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Gokhale, Sanmitra; Blomquist, Johan; Lindegren, Martin; Richter, Andries; Waldo, Staffan

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Sanmitra Gokhale, *Wageningen University & Research*; Johan Blomquist, *Swedish University of Agricultural Sciences*; Martin Lindegren, *Technical University of Denmark*; Andries Richter, *Wageningen University & Research*; Staffan Waldo, *Swedish University of Agricultural Sciences*

ABSTRACT

Managing economic risk is a challenging endeavor for fishers. One of the ways to mitigate such risk is through income diversification spanning even beyond fishing activities. However, the role of non-fishing income on risk management has been poorly understood. Here we investigate the relationship between fishing risk levels and secondary incomes by analyzing risk levels of fishers' incomes from fishing, non-fishing, and partner income sources for Swedish fisheries from 2004 to 2015. We find that fishers with a balanced share of fishing and secondary incomes have lower risk levels than fishers who primarily rely on fishing income. Both non-fishing income and partner income reduce risk levels.

Key words: Fisheries, fisheries portfolio, income diversification, livelihood diversification, risk management.
JEL code: Q22.

INTRODUCTION

Commercial fishing is a risky activity. In addition to being one of the most dangerous livelihoods (Drudi 1998), fishers face a wide array of economic risks, such as competition from other fishers, volatile market prices, varying resource abundances, and changing government regulations (Kasperski and Holland 2013; Sethi 2010; Teh et al. 2008). Furthermore, climate change has and will continue to present a major risk (Free et al. 2019), affecting fisheries in a multitude of ways (Brander 2010; Lindegren and Brander 2018; Tunca et al. 2019). Also, government actions to mitigate climate change can themselves impact fisheries. An example is offshore windfarms, which have a mixed impact on fish habitats and unclear impacts on fisheries (Snyder and Kaiser 2009; Bergström et al. 2014; Lindeboom et al. 2011). Thus, fishers face a variety of known risks and wider uncertainties. One of

Sanmitra Gokhale is a PhD candidate in the Environmental Economics and Natural Resources group, a subgroup of the Department of Economics, Wageningen University & Research, PO Box 8130, 6700EW, Wageningen, Netherlands (email: sanmitra.gokhale@wur.nl). **Johan Blomquist** is a PhD and researcher at the Department of Economics, AgriFood Economics Centre, Swedish University of Agricultural Sciences (SLU), PO Box 7080, 220 07 Lund, Sweden (email: johan.blomquist@slu.se). **Martin Lindegren** is a senior researcher with the Centre for Ocean Life, Technical University of Denmark, Kemitorvet Building 201, room 158, 2800 Kgs. Lyngby, Denmark (email: mli@aqua.dtu.dk). **Andries Richter** is an associate professor in the Environmental Economics and Natural Resources group, a subgroup of the Department of Economics, Wageningen University & Research, PO Box 8130, 6700EW, Wageningen, Netherlands (email: andries.richter@wur.nl). **Staffan Waldo** is an associate professor in the Department of Economics, AgriFood Economics Centre, Swedish University of Agricultural Sciences (SLU), PO Box 7080, 220 07 Lund, Sweden (email: staffan.waldo@slu.se).

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the key avenues for fishers to manage and adapt to these risks has been to decrease their sensitivity and vulnerability to change by diversifying their incomes via multiple sources within and outside of fisheries (Kasperski and Holland 2013; Holland et al. 2017; Perruso, Weldon, and Larkin 2005; Sethi 2010). Within fishing activities, fishers have diversified their incomes by holding a diverse set of quotas, using different gear, and fishing different target species in different regions (Sethi 2010; Kasperski and Holland 2013). Outside of fishing, some fishers have other sources of income, such as working within the tourism industry and farming. They may also rely on income from other members of their household engaged in non-fishing activities (Teh et al. 2008; Minnegal and Dwyer 2008; Smith 1988). Although the role of diversification of income through fishing activities has been well studied (Kasperski and Holland 2013; Holland et al. 2017; Perruso, Weldon, and Larkin 2005; Anderson et al. 2017), the role of non-fishing and particularly partner income diversification is largely unknown and requires further investigation.

Income diversification has been a prominent risk management method widely used in fisheries around the world (Kasperski and Holland 2013; Teh et al. 2008; Minnegal and Dwyer 2008; Sethi 2010). Literature on income diversification of fishers has typically focused on diversification within fishing activities (Sanchirico, Smith, and Lipton 2008; Edwards, Link, and Rountree 2004; Baldursson and Magnusson 1997). Perruso, Weldon, and Larkin (2005) use trip-level data of US Atlantic and Gulf of Mexico pelagic longline fleet and find that larger vessels are more likely to receive higher and more stable returns than are smaller vessels. They also point out that impacts of policies can be unevenly distributed across various segments of the fleet. Kasperski and Holland (2013) investigate income diversification among West Coast and Alaskan individual fishing vessels in the US. They find decreasing levels of diversification over 30 years, and vessels with relatively higher concentrated incomes were more likely to exit the industry than their less concentrated counterparts. They also find a concave (dome-shaped) relationship between income diversification and revenue variance. Anderson et al. (2017) use Alaskan fisheries data and find that fishers with greater species diversity in fishing permits have lower revenue risk levels. To the best of our knowledge, only one study has been conducted on risk in Swedish fisheries: Eggert and Martinsson (2004) found approximately 50% of Swedish fishers to be risk neutral, while the other 50% were considered risk averse.

While many studies have examined fishers' income diversification through various fishing income sources, only a handful of studies have also examined income diversification through non-fishing income and the role of partner income. Teh et al. (2008) conduct semi-structured interviews and mailed questionnaires with fishers, managers, and individuals in the marine recreation sector in Hong Kong. They find that small-scale fishers have more diversified livelihoods and have income diversified into non-capture fishing activities. This has allowed them to adapt better than trawl fishers who do not have any non-fishing activities. They also find that over half of the fishers are willing to leave their occupation and seek an alternate livelihood. However, lack of education, high capital investment needs, and legal/administrative barriers make it difficult to expand into alternative income options. Smith (1988) conducted interviews with New England fishers and their families and reported fishers taking excessive physical risks (such as fishing in bad weather) because of economic and regulatory pressures. She also found up to 15% of fishers having engaged in illegal smuggling of narcotics at least once to manage economic risks and protect their livelihood in fisheries. Smith (1988) also points out the role of partner income in managing economic risks within fisheries. She found that in the New England fisheries, alternative income from other members of the household (mostly women) have proven important especially in economically marginalized communities. It also served another purpose, since wages from jobs allowed the women to access unemployment benefits in tougher times. Other studies, such as Minnegal and Dwyer (2008) for Australia and Sievanen (2014) for Mexico, also point to the importance of partner and non-fishing income in managing risks. White and Scheld (2022) argue that diversification across income sources reduces risk and find that fishers in Virginia (US) have increased their diversification into other seafood industries during the 1994–2018 period. Overall, past studies have suggested that fishers use secondary sources of income (non-fishing and partner incomes) to manage their risk levels, making this income integral to their ability to adapt to economic downturns in fishing (Teh et al. 2008; Minnegal and Dwyer 2008; Leu 2019; Allison and Ellis 2001).

While quantitative studies on non-fishing income are relatively few, there is a large body of literature in agriculture on off-farm income and its relationship to income volatility. Mishra and Goodwin (1997) found that among farmers in Kansas, those who face higher income variability were more likely to engage in off-farm income-generating activities. Contrasting them, Vergara et al. (2004) found the level of income, rather than income variation, to be the main motivating factor for limited-resource farmers and their spouses to pursue off-farm income. Mishra and Sandretto (2002) examine the stability of farm income and the role of off-farm income in managing income variation. They find that off-farm income has been a major contributor to increasing net farm household wealth, such that low farm income no longer equates to low household income relative to non-farming households. They also found that off-farm income is less volatile than farm income. Key, Prager, and Burns (2018) also find that off-farm income of American farmers is relatively less volatile than farming income, while being higher than non-farm household.

Failure to properly manage economic risks can have a profound impact on the well-being of fishers and their fishing communities. Anthropological studies such as Smith (1988), policy-oriented studies such as Teh et al. (2008) and Brugère, Holvoet, and Allison (2008), as well as local case studies applying the so-called sustainable livelihood approach (Allison and Ellis 2001) have all emphasized the need for a diverse and flexible livelihood, partially including sectors and sources of income outside fishing (Allison and Ellis 2001; Coulthard 2008; Badjeck et al. 2010; Iwasaki, Razafindrabe, and Shaw 2009). However, a major void in this largely qualitative literature is that of a quantitative economic analysis on income diversification and risk. Impact of economic risks can go beyond individuals and affect entire communities as well. Examples include (but are not limited to) the economies of Faroe Islands, Newfoundland (Canada), and Greenland, which have been drastically affected by large-scale declines in cod abundance in the past (Hamilton and Haedrich 1999), or fishers in Hong Kong who saw their livelihoods threatened because of steep rises in fuel prices and lack of government regulation (Teh et al. 2008). Therefore, understanding the risks fishers face and their risk management strategies is important in discerning their capacity to adapt to economic shocks and safeguard their livelihoods.

In this paper, we examine the role of secondary income sources on fishers' total income risk exposure. We analyze risk, that is, variations of income, by calculating each fisher's portfolio risk and coefficient of variation using available data on Swedish fishermen between 2004 and 2015. Our case study aims to disentangle total risk exposure of Swedish fishers to understand how two secondary income sources, namely non-fishing income and partner income, may mitigate the overall risks that fishing households encounter, while accounting for regional and fishery-specific differences. By including both non-fishing and partner income in the analysis, our study gives a more comprehensive understanding of income diversification among fishing households. Overall, our findings suggest that both non-fishing and partner incomes play important roles in reducing the total risk that fishers' households are exposed to.

BACKGROUND ON SWEDISH FISHERIES AND DATA SOURCES

For our analysis, we collected and analyzed a unique dataset of fishing and non-fishing incomes and activities of Swedish fishermen and their households between 2004 and 2015. During that period, Swedish fisheries were active in both the Skagerrak/Kattegat and the Baltic Sea. Economically important fleet segments are fisheries for shrimp (*Pandalus borealis*) and Norwegian lobster (*Nephrops norwegicus*) in the Skagerrak/Kattegat using trawl or creel and fisheries for cod (*Gadus morhua*) in the Baltic Sea using trawl or gill nets. Other fisheries include vendace (*Coregonus albula*) fishing in the northernmost parts of the Baltic Sea, and fisheries for European eel (*Anguilla anguilla*), which takes place in both the Baltic and the North Sea.[1] Although the above are the main species, many fishers combine this with seasonal fisheries for other species, such as herring, mackerel, pike-perch, and turbot. Since Sweden is a member of the European Union fisheries are regulated within the Common Fisheries Policy (CFP; EU 2013). Swedish management has not adopted a single system for fisheries regulation under the CFP framework. Instead, the regulations vary between different types of fisheries using licenses for restricting access to the industry, input-regulating measures such as gear restrictions, and (often short-term) nontransferable individual fishing quotas. Thus, fisheries regulation for the studied fishers can be described as regulated open access that differs among different fisheries. In this system it is possible for most fishers to target multiple species, but it can be difficult to change species composition to completely new species because of regulations restricting access (and it was not possible to buy quotas since no system with individual transferable quotas [ITQs] was in place), and many fishers find their possibilities to switch between species restricted (Waldo et al. 2020). For example, in the Baltic Sea fishery along the Swedish south coast, fishers have traditionally altered between cod, herring, eel, and salmon. However, both the eel and the salmon fisheries are strictly regulated and are not an option for most fishers. When the coastal cod fishery has been impacted by seals predating from the nets, many fishers chose to exit the industry rather than fishing for alternative species (Blomquist and Waldo 2021). With fisheries regulations restricting the choice set available to reduce risk by diversifying within fisheries, alternatives outside the fishing sector are important.

We obtained annual labor market and household characteristics data between 2004 and 2015 for all Swedish fishers from the Swedish Longitudinal Integrated Database for Health Insurance and Labour Market Studies (LISA) database from Statistics Sweden (https://www.scb.se/en/LISA). This source includes data on fishers' earned income from different industries,[2] income transfers from social security systems, and their partner income. From these data we define non-fishing incomes as an individual's total income minus income from the fisheries sector. The number of individuals receiving income from fisheries has fluctuated between 1,336 and 1,782 during this period. We also obtained the following demographic characteristics: age, children, educational level, and marital status. The variable *children* takes a value of 1 if children under age 18 are present in the household. To include education, we include a categorical variable capturing three levels of education: (1) basic level (9 years of compulsory school), (2) high school education (10–12 years of education), and (3) university level (>12 years of education). To achieve a detailed understanding of fishing activities, we obtained logbook data of Swedish fishers from the Swedish Agency for Marine and Water

1. More on catches, gear technology, and fleet segment economics in Swedish fisheries is available in Bergenius et al. (2018) and Waldo and Blomquist (2020).

2. The classification of fishing and non-fishing earnings is based on the Swedish Standard Industrial Classification system (SNI codes).

Management (https://www.havochvatten.se) consisting of revenues from various fisheries for each individual fisher (license holder), along with information on the vessels and gear. This implies that employed fishers not holding a fishing license are excluded from the sample. The number of license holders has varied between 1,049 (in 2004) and 856 (in 2015) during the time period. As we are only interested in license holders who have the decision authority over the catch portfolio, we decided to exclude large pelagic vessels (>24 meters targeting herring, sprat, and mackerel), which are typically owned by larger companies and have a more complex decision structure. In total, 51 pelagic license holders were excluded from the sample, thus leaving a sample of demersal vessels (targeting cod, Norwegian lobster, etc., as discussed above). We also omit individual fishers who are not present in both (LISA and logbook) databases[3] and who are not frequently engaged in fishing activities (i.e., with reported catches and fishing incomes in a minimum of four years during the period 2004–15). The final sample consist of 721 fishers. Among them, 12% land only one species per year, while 68% land five or fewer species. From the logbook data, we retrieve information on catch quantity and species composition. To convert catches to revenues, we used average landing price per species and year (gathered from the Swedish Agency for Marine and Water Management). The labor market data from the LISA database are given in earned income. To obtain income shares coming from different fisheries, we calculated the share of revenues from each species out of the total revenues and then multiplied that with total income from fishing.[4]

MEASURING RISK AND INCOME DIVERSIFICATION

We use portfolio risk and the coefficient of variation (CV) as our measures for economic risk the fisher faces. CV is the ratio between the standard deviation and the mean. The benefit of using CV is that it is a simple, standardized way of measuring risk.[5] As it infers risk exposure through variation over time, CV is a measure that does not itself vary over time, but it does vary between individuals. A key drawback of CV is that it does not explicitly capture the variations *between* income sources. In a fisheries case, CV will measure the ratio of the standard deviation of a fisher's total income and the mean income over time. However, it will not take into account the relationship between their incomes from the various fish stock they harvest or the various non-fishing income they may have. Thus if two fishers have the same total incomes for each year, their CVs will be identical since the mean and standard deviation of the total incomes—the components required to calculate the CV—will be the same. One fisher may be entirely reliant on a single stock for all their income, while another fisher may harvest several stocks and have non-fishing income. However, because their net incomes may be similar within our data, their CVs will be similar as well. In such cases, the CV provides an ex post outcome of the risk in the sample period, but it does not provide an understanding of the underlying drivers of income variation. If two or more sources of income (such as two fish stocks) are highly correlated, they can be susceptible to similar shocks. However, if they are uncorrelated, minimally correlated, or negatively correlated, one income source can act

3. Workers on fishing vessels are an example of individuals who would get income from fishing, thus appearing in the LISA database but not present in the logbook.

4. For example, if a fisher has €100,000 in total revenues out of which €30,000 are from cod in the landings dataset, his share of revenues from cod will be 30%. We then calculated 30% of total income the fisher earned from fisheries (reported in the LISA data) and assigned that as income from cod. This calculation makes the implicit assumption that costs are similar across various fisheries.

5. Sethi and Dalton (2012) highlight some of the limitations of using CV as a risk measure, and they suggest other risk measures suitable for risk management of natural resources, such as semi-deviation, conditional value at risk, and probability of ruin. Still, we use CV as a simple risk metric in addition to portfolio risk, which is more complex.

as a counterbalance to another.[6] The CV cannot be used to explore such relationships between income sources. Incomes from different fisheries are also likely to face similar risk factors (ecological, regulatory, etc.) as compared with a combination of fishing and secondary incomes, especially those of small and medium-sized fishers. The discussion above suggests that it may be useful to supplement CV with another metric that explicitly accounts for the covariance between various sources of income. Portfolio risk takes into account the covariance between various income sources in its calculation. It also varies between individuals and over time. We build up the portfolio risk metric based on modern portfolio theory (Markowitz 1952), while adapting it for the fisheries case and our data. Risk within fisheries has been analyzed in the literature using the portfolio approach, but only within fishing incomes and at a fisheries level rather than at an individual level (Sanchirico, Smith, and Lipton 2008; Edwards, Link, and Rountree 2004; Baldursson and Magnusson 1997). Previous studies have also not taken into account any sources of secondary incomes, which is a focus of our work. However, using portfolio risk has a few drawbacks. It requires additional assumptions regarding setting a benchmark of potential return. Nevertheless, both metrics provide an insight into the economic risk level of a fisher: CV gives more of a snapshot into the current risk, while portfolio risk can speak more toward the future robustness to shocks. As a result, we opt to use both CV and portfolio risk in our analysis.

INCOME DIVERSIFICATION

Individual fishers can have incomes from harvesting various fish stocks, engaging in non-fishing income activities, and having other members of their household generating income. We define non-fishing income (NFI) as the income a fisher earns from activities outside of fishing. We also define partner income (PI) as the income generated by members of the household *excluding* the fisher. PI could also include other members of the household, such as any income earned by a child, though in practice it will usually consist of partner income. We define secondary income sources as partner income and non-fishing income (PI + NFI). We define total household income (TI) as the fishing income, non-fishing income, and partner income combined; that is, the total income earned in the household *including* that of the fisher. Thus, the total income from a fisher's household can be represented as follows:

$$\mathrm{TI}_{kt} = \left[\sum_{i=1}^{n} \mathrm{FI}_{ikt}\right] + \mathrm{NFI}_{kt} + \mathrm{PI}_{kt}, \tag{1}$$

where TI_{kt} is the total household income of fisher k at time t, FI_{ikt} is the fishing income of fisher k from fish species i at time t. NFI and PI are non-fishing income and income from other members of the household. There might be cases where a fisher or their household has more than one source of non-fishing income (such as if a fisher has two part-time jobs in addition to fishing or a partner has income from multiple businesses/jobs). Our data do not allow us to disaggregate non-fishing income or partner income into its various smaller income streams. While fishing income is disaggregated to include income from harvesting various fish stocks, non-fishing income and partner income are aggregated values and act as singular sources of income. This is reflected in equation 1, where FI is a summation of income from various fish stocks while NFI and PI are singular values for each fisher. Finally, while we do not have data for the quota that

6. We present a stylized numerical example in online appendix table A3.

each individual fisher holds, we assume that a fisher has the ability to adjust their portfolio based on any fish stock they have fished in our time frame.

COEFFICIENT OF VARIATION AND VARIANCE DECOMPOSITION

Our data include fishers from different parts of Sweden with a wide range of incomes. To ensure a standardized comparison of income variability at the individual level, we calculate CV as follows:

$$\mathrm{CV}_k = \frac{\sigma_k}{\mu_k}, \tag{2}$$

where CV_k is the coefficient of variation of income for individual k, σ_k is the standard deviation of income, and μ_k is the mean income. In addition to the CV, we decompose the variance of the total income into its parts, where Var(TI) = Var(FI + NFI + PI). Thus, we get three variance terms and three covariance/correlation terms, showing the relationship between the three sources of income. This approach allows us to gain a deeper insight into the source of the variance in a similar manner to Mishra and Sandretto (2002). To ensure a standardized comparison of income variability at the individual level, it is also relevant to look at the CV. In doing so, the variance components have been normalized using the mean of total income. For example, the non-fishing income component is obtained as $\widehat{\mathrm{CV}}_{\mathrm{NFI}} = \sqrt{\mathrm{Var(NFI)}}\,/\,\mu_{\mathrm{TI}}$. The mean of total income is used in the denominator to make the three CV measures more comparable on a fisher-household level.

PORTFOLIO RISK

Portfolio risk is based on expected returns on an asset. In financial markets, the market capitalization of a company provides a rough estimate of the total value of the company, and the expected return from an asset is calculated based on historical prices of the asset. However, it is difficult to calculate the expected returns from fishing or labor income in a similar way. For fishing, the fish stock can be viewed as the asset utilized by fisheries for generating income streams. The return from fishing is the income (revenues minus costs) earned by the fishers. The present value of future income streams could in theory be used to calculate the value of the fish stocks. However, in the empirical data we do not know which part of the fishing income stems from which stock. As a result, we cannot directly estimate the value of a stock utilized by a fishery or directly calculate a rate of return. To resolve this issue, we allocate fishing income based on revenues per stock (which is known on stock level by using landings times average prices) such that if a fisher has 50% of revenues from a stock we assume that 50% of income is also from the stock. The fishing income from each stock and year is used to calculate the net present value (NPV) of income from each stock as follows:

$$S_{it} = \sum_{k=1}^{m} \mathrm{FI}_{kit}, \tag{3}$$

where S_{it} is the total income from fish stock i at year t, FI_{kit} is the fishing income (FI) of fisher k from stock i at year t. The total value of each fish stock is calculated using the formula $\mathrm{NPV}_i = \overline{S_i}/r$, where $\overline{S_i}$ is the average total income of (stock) i across our entire time period and r is the discount rate.[7] Then, we calculate return from each fish stock as annual income divided by the value of fish

7. We assumed a discount rate of 10%, which is on the high side, though not unreasonable for evaluating private income streams. Note that the discount rate is only used to calculate potential returns of alternative economic activities, so applying the same discount rate across activities and fishers is only affecting the overall scale of the NPV.

stock, that is, S_{it}/NPV_i. This gives us something akin to a dividend, where we calculate returns as the income a fish stock generates relative to its estimated total value. The variation in the return from the fish stocks (σ) is used to calculate the fishing portfolio risk (FPR) as follows:

$$\mathrm{FPR}_{kt} = \sqrt{\sum_{a=1}^{n}\sum_{b=1}^{n} w_{akt} w_{bkt} \sigma_a \sigma_b \rho_{ab}}, \tag{4}$$

where w_{akt} and w_{bkt} are weights of fishing income from each stock (where $a, b = 1, 2, \ldots, n$) for fisher k at time t. The weights are calculated as income of stock a for fisher k in time t divided by total fishing income for fisher k in time t. The σ_a and σ_b are the standard deviation of returns of each stock, and ρ_{ab} is the correlation coefficient between the returns from different stocks. From equation 1, we have n fish stocks that are the possible fishing income sources for the FPR measure.

An entire risk profile of a fisher would include the non-fishing and partner incomes. To understand the role of non-fishing and partner income in a fisher's total household income risk, we calculate three sets of portfolio risks: (1) portfolio risk of income from fishing activities alone (FPR above), (2) portfolio risk of fishing and non-fishing activities, and (3) portfolio risk that includes fishing, non-fishing, and partner income activities. As described below, to calculate these measures, we treat non-fishing and partner incomes in a similar way as returns from fish stocks. In the calculations, we account for region-specific differences by dividing the fishers into three regions—east, west, and south—based on the counties they live in (see online appendix table A2). Thus, we calculate total non-fishing income (NFI) and partner income (PI) as follows:

$$N_{pjt} = \sum_{k=1}^{m} I_{kpjt}, \tag{5}$$

where N_{pjt} is the total income from secondary income source p (either NFI or PI), from region j in the year t. I_{kpjt} is the total income from secondary income source p (either NFI or PI), of fisher k, from region j in the year t. We calculate total portfolio risk (TPR), which includes non-fishing and partner income in addition to fishing income, in the following manner. We calculate the expected return on NFI and PI as $N_{pjt}/\mathrm{NPV}_{pj}$, where N_{pjt} (from equation 5) is total annual income of income source p (either NFI or PI), from region j, at year t. NPV_{pj} is the net present value of income source p (either NFI or PI) in region j. Similar to above, the NPV_{pj} is obtained as $\mathrm{NPV}_{pj} = \bar{N}_{pj}/r$, where $\bar{N}_{pj}$ is the average total income of income source p in region j across our entire time period, and r is the discount rate. Then, TPR is calculated as follows:

$$\mathrm{TPR}_{kt} = \sqrt{\sum_{a=1}^{n+2}\sum_{b=1}^{n+2} w_{akt} w_{bkt} \sigma_a \sigma_b \rho_{ab}}. \tag{6}$$

Compared with equation 4, we have n fish stocks that are the possible fishing income sources, and we add two more sources of income, namely non-fishing income and partner income—thus having the summation end at $n + 2$. The portfolio risk of fishing and non-fishing activities is obtained in the same way, but excluding partner incomes.

EMPIRICAL MODEL

One of the primary goals of this paper is to understand whether diversifying fishing income with non-fishery and partner income reduces income risk. To analyze this question, we estimate the relationship between fishers' CV and the share of their total income originating from non-fishing income, partner income, and fishing income. However, as these variables sum to 1 by definition, a linear regression model including all of them as explanatory variables would suffer from collinearity problems. Moreover, since one variable (e.g., share of total income from partner income) can only increase in relative terms if some other(s) decrease, estimated (beta-) parameters of the linear regression model cannot be interpreted in the traditional way (i.e., keeping all other variables constant).

When dealing with compositional explanatory variables, one typically considers ratios between the compositional parts (i.e., the income shares in our case) rather than the income shares directly. A common way of specifying a regression model with such explanatory variables is the additive log-ratios model (see, e.g., Greenacre 2021). For fisher k, define SNFI_k, SPI_k, and SFI_k as the share of total income originating from non-fishing income, partner income, and fishing income, respectively. The so-called log-contrast regression model (Aitchison 1982; Aitchison and Bacon-Shone 1984) is formulated as follows:

$$\log_2(\text{CV}_k) = \beta_0 + \beta_1\log_2(\text{SNFI}_k) + \beta_2\log_2(\text{SPI}_k) + \beta_3\log_2(\text{SFI}_k) + \epsilon_k, \tag{7}$$

where CV_k is the coefficient of variation for fisher k, and ϵ_k is an i.i.d. error term. The regression is implemented with the restriction ($\beta_1 + \beta_2 + \beta_3 = 0$) to capture the fact that a variable can only increase its relative importance if others decrease. The $\log_2$ transformation is used to ease interpretation of the estimated coefficients, as it shows the effect of doubling the ratio of shares (e.g., Müller et al. 2018). For example, if $\beta_1 = -0.05$, CV decreases with 3.5% ($2^{0.05}1 = 0.035$) when the ratio between SNFI_k and each of the other two income sources doubles.[8] We also include a vector of control variables, X_k, in the regression model including demographic characteristics, number of vessels, and region dummies.

RESULTS

Our final dataset contains 721 individual fishers, fishing 70 species of fish, from 2004 to 2015. Among them, 691 (96%) had some non-fishing income (>0 in one year out of all their years recorded). A somewhat lower number, 599 (83%), have partner income and 574 (80%) have both sources of income. Overall, all but five individuals have some form of secondary income (either non-fishing, partner, or both), showing that incomes from other sources are commonplace among Swedish fishers. Summary statistics of the data can be found in table 1. The average Swedish fisher is around 52 years of age and owns around one vessel (1.21 vessels). The average non-fishing income is about 20.5% of the total household income while partner income is 36.7%, with the rest (42.8%) being fishing income. These numbers have been almost constant over time (not reported here).

Table 1 also separates the data based on whether a fisher's fishing income constitutes greater than 75% of their total income as compared with fishers as a whole. We find that the average individual with a majority of income from fishing is almost four years younger (48.48 years vs. 52.44 years) and has higher fishing income (€22,280 vs €15,867). However, their total household income is lower (€25,300 vs. €38,980), and their average risk level measured as CV is higher.

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8. The model is estimated with constrained least squares (implemented in Stata 17 using the *cnsreg* command). We refer to Coenders and and Pawlowsky-Glahn (2020) and Greenacre (2021) for a more in-depth discussion of compositional regression models.

Table 1. General Summary Statistics

	All Observations (N = 6,088)			Fishing Income > 0.75 (N = 699)		
	Mean	Median	SD	Mean	Median	SD
Risk measures						
Coefficient of variation (CV)	0.304	0.257	0.187	0.382	0.366	0.182
Fishing portfolio risk (FPR)	0.025	0.021	0.012	0.026	0.022	0.011
Total portfolio risk (TPR)	0.016	0.016	0.010	0.024	0.021	0.011
Variables						
Age (years)	52.44	53.00	12.03	48.48	48.00	9.036
Children – D	0.289	0	0.453	0.057	0	0.232
Married – D	0.555	1	0.497	0.067	0	0.251
Elementary school – D	0.528	1	0.499	0.382	0	0.486
High school – D	0.385	0	0.487	0.516	1	0.500
University – D	0.088	0	0.283	0.102	0	0.302
Number of vessels	1.210	1	0.452	1.263	1	0.516
Large scale – D	0.214	0	0.410	0.243	0	0.429
Small scale – D	0.786	1	0.410	0.757	1	0.429
Region east – D	0.261	0	0.439	0.318	0	0.466
Region south – D	0.273	0	0.445	0.237	0	0.426
Region west – D	0.467	0	0.499	0.445	0	0.497
Fishing income (FI) (€ 000)	15.87	12.32	13.53	22.28	19.63	16.99
Non-fishing income (NFI) (€ 000)	6.989	3.650	8.870	1.833	0.130	3.922
Partner income (PI) (€ 000)	16.12	14.27	16.43	1.192	0	4.635
Total household income (TI) (€ 000)	38.98	35.89	22.79	25.30	21.68	19.12
Percentage of total income						
Fishing income (FI)	0.428	0.405	0.241	0.885	0.881	0.082
Non-fishing income (NFI)	0.205	0.137	0.201	0.080	0.060	0.076
Partner income (PI)	0.367	0.402	0.227	0.035	0.000	0.062

When we look into the distribution of fishers' total household income coefficient of variation and fishing portfolio risk, we see that they are skewed to the right (figure 1). The figure shows that the fishing portfolio risk measure is quite similar between the two groups of fishers. However, this is not the case for the CV risk measure, which also considers non-fishing and partner income. The majority of fishers with $FI/TI < 0.75$ have a CV below that of 0.5, which is in contrast to fishers with fishing income above 75% of their total income.[9] This group has their CV distributed more evenly, between 0 and 1, which suggests that secondary incomes may reduce total income volatility. The average CV for fishers with $FI/TI \leq 0.75$ is 0.292 with a 95% confidence interval of [0.278, 0.307].[10] The corresponding value for fishers with $FI/TI > 0.75$ is 0.369 with a 95% confidence interval of [0.330, 0.411].

The distribution of CVs shows us an overall spread of risk between these groups, but it does not speak to the change in risk over time. In order to gain insight into how income risk has changed over the time period and to see the influence on risk based on the secondary income sources, we also plot the average portfolio risk for each year (figure 2). It shows how four income portfolios—FI, NFI, PI, and TI—change over our time period. We see a large risk reduction with

9. While is not a formal categorization of CV and risk levels, we suggest that a CV at 0.3 or below indicates a low risk level; values between 0.3 and 0.6 indicate a medium risk level; and values between 0.6 and 1 indicate a high risk level. Values beyond 1 indicate that the income standard deviation is higher than the mean and the fisher has an extremely volatile income; that is, the risk levels are extremely high.

10. The confidence intervals are estimated with nonparametric bootstrap (Efron and Tibshirani 1994) with 1,000 replications.

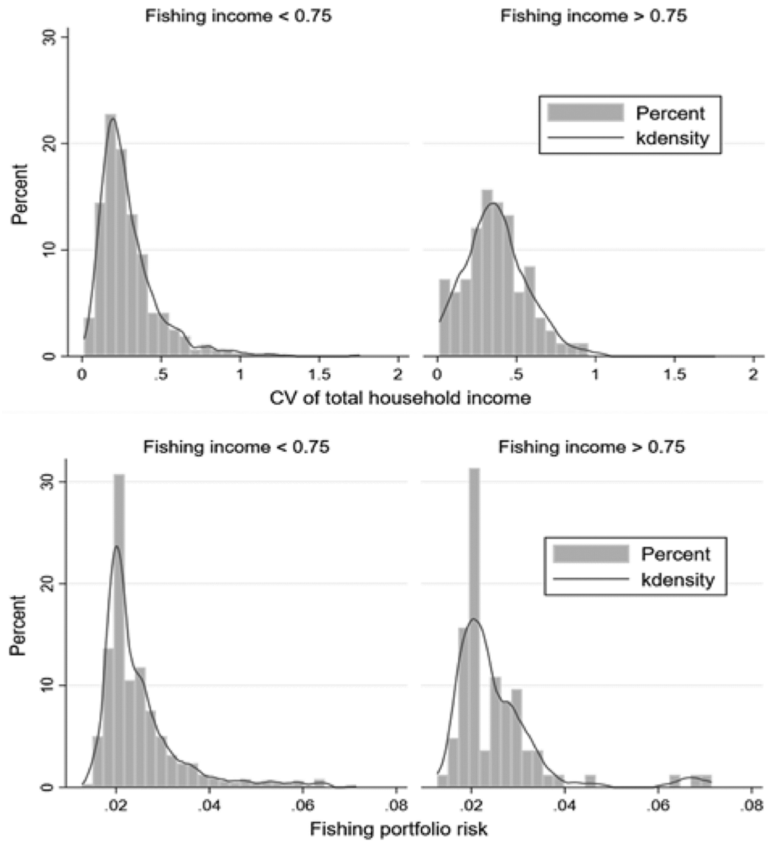

Figure 1. Distribution of Coefficient of Variation (CV) of Fishers' Entire Household Income (TI) and Fishing Portfolio Risk by Whether a Fisher Has FI/TI > 0.75

the addition of non-fishing income, and an even larger reduction of risk when partner income is accounted for, suggesting that partner income may have a large role to play in reducing total household risk levels. A possible explanation of the difference in the impact of the two is the relative weightage of each type of secondary income to the total household income (approximately 20% for non-fishing vs. 37% for partner income). We suspect partner income is also likely to be more stable—especially if the partner receives a fixed wage—as compared with fishing income, which is more volatile.

We also expect small-scale fishers and large-scale fishers to have different risk profiles (table 2). Small-scale fishers are regulated differently, typically use different types of gear, and have a lower fishing capacity than large-scale fishers. Large-scale fishers generally show a lower fishing portfolio risk than small-scale fishers and thus have different risk exposure (figure 3). In the studied time period, we see their risks converging, with larger vessels increasing their portfolio risk and smaller vessels decreasing (on average). This trend is especially pronounced from 2008 onwards. A possible explanation for the convergence is the decreasing biomass of commercial-sized cod (≥35 cm) in the Baltic Sea after 2008 (ICES 2019). A close examination of the portfolio weights of the different species (w_{akt} in equation 4) shows that the dependence on cod has decreased for both small-scale and large-scale vessels (results not shown). For the small-scale vessels, this has implied a more diverse

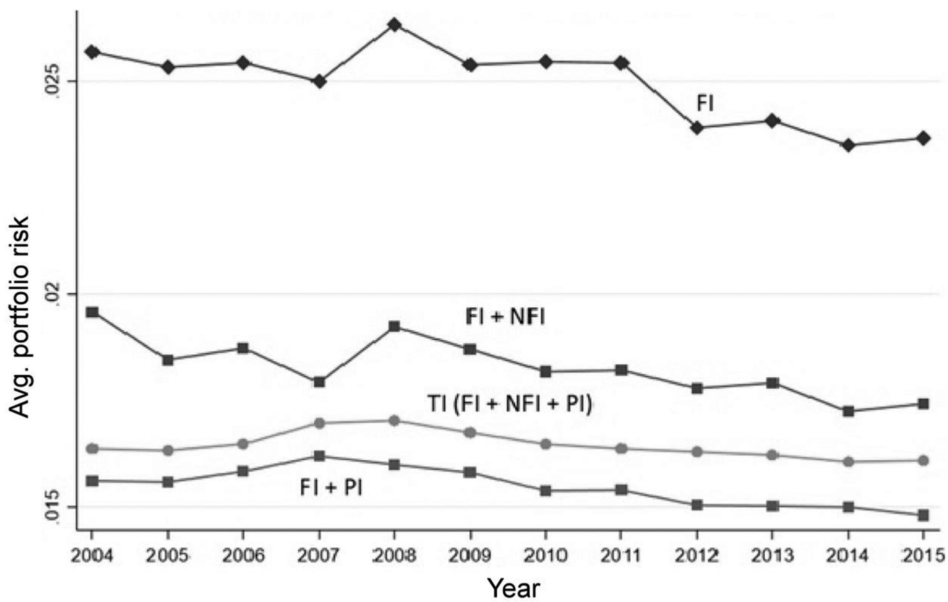

Figure 2. Average Portfolio Risk over Time. The portfolios include those with only fishing income (FI), fishing and non-fishing income (FI + NFI), fishing and partner income (FI + PI), and fishing, non-fishing, and partner income (TI). Portfolios which include partner income show a significantly lower portfolio risk than others.

fishing portfolio as cod catches are no longer the single most important source of revenue. For large-scale vessels, which are more dependent on crustaceans (Norwegian lobster and northern prawn), the lower revenue from cod has further increased the dependence on crustaceans, which has increased the fishing portfolio risk measure. Furthermore, a number of fisheries management reforms, such as the introduction of an ITQ system for pelagic species (which also affected fleet segments outside the system) and a scrapping program for cod trawlers, were introduced in 2008 and 2009 (Blomquist and Waldo 2018; Waldo et al. 2013). An in-depth analysis of which factors have causally affected the fishing portfolio risk is beyond the scope of this paper.

The variance decomposition of total income (TI) is given in the top panel of table 3. As before, the average values of the various variance components (variance, covariance, and correlation) are presented for two groups: fishers with $FI/TI > 0.75$ and fishers with $FI/TI \leq 0.75$. When it comes to the correlation coefficients (ρ), the table indicates (**) whether they are statistically significant different from zero at the 5% level. Table 3 shows that there is a negative covariance/correlation between fishing and non-fishing incomes, which is expected as individuals divide their working time between different activities. The estimated covariance/correlation between fishing and partner incomes is positive but much smaller in magnitude. In fact, the average correlation coefficients (ρ(FI, PI)) between FI and PI are statistically insignificant from zero at the 5% level.

We also see that the total variance is lower for fishers with $FI/TI > 0.75$. However, as their income levels are also lower, their CV is higher. The bottom panel of table 3 displays the different CV terms, in which the standard deviation terms have been standardized with total income.[11] Looking first at the group of fishers highly dependent on fishing income, we see that their CV component for

11. To be comparable between the two groups, the average CV terms are calculated including only fishers with nonzero incomes.

Table 2. Mean Values for Vessel Size and Region

	Vessel Size		Region		
	Large Scale (>12 m) (N = 1,303)	Small Scale (<12 m) (N = 4,785)	East (N = 1,590)	South (N = 1,656)	West (N = 2,842)
Risk measures (mean values)					
Coefficient of variation (CV)	0.302	0.305	0.340	0.301	0.286
Fishing portfolio risk (FPR)	0.021	0.026	0.026	0.022	0.026
Total portfolio risk (TPR)	0.017	0.016	0.019	0.013	0.017
Income variables (mean values) (€)					
Fishing income (FI)	23,919	13,678	13,628	13,318	18,601
Non-fishing income (NFI)	4,976	7,535	6,753	7,085	7,064
Partner income (PI)	18,205	15,557	13,707	14,787	18,251
Total household income (TI)	47,100	36,771	34,088	35,190	43,915
Percentage of total income (mean values)					
Fishing income (FI)	0.511	0.405	0.438	0.404	0.436
Non-fishing income (NFI)	0.128	0.226	0.218	0.226	0.186
Partner income (PI)	0.360	0.369	0.344	0.370	0.378

fishing income is significantly higher than the CV terms for secondary incomes. This is in contrast to the group of fishers with $FI/TI \leq 0.75$, where the CV terms of fishing income and partner income are of similar magnitudes, suggesting that fishers with a balanced share of fishing and secondary incomes have lower risk levels.

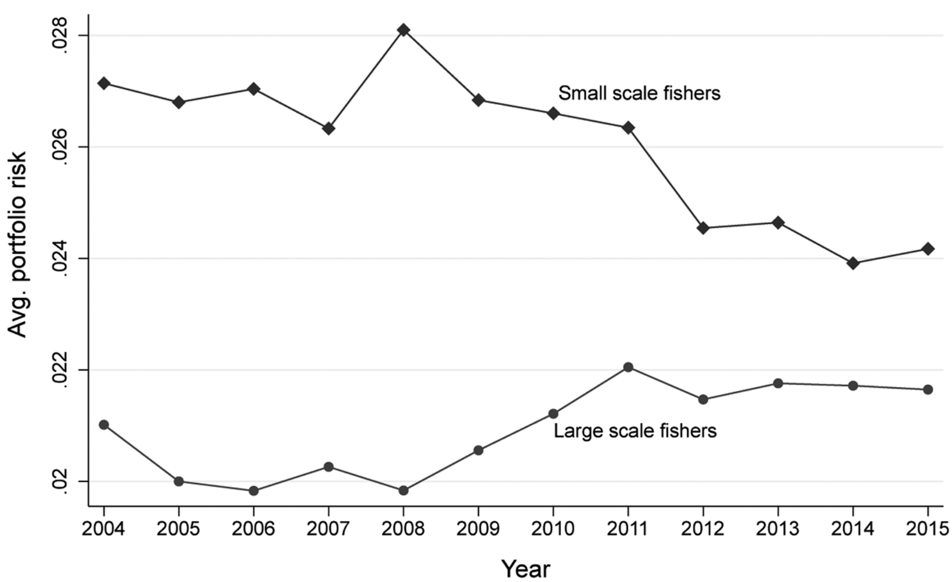

Figure 3. Fishing Income Portfolio Risk across Time Based on EU Vessel Classification. Small-scale fishers are those that have vessels smaller than 12 meters in length. All other fishers are large-scale fishers. Large-scale fishers have a lower fishing portfolio risk across time, although their risk has been trending upwards since 2008. Similarly, small-scale fishers have a higher portfolio risk, although it is generally trending downward.

Table 3. Variance Decomposition of Total Income (averages across fishers)

	Fishers with FI/TI ≤ 0.75 (N = 638)	Fishers with FI/TI > 0.75 (N = 83)
Variance terms (€ 000)		
σ^2 (FI)	57,147	120,835
σ^2 (NFI)	34,666	16,897
σ^2 (PI)	130,863	15,633
2σ (FI, NFI)	–19,992	–18,073
2σ (FI, PI)	1,999	959
2σ (NFI, PI)	2,895	253
σ^2 (TI)	199,385	136,504
Correlation coefficients		
ρ(FI, NFI)	–0.155**	–0.124**
ρ(FI, PI)	0.025	0.098
ρ(NFI, PI)	0.041	0.056
CV terms (normalized with TI)		
$\widehat{CV}_{FI}$	0.156	0.350
$\widehat{CV}_{NFI}$	0.119	0.116
$\widehat{CV}_{PI}$	0.200	0.204
$\widehat{CV}_{TI}$	0.292	0.369

Note: The term σ^2 is the average variance of the three income components—fishing (FI), non-fishing (NFI), and partner (PI)—across all individuals. The term 2σ (A, B) is the average of two times the covariance between income sources A and B. The term ρ(A, B) is the correlation coefficient between income sources A and B. CV: coefficient of variation. TI: total household income. ** $p < 0.05$.

The results so far suggest that secondary income sources may play a role in reducing total risk levels (as measured by CV). To further understand the relationship between total risk levels and secondary income sources, we estimate the log-contrast regression in equation 7. The results are presented in table 4. Column 1 shows the results without additional explanatory variables, and in column 2 various fisheries-related explanatory variables have been included in the regression. Column 3 shows the results with additional demographic variables. Looking at the first column, we see a positive relationship between income variability and the share of income originating from fishing. More specifically, when the ratio between the fishing income share and the secondary income sources doubles, CV increases with 6.3% ($2^{0.0875} - 1$). The coefficients on both secondary income sources (non-fishing and partner incomes) are negative and statistically significant at the 5% level, indicating that they both are associated with lower total risk levels. To put this result in perspective, the share of fishing income is on average 0.43 (see table 1), and doubling the ratio between fishing and secondary incomes implies an increase from 0.43 to around 0.6. In other words, increasing dependency on fishing incomes from 0.43 to 0.6 is associated with a 6.3% increase in income variability as measured by the CV.

The results in column 2 show that the same conclusions hold when controlling for fisheries-related explanatory variables. Thus, the positive relationship between the CV and the share of income originating from fishing cannot be explained by region of fishing, number of vessels, and whether the fishing activity is small scale or large scale. When demographic variables are added as controls, the coefficient on fishing income decreases in magnitude but is still positive and statistically significant. The negative coefficients on marital status and age in column 3 suggest that these factors reduce

Table 4. Impact of Income Sources on Total Risk – CV (including fishing income, non-fishing income, and partner income)

	CV – Total Income (1)	CV – Total Income (2)	CV – Total Income (3)
Share of non-fishing income	–0.0392***	–0.0431***	–0.0078
	(0.0148)	(0.0154)	(0.0160)
Share of partner income	–0.0483**	–0.0492**	–0.0412*
	(0.0233)	(0.0238)	(0.0231)
Share of fishing income	0.0875***	0.0923***	0.0490**
	(0.0214)	(0.0216)	(0.0217)
Small-scale vessels – D		0.0408	0.0173
		(0.0793)	(0.0805)
Region south – D		–0.134	–0.191*
		(0.0994)	(0.0989)
Region west – D		–0.200**	–0.236**
		(0.0925)	(0.0930)
Number of vessels (2) – D		–0.100	–0.0722
		(0.0932)	(0.0893)
Number of vessels (3) – D		–0.222	–0.339
		(0.210)	(0.236)
Number of vessels (4) – D		0.0522	0.0390
		(0.0623)	(0.0784)
Age			–0.0157***
			(0.00410)
Children – D			–0.0330
			(0.0872)
Married – D			–0.144*
			(0.0816)
High school – D			0.0830
			(0.0727)
University – D			0.149
			(0.131)
Constant	–2.074***	–1.958***	–0.961***
	(0.0439)	(0.107)	(0.267)
Number of observations	574	574	574

Note: Column 1 shows the results without additional explanatory variables. In column 2, various fisheries-related explanatory variables have been included. Column 3 shows the results with additional demographic variables. Standard errors are shown in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

income variability. Marital status is correlated with partner income, which could explain the loss in statistical significance of the partner income variable.

DISCUSSION

Commercial fishing is a challenging and economically risky business. Fishers must navigate a wide array of economic risks, many of which are entirely beyond their control, such as prices, health of fish stocks, and changing regulations (Kasperski and Holland 2013; Sethi 2010). Some of these risks arise because of the uniqueness of fish as a natural resource and its weak property rights. Additionally, fishers do not have access to all the risk management tools that other natural resource producers have (Kasperski and Holland 2013). This makes risk management a difficult, but critical, task for fishers.

Income diversification is a key tool for risk management across natural resource sectors (Alobo Loison 2015; Leu 2019; Allison and Ellis 2001). In this paper we analyzed the role of secondary income sources in fishers' total household risk levels. We found that almost all Swedish fishers have some form of secondary incomes (partner or non-fishing income) that support their households. On average, fishers with a balanced share of fishing and secondary incomes have lower risk levels than fishers who primarily rely on fishing income.

The regression results show that partner and non-fishing incomes reduce income variability by similar magnitudes. However, qualitatively these two secondary income sources are very different and likely to have differing underlying risk factors. While fishing income is an owner-operated business, partner income may include a partner owning their own business, working part-time/seasonal jobs, or holding full-time, stable jobs with predictable income. As a result, while the volatility of a partner's income might in some cases be similar to fishing income, both the income's resilience in face of an economic shock and the kind of economic risk the two income sources are exposed to are likely to be different. This is evident from the variance decomposition showing small and statistically insignificant correlation between fishing income and partner income.

Non-fishing income, on the other hand, relates to earnings from other sectors and income from social security insurance, which works to stabilize total income. The complementary character of non-fishing income is also reflected in the negative covariance between fishing and non-fishing income (table 3), which may be due to the seasonal character of many fisheries. Fishers may rely on non-fishing income to generate additional income when the total allowable catch is filled and the fishery is closed. Fishers may also consciously combine risky fishing activities with less risky non-fishing activities. Vergara et al. (2004) found the level of income to be a driving factor in farmers' decisions to seek off-farm income. Fishers may have the same motivation, especially if they do not have a high income from fisheries. (Swedish fishers have an average income level below the average Swedish income; Nielsen et al. [2018].) A limitation of our paper is that we cannot speak to the underlying motivation of the fishers seeking non-fishing income. On one hand, fishers with higher fishing risk may be encouraged to engage in non-fishing activities to mitigate their fishing risk and supplement their fishing incomes. On the other hand, fishers with secondary income may be in the luxurious position to tolerate higher risk exposure in fisheries.[12] In that sense, our findings would be consistent with both a story of fishers having secondary incomes being able to tolerate a higher fishing risk or a story of fishers with higher fishing risk seeking secondary incomes more as a risk buffer. Most likely, these are not isolated decisions. Turning to fishing income, we find that a larger share of fishing income is associated with higher total risk, while partner and non-fishing income have the opposite effect. One possible explanation for this is that Swedish fisheries are strictly regulated and many fishers are no longer allowed to fish for some of their traditional species (a typical example being the ban on drift nets for salmon imposed to reduce bycatch of marine mammals). As a result, as their share of income in fisheries increases, it is dependent on the success of fewer fisheries, thus adding more volatility.

An open question is also how engaging in non-fishing activities may affect risk in the long run that is not captured by our data. Teh et al. (2008) find that while up to 75% of fishers in

12. This point is nicely illustrated with an old Norwegian joke: "A fisherman won in the lottery and got interviewed by the local newspaper. Being asked what he would do with that money, he answered, 'That is just wonderful. Now I can continue fishing.'"

Hong Kong were willing to leave the fishing industry and engage in non-fishing jobs, they were pessimistic about their prospects owing to their limited education and skills outside of the fishing sector. It might be important also for Swedish fishers to gain non-fishing-related skills in order to adequately transition outside of fishing in case the need arises. An illustrative example is Swedish fishers engaged in marine transport where they utilize their skills in running vessels, but in general the sources of non-fishing income are widely diverse across various industries (Nielsen et al. 2017). Fishers already engaging in non-fishing activities are likelier to hold skills in these sectors that they can convert as their primary source of income in case of a major economic shock to their fishing business. Thus, these fishers will likely be more robust to fishing risks. It will also reduce the need for large government intervention and assistance if there is a widespread downturn to the Swedish fisheries industry. Encouraging non-fishing income-generating activities may be most appealing for younger fishers who are likelier to face large economic shocks in the future than are older fishers, and finding new employment might also be more beneficial for younger fishers, who have their career in front of them.

The link between fishing and non-fishing incomes may also hold important policy implications, as risk exposure can be reduced by fisheries diversification and with diversification outside fisheries. Starting with the latter, one policy option may be to stimulate job-training courses to develop skills and allow for an easier transition in the event of an economic shock. Branco and Féres (2021) found that when faced with a drought, Brazilian rural farming households routinely turned to secondary non-agricultural jobs. The ratio of secondary job hours to farm work hours drastically increased during such times. We anticipate fishers to behave in a similar manner by diversifying into non-fishing income in the event they face an external economic shock (such as an oil spill or fishery closure) that prevents them from fishing. However, diversifying into non-fishing income can require significant time (Leu 2019), as well as the support of formal and informal institutions (Liu, Cheng, and Cheung 2017). As a result, secondary skills training and policies helping fishers transition to non-fishing industries, based on regional factors, will need to be in place on an ongoing basis and not as a reactionary measure to a fisheries shock. Notably, the European Maritime and Fisheries Fund (EMFF 2014) provides support for diversification to activities such as angling tourism, restaurants, and environmental services related to fishing. Increasing diversification *within* fisheries often requires fisheries policies to allow fishers to change fishing patterns through new fishing opportunities. In that light, the current regulations (with licenses, input restrictions, group quota) are much more restrictive than an open-access situation (without any regulation), and also more restrictive than a system of ITQs where fishers can trade quotas in order to optimize their fishing portfolio. Evaluating those fisheries policies in terms of adaptive capacity of users may result in a more enabling set of rules. Also, policies could incentivize the use of underutilized species (e.g., bycatch) and increase their value, where governmental support could be provided for innovation and processing of such products within the EU through the EMFF.

Finally, non-fishing income and partner income are key avenues to understanding the entire risk profile of a fisher and their household. As nearly all Swedish fishers in our sample have some form of secondary income, focusing solely on their fishing portfolios leads to an incorrect estimation of fishers' true risk levels. With the impact of shocks to the fishery being uneven across the world, regional understanding of fishers' entire risk profile, including non-fishing and partner income and their potential sources, may provide insights into developing policies aiding in their adaptation to climate change, pandemics, resource depletion, and other shocks. Without such data, adaptation policies risk being ineffective at best or counterproductive at worst.

CONCLUSION

We find that nearly all of the Swedish fishers in our sample have at least one source of secondary income (non-fishing or partner), if not both. Secondary income sources represent *more* than half of the total household income of the average fisher, suggesting that they are critical to the financial well-being of the average fisher's household. Fishers with mostly fishing income (approximately 10% of our sample) typically have higher risk levels and lower total income than those with a more balanced share of fishing and secondary incomes. Our results show that both partner and non-fishing incomes reduce total household risk levels.

Overall, the average Swedish fisher in our sample harvests more than one stock (just 12% land only one species a year; see online appendix table A4) and has secondary income sources, indicating that most fishers use income diversification within and outside of fishing as a risk management strategy. These secondary income sources play a key role in reducing their risk level and may act as an important adaptation measure, especially when facing an uncertain future under climate change.

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