a risky wage in the second period. The agent maximizes utility by adjusting effort (e_t) and consumption (c_t) in both periods and precautionary savings (y) in the first period. Agents have one unit of time that they can distribute between leisure (l_t) and fishing effort. That is: $l_t \equiv 1 - e_t$. To summarize, agents face the following maximization problem.

$$\max_{c_1, c_2, l_1, l_2, s} U = u(c_1, l_1) + \mathrm{E}u(c_2, l_2) \tag{1}$$

Preferences are time-separable and strictly concave $u_{cc} < 0$, $u_{ll} < 0$ and $u_{cl} = 0$. Also the agent exhibits prudence $u_{ccc} > 0, u_{lll} > 0$, which is necessary for generating precautionary savings.[2] There is no time-discounting. As in Jayachandran (2006) we assume that the agent has Stone-Geary preferences over consumption and leisure. This implies that there is a subsistence threshold or minimum level of consumption indicated by $\underline{c}$. Setting $\underline{c} = 0$ would reduce the function to Cobb-Douglas preferences.

$$u(c_t, l_t) = \log(c_t - \underline{c}) + \frac{1-\alpha}{\alpha} \log(l_t) \quad \text{where} \quad \alpha \in (0, 1) \tag{2}$$

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[2] The expected wage and income are constant across periods and savings would equal zero in the absence of risk. All savings are generated as a response to risk and are therefore precautionary savings.

In our setting, it is most natural to think of the agent as being or representing a household. We highlight that fishing is the only source of planned income in our model. In reality, agents may have additional sources of income, like outside jobs or rents from owning or cultivating land. One way to think about the model is that this income is captured by the utility derived from leisure. Another way to think about the model is that this income is captured by the term $\underline{c}$, which could also be a random variable that represents unplanned expenses like a hospital bill, the cost of fixing a car or windfall gains like winning in a lottery or an inheritance. In our data, fishing constitutes, on average, between 86% and 90% of household income for unrestricted and restricted fishers, respectively.

Effort produces income according to a Schaefer production function such that the effective wage rate is determined as follows, $w_t = pqx_t$, where x_t is the resource stock in period t, p is the resource price and q the catchability. The second period wage is uncertain due to a shock to the resource stock. Also, the resource stock is affected by the fishing effort in the first period, such that:

$$x_2 = Z \cdot g(x_1 - h_1(e_1)) \tag{3}$$

where h_1 is total fishery harvest in period 1 (which depends on effort), g is the resource growth function and Z is a random variable, where $log(Z)$ is normally distributed with variance σ^2 and mean $\mu = -\sigma^2/2$, such that $\mathrm{E}[Z] = 1$. Agents are myopic in the sense that they do not take the effect of their effort on total harvest, and hence the next period's stock, into account. As a consequence, the resource dynamics will play a limited role in the derivation of the (myopic) agent's optimal effort and saving choices that we analyze in the next subsection, but it will play a major role in the welfare analysis of section 3.2.

In addition to the subsistence threshold $\underline{c}$, we capture the setting of a developing economy setting by allowing the gross interest rate on savings, D, to be smaller than 1. In other words, transferring savings through time can be costly due to inflation, bank costs or other transaction costs. In many developing economies, these costs can be substantial.[3] This leads to the following period budget constraints:

$$c_1 = w_1 e_1 - y \tag{4}$$

$$c_2 = w_2 e_2 + Dy \tag{5}$$

3.1 Optimal effort and savings choices

We now turn to the optimal effort and savings decisions. An unrestricted agent can choose $e \in [0, 1]$, while a restricted agent can only choose $e \in [0, \overline{e}]$. We will first solve the problem for an unrestricted agent, to then highlight the effects when labour flexibility is limited by harvest regulations.[4]

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[3] According to The World Bank (2019) the real interest rate in Chile has been negative in several years between 2004 and 2018. Furthermore the uptake of interest bearing financial instruments is very low in Chile as only 21.1% of those aged 15+ saved at a financial institution in 2017.

[4] Although most harvesting regulations come in the form of quotas in reality, their implication, for the purpose of a model that analyzes the effect of (limited) labour flexibility on income, is the same as an effort restriction.

Directly inserting the budget constraints (4) and (5), and focusing on savings and effort as choice variables, the unrestricted agent's objective in the first and second period are:

$$W_1 = \max_{e_1,y}\left\{\log\big(w_1e_1 - \underline{c} - y\big) + \frac{1-\alpha}{\alpha}\log\big(1-e_1\big) + \mathrm{E}\big[W_2(y;Z)\big]\right\} \tag{6}$$

$$W_2(y;Z) = \max_{e_2}\left\{\log\big(w_2(Z)e_2 - \underline{c} + Dy\big) + \frac{1-\alpha}{\alpha}\log(1-e_2)\right\} \tag{7}$$

where the expectation in (6) is taken with respect to the random resource shock Z. The shock determines the second period wage, highlighted by writing w_2 as $w_2(Z)$ in (7). Taking second period wage as given, solving the first-order-condition for (7) yields the following optimal effort for an unrestricted agent (denoted by the superscript u):

$$e_2^u(y;Z) = \alpha + (1-\alpha)\frac{\underline{c} - Dy}{w_2(Z)} \tag{8}$$

Correspondingly, first-period optimal unrestricted effort is given by:

$$e_1^u(y) = \alpha + (1-\alpha)\frac{\underline{c} + y}{w_1} \tag{9}$$

We now emphasize an important aspect of this model, which is the unrestricted agent's second-period response to wage shocks:

$$\frac{\partial e_2^u(y;Z)}{\partial Z} = -(1-\alpha)\frac{\underline{c} - Dy}{w_2(Z)^2}w_2'(Z) \tag{10}$$

Unrestricted agents are able to smooth consumption either through depleting savings or adjusting effort. As equation (10) highlights, the strength of the effort response is influenced by the minimum level of consumption ($\underline{c}$). When y and $\underline{c}$ are zero, we have $\frac{\partial e_2^u(y;Z)}{\partial Z} = 0$, and optimal effort is independent of the effective wage w_2. For positive values of $\underline{c}$, the agent is closer to the subsistence threshold, and as a result the income effect becomes relatively stronger to the substitution effect. When the income effect dominates the substitution effect, agents will supply more effort when the wage rate decreases.[5] The reason is that additional consumption is particularly valuable close to the subsistence threshold. Therefore, the greater $\underline{c}$, the stronger the ex-post labour supply responses are to negative shocks. See Figure 1.

The key point is that the restricted agent cannot adjust effort freely to negative wage shocks. For a positive wage shock, the restricted agent's effort response will be identical to the unrestricted agent (conditional on savings y), but for a (sufficiently) negative shock it will be capped at $\overline{e}$. That is, we have:

$$e_2^r(y;Z) = \begin{cases} e_2^u & \text{if } e_2^u \leq \overline{e} \\ \overline{e} & \text{if } e_2^u > \overline{e} \end{cases} \tag{11}$$

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[5] Because $w_2 = pqx_2 = pqg(x_1 - h_1)Z$, we have $w_2'(Z) > 0$ and when $\underline{c} > Dy$, we have $\frac{\partial e_2^u(y;Z)}{\partial Z} < 0$.

Figure 1: Change in unrestricted fishing effort in response to the resource shock. The solid line indicates the response when the minimum consumption threshold ($\underline{c}$) is zero. The dotted line shows $\underline{c} = 0.32$. Parameter values as in Table 1; $y = 0$.

Now given that restricted agents anticipate that the effort constraint may become binding in the second period, they will require more precautionary savings than unrestricted agents. To see this, note that by the envelope theorem, we have $\frac{\partial W_2}{\partial y} = \frac{D}{w_2 e_2^* - \underline{c} + Dy}$, where e_2^* is given by (8) for the unrestricted agent and by (11) for the restricted agent. Clearly, $\frac{D}{w_2 e_2^* - \underline{c} + Dy}$ is decreasing in e_2^* and since $e_2^u \geq e_2^r$ (with $e_2^u > e_2^r$ for $e_2^u > \overline{e}$), the marginal utility from savings is larger for restricted agents once the effort constraint binds.

In general, there are no closed form solutions for savings in dynamic models with stochastic income and endogenous labour supply (Nocetti and Smith, 2011). Therefore, we numerically solve the optimal precautionary savings decision for restricted and unrestricted agents, illustrated in Figure 2 (using the parameter values shown in Table 1). In the numerical simulations, we assume that effort is restricted at the optimal first-period effort level of an unrestricted agent $\overline{e} = e_1^u(y^u)$ (where y^u refers to optimal unrestricted savings). This assumptions neutralizes any dynamic effects on the resource stock as both agents apply the same level of first-period effort. In other words, we have $\mathrm{E}[w_2^r] = \mathrm{E}[w_2^u]$. Moreover, we assume that the resource stock is in steady-state, that is $w_1 = \mathrm{E}[w_2]$.

When the minimum consumption threshold is zero the model predicts that restricted and unrestricted agents require the same amount of savings. This is unsurprising, as in this case second period labour supply is not used to compensate for negative shocks, see Fig 1. As effort is unresponsive to shock, the effort constraint will also never become binding in the second period. However, when the minimum consumption threshold is positive, the income effect dominates over the substitution effect. In this case, effort supply increases as wage decreases. Effort is used to buffer shocks, which in turn decreases unrestricted agents' need for savings. Restricted agents anticipate that they may not be able to increase effort at low wages, and hence have a higher need for savings. Agents' optimal precautionary savings increase the higher the minimum level of consumption $\underline{c}$, and they increase stronger for restricted than for unrestricted agents.

In developing countries it is reasonable to assume that saving is costly. When the the gross interest rate decreases, so does the marginal utility gained by saving, and unsurprisingly savings decrease for both restricted and unrestricted agents. As shown in Figure 2, the difference in savings between restricted and unrestricted agents is substantially larger when

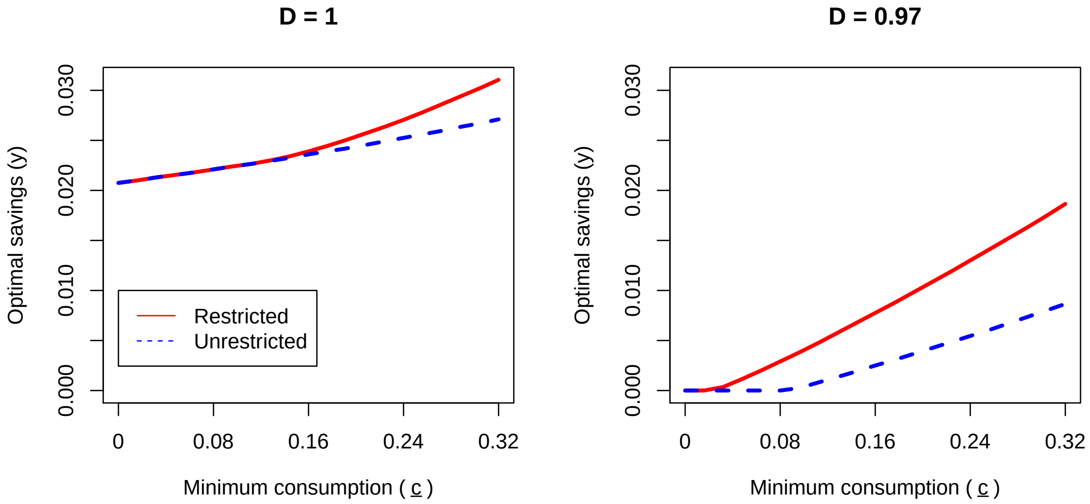

Figure 2: Optimal savings as a function of the minimum consumption threshold. In the left panel, savings is costless ($D = 1$), in the right panel there is a cost to savings ($D = 0.97$). The red solid line represents the restricted agents and the blue dotted line represents unrestricted agents. Parameter values as in Table 1

there is a moderate cost to saving ($D = 0.97$) compared to the situation were savings is costless ($D = 1$). In other words, both factors that characterize many developing economies, larger values of $\underline{c}$ and lower values of D, increase the need for savings of restricted compared to unrestricted agents.

We now discuss how the underlying variability of the resource stock (σ^2, the variance of Z) affects optimal savings (Figure 3). As expected, both restricted and unrestricted agents require more savings the larger σ, but a mean-preserving spread of Z induces a higher need for precautionary savings for restricted than for unrestricted agents.

To see this formally, let $\hat{Z}$ be the threshold shock to the resource at which the second-period effort constraint becomes binding.[6] Now for any $Z \leq \hat{Z}$, the effort constraint becomes binding and the marginal utility from precautionary savings, $\frac{\partial W_2}{\partial y}$ is larger for the restricted than for the unrestricted agents, and the unrestricted agents save more. A mean-preserving spread of Z means that outcomes of $Z \leq \hat{Z}$ become more likely.

To summarize, model predictions depend on how close resource users are to the subsistence threshold and the cost of savings. Particularly under condition found in developing country fisheries, we find that restrictive quotas increase the need for precautionary savings.

Prediction. *Compared to an unrestricted agent, a restricted agent:*

1. *Requires more savings to balance their budget:* $y^r > y^u$
2. *Is more sensitive to a mean-preserving spread of* Z *(requires more additional savings the larger the variance in* Z*).*

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[6] That is, for our numerical simulations, $\hat{Z}$ is defined by $\overline{e} = e_1^u(y^u) = e_2^u(y^u; \hat{Z})$. Using (9) and (8), it is easy to see that $\hat{Z} = \frac{c - Dy^u}{c + y^u}$ (where we have made use of our assumption that $w_1 = E[w_2]$ and hence $w_2 = w_1 Z$).

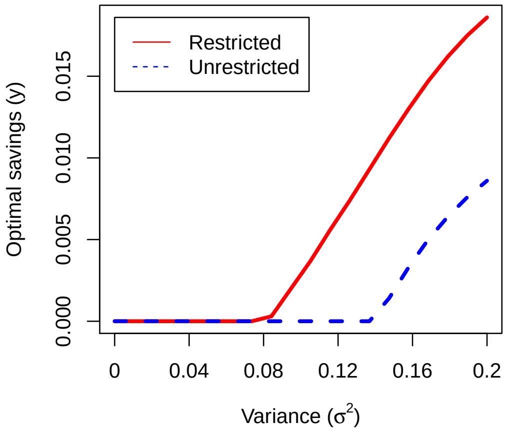

Figure 3: Optimal savings as a function of the variance in the resource shock (σ). Subsistence threshold $\underline{c} = 0.32$, gross interest rate $D = 0.97$, remaining parameter values as in Table 1.

3.2 Welfare analysis

In this section, we highlight the welfare consequences of effort restrictions, given optimal labour and savings responses. To this end, we assume that there are N agents in the economy. Consequently, aggregate harvest is $h_t = Nqx_te_t$. We specify that resource growth follows a power growth function so that $x_2 = Z \cdot (x_1 - Nqx_1e_1)^\gamma$. The parameters employed in our numerical simulations are shown in Table 1. The growth parameter γ is adapted so that the resource is in equilibrium at a value of $x_1 = 0.8$. That is, for $x_1 = 0.8$, restricted and unrestricted agents agents choose an effort level such that $\mathrm{E}[x_2] = x_1$.[7]

Table 1: Parameter values used in numerical illustrations

Subsistence threshold $\underline{c}$	[0, 0.32]
Utility weight on leisure α	0.4
Variance of resource shock σ^2	0.2
Catchability coefficient q	0.1
Resource price p	20
Number of agents N	10
Resource growth parameter γ	[0.228, 0.304]
Equilibrium resource level $\bar{x}$	0.8

In Figure 4 we plot the welfare difference between unrestricted and restricted agents for different levels of the initial resource stock x_1. When x_1 is at the equilibrium level 0.8, unrestricted agents optimally choose an effort level that, in expectation, just leads to the same resource stock in the second period. That is, we have rigged the model so that there are no benefits to restricting effort – by construction (we return to to this issue below). Because there are no gains from restricting first-period effort at $x_1 \geq \bar{x}$, but restricted agents fear that the constraint becomes binding in the second period for a bad

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[7] The optimal unrestricted effort level depends on $\underline{c}$ and D, so that $\gamma = \frac{ln(\bar{x})}{ln(\bar{x} - Nq\bar{x}e_1^u)}$

shock to the resource stock, their welfare is lower than the welfare of unrestricted agents. Unrestricted agents have a higher welfare than restricted agents for all $x_1 \geq \bar{x}$, but the higher the initial stock, the less likely it is that a shock to the resource stock is so bad that the effort constraint becomes binding in the second period. Hence, the difference between unrestricted and restricted agents gets smaller at some point as x_1 increases from $\bar{x}$.[8]

Now, when the initial resource stock is lower than the equilibrium level (as x_1 decreases from $\bar{x}$ to the right in Figure 4), there is a gain to restricting effort. When the initial resource stock is below $\bar{x}$, unrestricted agents use more effort to compensate for the low wage rate. Doing so, however, can lead to a poverty trap because unrestricted agents unwillingly depress the following-period wage rate. As we have assumed agents to be myopic, they do not take this externality on the resource stock into account. Restricted agents are insulated against this externality by construction. These agents cannot increase effort to buffer the low wage rate in the first period, but they will not apply excessive effort. Their second period wage rate will consequently not be as depressed. The positive effect of greater resource recovery for restricted agents quickly outweighs the cost of being restricted. Figure 4 shows that the potential cost of a poverty trap quickly outweigh the gains of labour flexibility.

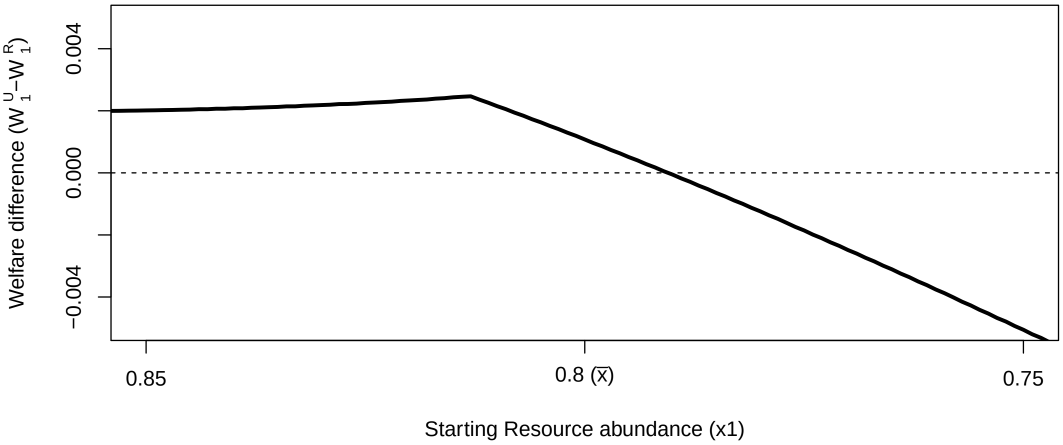

Figure 4: Welfare difference between unrestricted and restricted agents for different levels of the initial resource stock x_1. Parameter values as in Table 1.

Note that equalizing first-period resource stock assumes away the arguably largest gain from restricting effort. Without restrictions, effort would enter until all rents are dissipated and the resource stock would converge to the open-access level. Effort restrictions, in contrast, are put in place precisely to bring the resource stock to higher levels. The short-term / long-term trade-off in terms of the average income is well known and depends crucially on the applicable discount rate. Here, our intention was to highlight an additional

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[8] Note that the kink at $x_1 = 0.81$ is due to the following effect: When the resource abundance is higher than $\bar{x}$, unrestricted agents exert less effort than the effort restriction (they save less and the wage is higher so less effort is needed). Restricted agents save more than unrestricted agents, and the effort constraint remains binding. However this means that restricted agents exert more effort than unrestricted agents for a while. As the stock grows even further restricted agents start savings less again comparably.

trade-off that concerns the variability of incomes. Our point is that there is this additional issue, whose empirical relevance we test in the remainder of our paper, that should be taken into account when weighing the costs and the benefits of fisheries rationalization. Our point is *not* that the overall costs of rationalization outweigh its benefits. To evaluate such a statement, we would need a different model. We would be very surprised if restricting effort would not yield a positive net-present-value.

4 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 unregulated by quotas 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.

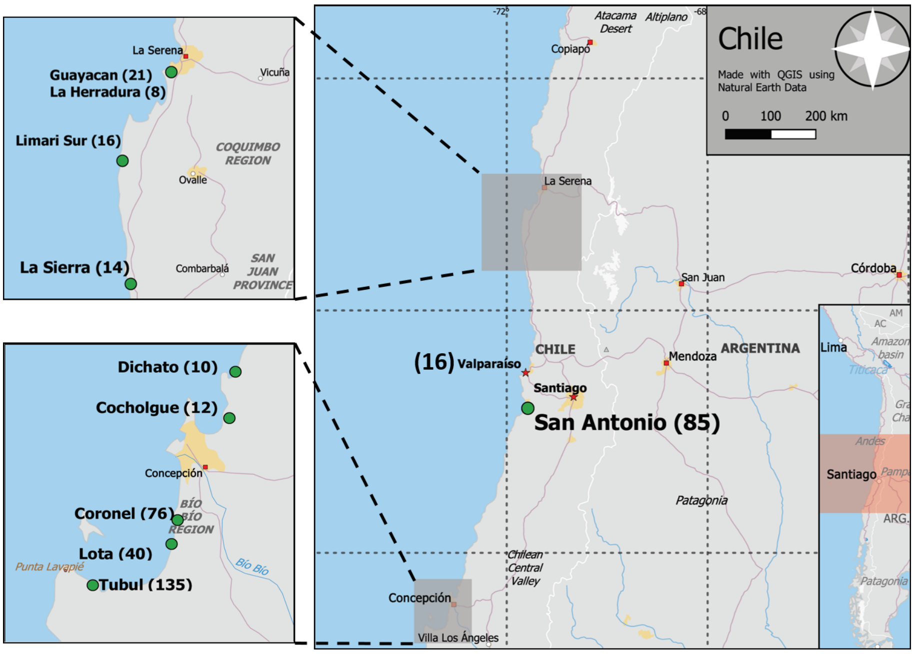

Figure 5: Map of Chile with green dots indicating visited locations. The number between brackets indicates fishers sampled from that location. Most of the visited locations were either near Concepción in the Bio-bío region or near La Serena in the Coquimbo region. These areas are marked with a grey overlay and a higher resolution zoom of these areas is presented on the left.

The Chilean fishing sector is divided into the industrial sector, which is comprised of a small number of large 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)[9]. The individual artisanal fishers operate on a relatively small

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[9] 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.

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 economically relevant fisheries are closed to new entrants, limiting diversification possibilities. 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 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. It can be difficult for unaffiliated fishers to gain membership to existing fisheries organisations 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).

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 is a restricted fishery with limited labour flexibility. The 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).

The number of restricted fisheries is limited in Chile, however these fisheries are generally larger in size. Between 2009 and 2019 a total of 75 finfish species where harvested in

Chile, 16 (21%) out of these species are under a TAC system and represented in average 92% of total annual finfish landings during this period. For crustaceans 3 (14%) out of 22 species annually landed between 2009 and 2019, were managed with TACs, representing in 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 and these quotas are often area specific.

Chilean artisanal fishers are diverse in their fishing activities and these activities are generally clustered in locations based on resource availability and processing infrastructure. Limits to resource availability can hamper diversification into new activities by established fishers, who can be further constrained by waiting lists for licenses and equipment costs. For example, in 2019, the Humboldt squid fishery had waiting lists of 663 vessels in the Bio-bío region and 102 vessels in the Valparaíso region. For an overview of the species targeted by fishers in the surveyed sample and the corresponding quota systems see the Appendix, Table A-1.

5 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 a survey among Chilean artisanal fishers.

From the survey, we obtain a standardized[10] measure of the respondent's need for precautionary savings, y_i. Moreover, 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. Finally, we estimate the variability of next years' fishing income of the respondents, V_i.

Having these measures at hand, we then test whether restricted fishers require more precautionary savings. 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:

$$y_i = \beta_0 + \beta_1 R_i + \beta_2 V_i + \beta_3 (R_i \times V_i) + \mathbf{X}_i \gamma + \varepsilon_i \tag{12}$$

We take the following steps 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. First, we control for a large vector of observable control variables $\mathbf{X}_i$ that may influence the perceived need for precautionary savings. Second, we alleviate concerns

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[10] Specifically, we measure 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.

about omitted variable bias that relates to the mode of production of the different fisheries that the respondents are active in by exploiting 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 weights of restricted and unrestricted catches. Finally, to address potential concerns about selection bias, 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.

5.1 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 Figure 5 for a map indicating the visited locations[11]. 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.

5.2 Measuring the need for precautionary savings

To measure the need for income smoothing trough precautionary saving, y_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[12].Our

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

[12] 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

question was phrased as follows:

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

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

Note that this question explicitly takes the respondent's household into account. As mentioned in the theoretical model, 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%).

5.3 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 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.

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 equation (13). That is, fishers harvesting only restricted species have a value of $R_i = 1$, whilst those harvesting only unrestricted species have a value of $R_i = 0$.

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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?"

$$R_i = \frac{\sum_x^{X_i^R} \pi_{x,i,j}}{\sum_x^{X_i} \pi_{x,i,j}} \tag{13}$$

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)[13]. 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 this species. Thus fishers harvesting the same set of restricted and unrestricted species will be evaluated as less restricted (and having higher labour flexibility) in locations where unrestricted species are comparatively more abundant and vice versa.

5.4 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) Guiso et al. (2002). 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 (Y_{max}) and minimum expected income (Y_{min}) 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 (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 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.[14] 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.

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[13] For certain species the price data was missing in 2017 and/or 2018, in these cases the average of the nearest available years was used

[14] 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%.

Based on the constructed distribution we calculate the standard deviation of the expected income, which will be used as the participants value for variability V_i.[15]

5.5 Control variables

We control for a number of characteristics that could influence precautionary savings choices. The base list of control variables includes family composition, gender and education is 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 and education for financial literacy.

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,[16] and whether they reside in a small fishing cove or in a larger town or city.

In addition to these observable characteristics discussed, participants may differ systematically with respect to their economic preferences, in particular prudence and risk aversion (for details, see Appendix A-3). 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.

Finally, 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).

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[15] 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.

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

6 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, in line with theoretical predictions, restricted fishers have a higher need for precautionary savings compared to unrestricted fishers. This result holds despite the observation that unrestricted fishers have a higher variability in fishing income. We also report where and how restricted and unrestricted fishers differ with respect to 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 theoretical prediction, a positive interaction between income variability and restrictive quotas. Finally, we discuss and address potential threats to causal inference.

6.1 Exposure to restrictive regulation

The distribution of R_i over our sample is presented in Figure 6. 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 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.

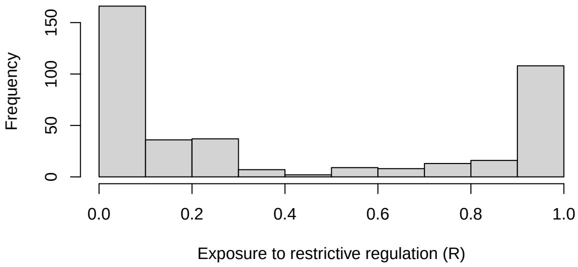

Figure 6: The distribution of R_i, showing how restricted fishers' harvesting opportunities are.

6.2 Differences in income variability and need for savings

Figure 7 shows the group averages and 95% confidence intervals of the need for precautionary savings (on the left) and income variability (on the right).

First, we compare the need for precautionary savings y between unrestricted and restricted fishers. The respective sample means of the two groups are 21.2 and 31.0 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.

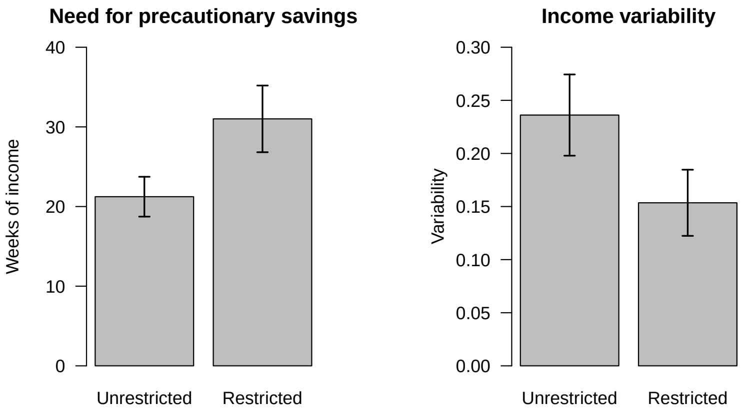

Figure 7: Average variability V_i (left panel) and the average need for precautionary savings for the unrestricted and restricted group, respectively. Error bars show 95% CI.

Next, we compare the income variability between the groups. As the need for precautionary savings would theoretically increase with income variability, it is possible that the higher need for restricted fishers is caused by a higher variability in fishing income.

We find that, on average, unrestricted fishers ($R_i \leq 0.5$) have a higher income variability from harvesting than restricted fishers ($R_i > 0.5$). 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, $p = 0.009$). 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.

In sum, we can confirm the theoretical predictions that restricted agents require more precautionary savings, even though they report lower variability in income from harvesting. 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. 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 children or parents to care for will substantially affect the household economy (linking the data back to the theoretical model, these factors could be thought of as an increase in the minimum level of consumption that must be met). 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 Table 2 we present summary statistics of the observed variables and test whether they differ between restricted and unrestricted fishers.

Table 2: 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. Test used: two sample t-tests (Age, Number of targets and % fishing income), chi-squared Test (remaining variables).

	Restricted	Unrestricted	p_values
Age	50.19 (11.48)	46.96 (13.09)	0.01
Gender (female = 1)	0.07	0.29	< 0.001
Children (yes/no)	0.82	0.84	0.691
Parents live here	0.75	0.79	0.44
City	0.54	0.27	< 0.001
Finished high school	0.59	0.43	0.003
Prefer secure job	0.45	0.46	0.896
Formal network	0.47	0.40	0.147
% Fishing income	86.07 (20.77)	86.52 (21.52)	0.834
# Target species	6.4 (5.59)	7.26 (6.34)	0.152
Invested < 500.000	0.64	0.33	< 0.001
Invested < 10 Mil	0.17	0.45	< 0.001
Invested > 10 Mil	0.19	0.21	0.765
Boat owner	0.16	0.33	< 0.001

Our sample is on average 48.2 years old, which is characteristic for the population of fishers (INE, 2010). Restricted fishers are on average 3.22 years older than unrestricted fishers ($p = 0.01$) 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).[17]

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. 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.

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

Our sample has on average 6.93 target species and there is no significant difference between unrestricted and restricted fishers. 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.

Finally, we compare the levels of prudence and risk aversion between unrestricted and restricted fishers. The left panel in Figure 8 shows the average number of prudent choices for the two groups. We find no difference with 2.82 and 2.72 prudent choices out of 5 for the unrestricted and restricted group respectively ($p = 0.51$, Wilcoxon rank sum test). In the first lottery 55% of the unrestricted group and 52% of the restricted group choose the prudent option, this difference is again not significant ($p = 0.57$). This indicates that there is no self-selection into restricted or unrestricted fisheries based on higher-order risk preferences. The right panel in Figure 8 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 3.90 invested points versus an average of 3.56 in the unrestricted group. The difference is significant ($p = 0.02$, Wilcoxon rank sum test) but small.

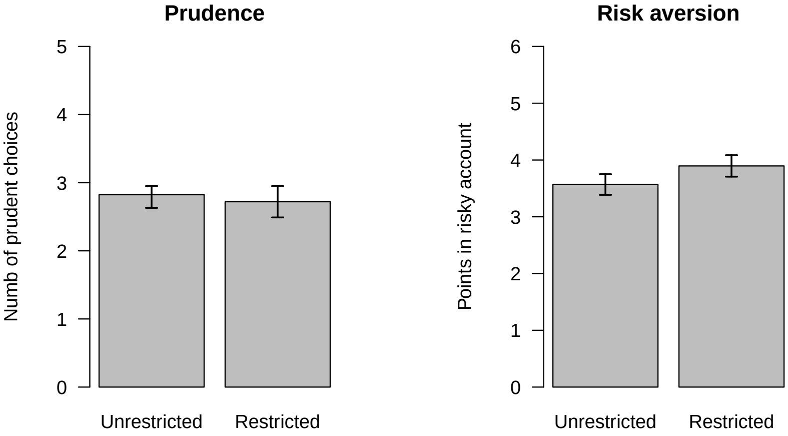

Figure 8: Average level of prudence and risk aversion for unrestricted and restricted group, respectively. Error bars show 95% CI.

In the next subsection, we turn to the results from our regression analysis where we (1) document that the difference in the need for precautionary savings holds when controlling for additional variables 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.

6.3 Regression analysis

Table 3 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 3 presents our most preferred specification where we include age, age-squared and a dummy variable whether the parents live in the same household or community with the fisher ("Parentshere") as control variables. 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. Similarly, the results are qualitatively robust to the inclusion of prudence and risk aversion as control variables, see Table A-2 in the Appendix.

Table 3: OLS Regression results. 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. Standard errors are not clustered for specification 4, as the number of clusters is very low (4).

	Dependent variable:					
	Weeks of savings					
	(1)	(2)	(3)	(4)	(5)	(6)
Restricted (R_i)	11.19**	11.53**	8.95	13.80**	11.47**	8.54*
	(5.12)	(5.48)	(5.96)	(6.70)	(4.74)	(4.80)
Variability (V_i)		2.68	−1.16	12.95	1.56	−2.72
		(5.41)	(6.26)	(16.32)	(4.49)	(5.59)
Restricted×Variability			16.04***			19.79***
			(6.05)			(6.33)
Age	1.12**	1.21***	1.25***	2.59	1.34*	1.28
	(0.47)	(0.40)	(0.39)	(2.53)	(0.79)	(0.83)
Age-Squared	−0.01**	−0.01***	−0.01***	−0.02	−0.01*	−0.01*
	(0.01)	(0.005)	(0.005)	(0.03)	(0.01)	(0.01)
Parentshere	7.41***	7.42***	7.69***	5.63	6.79***	6.72***
	(1.61)	(1.85)	(1.88)	(7.41)	(2.17)	(2.26)
Constant	−11.83	−14.57*	−14.97**	−53.82	−16.29	−13.86
	(10.03)	(7.63)	(7.17)	(59.10)	(22.47)	(24.37)
Observations	398	373	373	78	272	272
R^2	0.07	0.08	0.08	0.10	0.06	0.07
Adjusted R^2	0.07	0.07	0.07	0.04	0.05	0.05

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

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 11.19 more weeks of precautionary savings than a fisher whose harvest comes exclusively from unrestricted species ($R_i = 0$). This effect is significant at the 5 percent level.

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

In the model specification presented in column (2) of Table 3, 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 3, 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 1 percent level. Correspondingly, the effect of harvesting quota restricted species as such decreases and loses significance ($p = 0.116$).

The positive coefficient on the interaction term $R_i \times V_i$, (column (3) of Table 3) confirms the second 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.

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

The first concern that we address is that the documented differences in the need for precautionary savings may not be due to differences in how restricted fishers are, but due to other factors, such as the mode of production. Here, we exploit the fact that a range of fishers use the same type of gears and target the same set of species, but – due to geographical differences – have very different portfolios of restricted and unrestricted catches. Specifically, in four of the visited locations there are fishers that are active in both the largest unrestricted fishery (Humboldt squid) and the largest restricted fishery (Anchoveta and Sardina común)[18]. 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.

Second, 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 272 fishers corresponding to specifications (2) and (3), 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.

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

7 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 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 (IUU) (FAO, 2018), 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 even in developed countries such as Chile. SERNAPESCA estimates that in 2019, 324.000 tons of marine resources have been illegally extracted, with an estimated value of 397 million USD[19].

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 regarding financial matters were phrased in relative terms. The only exception being the capital investment in fishing gear. We find that for the savings

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[19] 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/)

and variability questions, respectively 5.8% and 6.2% of respondent choose not 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 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), NQ (no quota). 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	NQ	NQ	NQ	NA	NA	NA
Lessonia berteorana	Algae	Huiro negro	TAC	NQ	NQ	67%	NA	NA
Durvillaea antarctica	Algae	Cochayuyo	NQ	NQ	NQ	NA	NA	NA
Macrocystis pyriphera	Algae	Huiro	NQ	NQ	NQ	NA	NA	NA
Lessonia trabeculata	Algae	Huiro palo	TAC	NQ	NQ	99%	NA	NA
Gymnogongrus furcellatus	Algae	Liquen	NQ	NQ	NQ	NA	NA	NA
Porphyra columbina	Algae	Luche	NQ	NQ	NQ	NA	NA	NA
Mazzaella laminaroides	Algae	Luga cuchara	NQ	NQ	NQ	NA	NA	NA
Sarcothalia crispata	Algae	Luga negra	NQ	NQ	NQ	NA	NA	NA
Gigartina skottsbergii	Algae	Luga roja	NQ	NQ	NQ	NA	NA	NA
Gracilaria chilensis	Algae	Pelillo	NQ	NQ	NQ	NA	NA	NA
Heterocarpus reedi	Crustaceans	Camarón nailon	TAC	TAC	TAC	66%	100%	$<$ 1%
Cancer porteri	Crustaceans	Jaiba limon	NQ	NQ	NQ	NA	NA	NA
Cancer edwardsi	Crustaceans	Jaiba marmola	NQ	NQ	NQ	NA	NA	NA
Homalaspis plana	Crustaceans	Jaiba mora	NQ	NQ	NQ	NA	NA	NA
Taliepus marginatus	Crustaceans	Jaiba patuda	NQ	NQ	NQ	NA	NA	NA
Cancer setosus	Crustaceans	Jaiba peluda	NQ	NQ	NQ	NA	NA	NA
Cancer coronatus	Crustaceans	Jaiba reina	NQ	NQ	NQ	NA	NA	NA
Ovalipes trimaculatus	Crustaceans	Jaiba remadora	NQ	NQ	NQ	NA	NA	NA
Cervimunida johni	Crustaceans	Langostino amarillo	TAC	NQ	NQ	93%	NA	NA
Pleuroncodes monodon	Crustaceans	Langostino colorado	TAC	NQ	NQ	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	NQ	NQ	NQ	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	NQ	NQ	NQ	NA	NA	NA
Cilus gilberti	Fish	Corvina	NQ	NQ	NQ	NA	NA	NA
Genypterus maculatus	Fish	Congrio negro	NQ	NQ	NQ	NA	NA	NA
Genypterus blacodes	Fish	Congrio dorado	NQ	NQ	NQ	NA	NA	NA
Trachurus murphyi	Fish	Jurel	TAC	RAE	TAC	73%	NA	107%
Ethmidium maculatum	Fish	Machueuelo	NQ	NQ	NQ	NA	NA	NA
Stromateus stellatus	Fish	Pampanito	NQ	NQ	NQ	NA	NA	NA
Brama australis	Fish	Reineta	NQ	NQ	NQ	NA	NA	NA
Strangomera bentincki	Fish	Sardina común	RAE	RAE	RAE	NA	NA	NA
Thyrsites atun	Fish	Sierra	NQ	NQ	NQ	NA	NA	NA
Merluccius gayi gayi	Fish	Merluza común	RAE	RAE	RAE	NA	NA	NA
Callorhinchus callorhynchus	Fish	Pejegallo	NQ	NQ	NQ	NA	NA	NA
Odontesthes bonariensis	Fish	Pejerrey	NQ	NQ	NQ	NA	NA	NA
Paralabrax humeralis	Fish	Cabrilla	NQ	NQ	NQ	NA	NA	NA
Venus antiqua	Molluscs	Almeja	NQ	NQ	NQ	NA	NA	NA
Aulacomya ater	Molluscs	Cholga	NQ	NQ	NQ	NA	NA	NA
Ensis macha	Molluscs	Huepo	NQ	NQ	NQ	NA	NA	NA
Fissurella spp.	Molluscs	Lapa	NQ	NQ	NQ	NA	NA	NA
Concholepas concholepas	Molluscs	Loco	NQ	NQ	NQ	NA	NA	NA
Mesodesma Donacium	Molluscs	Macha	NQ	NQ	NQ	NA	NA	NA
Tagelus dombeii	Molluscs	Navajuela	NQ	NQ	NQ	NA	NA	NA
Mulinia Edulis	Molluscs	Taquilla	NQ	NQ	NQ	NA	NA	NA
Trophon geversianus	Molluscs	Caracol	NQ	NQ	NQ	NA	NA	NA
Dosidicus gigas	Molluscs	Jibia	TAC	TAC	TAC	70%	70%	70%

A-2 Supplementary Figures

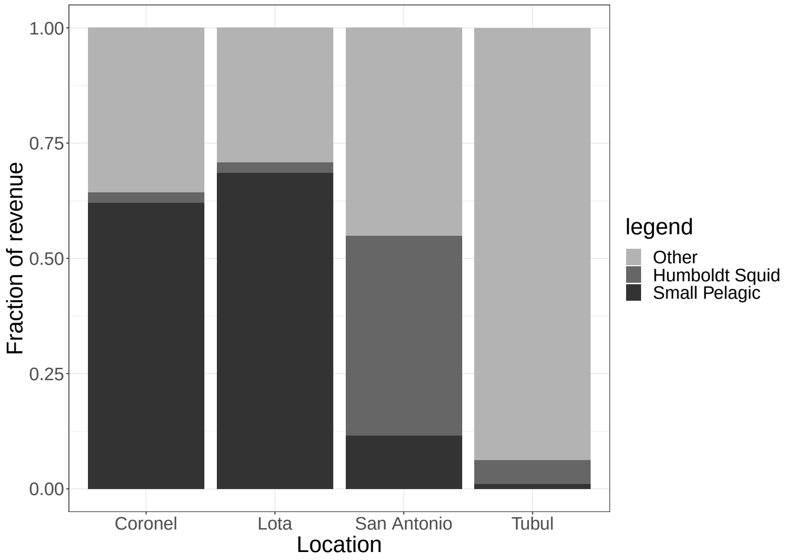

Figure A-1: The bars in the graph indicate the relative revenues generated between 2008 and 2017 by the unrestricted Jibia (Humboldt Squid) fishery and the restricted fishery for small pelagics (Anchoveta and Sardina Común). The graph also includes a group for all other fisheries.

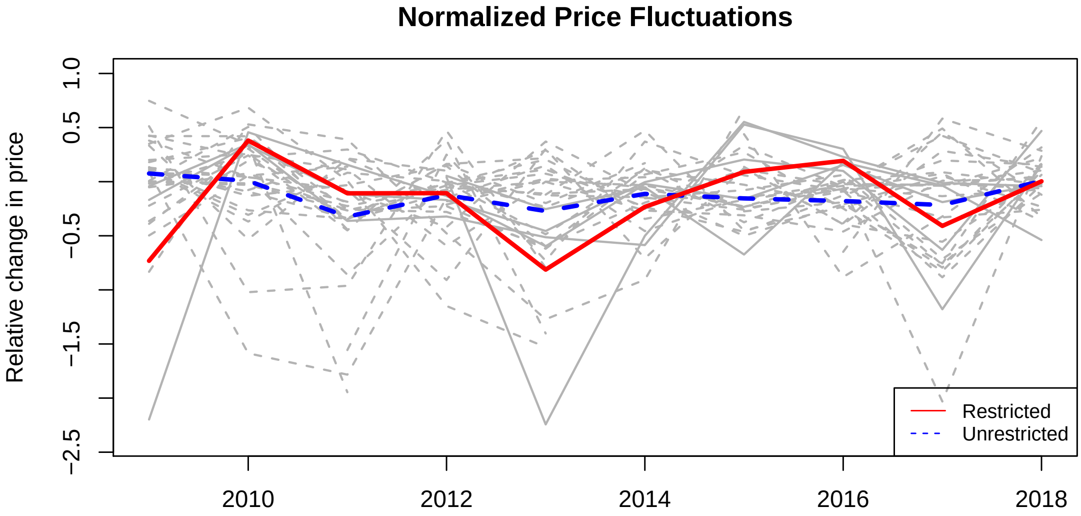

Figure A-2: Time series of relative price fluctuations for restricted species (dotted lines) and unrestricted species (solid lines). The thick lines show the development of the annual averages. Relative price fluctuations do not differ between restricted and unrestricted species ($p = 0.41$, two-sample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

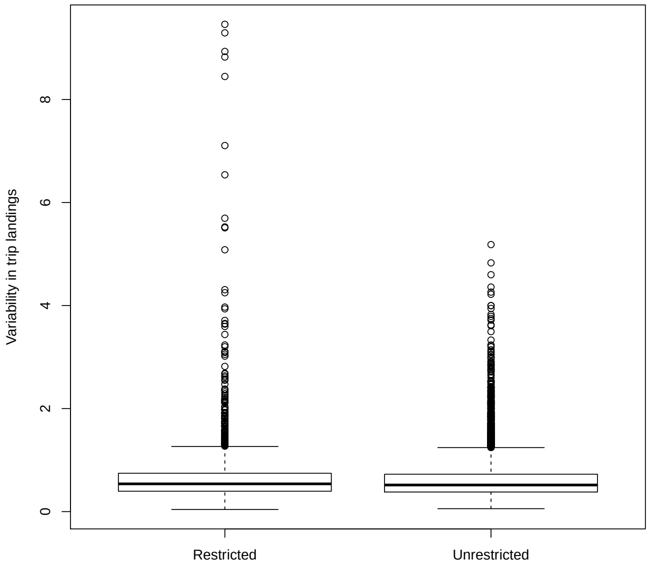

Figure A-3: Boxplot of the trip-to-trip coefficient of variation for the restricted and unrestricted fisheries. The respective averages (0.634 and 0.629) do not differ ($p = 0.59$, two-sample t-test). To arrive at the trip-to-trip coefficient of variation, we have classified each trip from the visited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

Agents are said to be prudent if their marginal utility function is convex $U'''(.) > 0$. This convexity generates a higher marginal utility for future consumption if income is uncertain. Therefore, prudent agents are more motivated to lower consumption now and generate additional precautionary savings when future income is uncertain (Leland, 1968; Sandmo, 1970). To test whether our participants have a convex marginal utility function, we use the lottery pairs designed by Eeckhoudt and Schlesinger (2006). Participants have to choose between allocating a mean-zero risk to either the good or bad outcome of another lottery, see figure A-4. The prudent option is to allocate the risk to the good outcome.[20] 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.

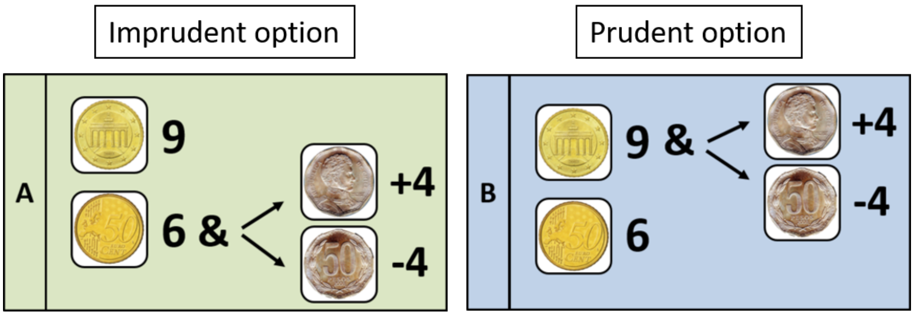

Figure A-4: The figure shows the two options participants can choose between when measuring prudence. In both options participants have to flip a coin, they receive the good outcome of 9 points when they throw heads and the bad outcome of 6 points when they throw tails. Beforehand participants make the 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 A-4. 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 A-4) or the good outcome (option B in Figure A-4). 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.

In Table A-2 we include prudence and risk-aversion as control variables jointly, see speci-

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

fication (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.

Table A-2: The table reports the OLS coefficients of specification (3) in table 3, with additional controls. Model specifications (1) (2) and (3) include prudence and risk-preference. By including prudence the sample size drops by 13, as the instructions for the elicitation task were slightly changed after the first session. Specifications (4) and (5) include the set of controls mentioned in section 5.5. Robust standard errors are clustered at the landings site level.

	Dependent variable:				
	Weeks of savings				
	(1)	(2)	(3)	(4)	(5)
Restricted (R_i)	8.77**	9.06**	8.63**	10.17	8.30
	(4.04)	(3.98)	(4.06)	(6.82)	(7.38)
Variability (V_i)	−1.40	−1.16	−1.56	0.14	0.09
	(4.74)	(4.67)	(4.73)	(5.60)	(6.48)
Restricted×Variability	15.68	15.09	16.41	15.16***	15.32**
	(17.13)	(16.98)	(17.48)	(5.44)	(6.09)
Age	1.06*	1.10**	1.13**	1.32**	1.59***
	(0.55)	(0.55)	(0.55)	(0.54)	(0.58)
Age-Squared	−0.01*	−0.01*	−0.01*	−0.01**	−0.02**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Parentshere	6.77**	6.82**	7.31***	8.48***	8.04***
	(2.72)	(2.73)	(2.71)	(1.81)	(2.19)
Prudence	−1.31	−1.33			
	(0.82)	(0.81)			
Risk preference	0.67		0.70		
	(0.89)		(0.88)		
Gender				3.31	4.06
				(3.04)	(3.00)
Children				0.62	−0.26
				(4.76)	(5.48)
% Fishing income				0.02	0.07
				(0.05)	(0.06)
City				−6.66	−7.04
				(5.35)	(4.58)
High School				1.60	2.78
				(2.33)	(2.45)
Boat Owner					−2.05
					(3.03)
Investment					−1.93*
					(1.17)
Constant	−6.73	−5.43	−13.70	−24.04***	−31.49***
	(13.07)	(12.89)	(12.35)	(6.47)	(8.71)
Observations	360	360	360	358	314
R^2	0.08	0.08	0.08	0.10	0.10
Adjusted R^2	0.06	0.07	0.06	0.07	0.06

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