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Risk and Risk Exposure in Norwegian Fisheries

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Abstract

Fishing is a risky occupation and fishers strive to minimize variance as well as maximize mean profits. In this paper, we present a near complete set of landing tickets between 2004 and 2013 and analyze it to study diversification trends in Norwegian fisheries for different fleet and regulatory types. We find no signs for different trends in diversification as a risk-mitigating strategy across different fleets or regulatory types. Moreover, develop a model of risk exposure by utilizing trip-level landings data to better understand what characterizes the risk exposure of Norwegian fishing vessels.

1 Introduction

Fishing is one of the last "frontier occupations" where economic success ultimately lies in the hands of nature. Fishermen harvest resources from the sea that may turn from bright and calm to dark and rough. Indeed, mortality risk in fisheries is more than 30 times higher than the average for industrial occupations. Also the volatility in income far exceeds that of other occupations. These facts naturally lead to the question whether commercial fishermen may actually love risk (Eggert and Martinsson, 2004)?

Most of the empirical studies indicate that the average commercial fisherman may be less risk averse than the average man on the street, but still, most fishermen do not love risk but are risk averse. Clearly, when agents are not risk neutral, it is interesting and highly policy relevant to analyze the variation of revenue in addition to the level of revenue itself. However, until recently, bio-economic models and empirical studies have almost exclusively focussed on the mean level of revenue as outcome variable (though there are obviously exceptions, see e.g. Smith and Wilen, 2005; Gourguet et al., 2014). For adequate policy responses that mitigate risk, it is essential to better understand the determinants of risk exposure and the individual behavioral adaptations to it.

Risk, in the general sense of stochasticity, has of course played a central role in fisheries economics: The literatures on production (Felthoven and Paul, 2004) location choice (Smith and Wilen, 2003), and portfolio analysis (Perruso et al., 2005) implicitly or explicitly deal with the mean-variance tradeoff. Additionally, there is a literature that attempts to recover

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risk preferences from production choices (Eggert and Tveteras, 2004), but identification is challenging (Just et al., 2010). Recently, however, a growing literature that directly analyzes risk exposure has emerged.

Pfeiffer and Gratz (2016) show that the introduction of catch share management in US West Coast fishery has lead to a dramatic decline to leave port in spite of bad weather. Essington (2010) and Sethi et al. (2012) study variability in annual harvest and revenue and find that fisheries under catch share programs have significantly lower risk that those under open-access management. In contrast, Kasperski and Holland (2013) find that vessels participating in ITQ fisheries in Alaska and the US West Coast are less diversified, and that lower diversification is associated with higher variability in income.

The first objective of this paper is to investigate whether for the Norwegian fishery the diversification trends are decreasing as in the US, or not.

Variability in annual income is a useful measure of the residual risk that the fishing firms bear and that could not be smoothed out by behavioral adaptions. However, it is not a good measure of the risk that the fishermen are exposed to, exactly because any measure of annual revenue variability will be mediated by the fishers' behavior. In addition, annual measures of income risk are heavily influenced by year-specific factors such as the size of the overall TAC and cannot capture the extent by which a "good catch" exceeds the average expected return, or by how much a "bad catch" falls short of the average expected return. Two revenue streams with vastly different volatility could lead to the same annual revenue.

The second objective of this paper is therefore to develop a model of risk exposure by utilizing trip-level landings data. We have obtained a near complete set of landing tickets between 2004 and 2013 and analyze it to better understand what characterizes the risk exposure of Norwegian fishing vessels.

2 Materials and Methods

2.1 Background and description of the data

Norway has a long coastline (including fjords and islands it actually is about twice the distance of the equator). Fishery has traditionally been a cornerstone of the economy in many coastal areas and it plays an important cultural and political role to this day. The Norwegian fishing fleet is very diverse. Small wooden vessels that are almost a hundred years old co-exist with large industrial trawlers or modern purse seiners.

To analyze the risk exposure of Norwegian fishing vessels, we have obtained the complete set of landing tickets from 2004-2013. These are in total 14.237 vessel-year observations (one observation per year from between 1.733 and 1.279 different vessels). From the total set, we have then excluded those vessels that landed on less than 8 occasions in a given year, or that were active only for specific seasonal fisheries, or that had a total revenue of less than 10.000 Norwegian kroner (10 NOK are ca. 1 Euro). This makes our dataset comparable with the statistics of the "professional fishing fleet operating year-round" that are published by the Directorate of Fisheries. We are thus left with 12.581 vessel-year observations.

To get a better overview of the fleet, we split our sample of vessels in four categories along the lines that are typically distinguished in Norwegian fisheries policy: First, there is the group of coastal vessels that use conventional gears and are below 28m long. For 62% of this group, the species that earns the highest revenue over the year is cod, followed by shrimps (13%), Saithe (8%), Anglerfish (5%), and Haddock (5%). However, as the Herfindahl index (HHI) shows, the harvest for a given trip consists of several species and is quite diverse (more on this measure of diversity below). Summary statistics for this group, that makes up the bulk of our sample (9.767 of 12.581 vessel-year observations and 1.483 of 1.850 different vessels as indicated by the lower-case n), are given in the first part of Table 1.

The second category is the ocean-going fleet. These are vessels that employ conventional gears (mostly longline) and are longer than 28 meters. This highly profitable segment of the fleet makes up only 649 observations (169 unique vessels) in our sample. The main target species in this fleet segment is much less concentrated. Cod still takes the top position, but only in 33%. The next in line are Saithe (24%), Ling (15%), and Shrimps (12%).

The third main category is the pelagic fleet. These are purse seiners or mid-water trawlers that mainly go for pelagic species such as herring or mackerel. They harvest the highest quantities on average, but the concentration of the main target species (in terms of value) is strongest here (with 93% Herring and 7% Mackerel).

Finally, the trawler segment that fishes mainly demersal species such as cod (main target in 46% of the cases), or Saithe (main target in 34% of the cases) make up the smallest part of the fleet in terms of vessel numbers. There are only 147 different trawlers in our sample. Still, these boats catch about 30% of the total Norwegian cod quota.

Figure 1 shows the seasonal pattern in the Norwegian landings (in terms of value, 7-day moving average). We present the total value of all species combined as well as a number of selected species. In particular the pelagic species herring and mackerel, show a clear seasonal pattern. Their harvest is almost entirely confined to the early winter and late fall with some landings in June and July. Looking at the cod harvest, one can clearly see how the Norwegian fleet targets the massive spawning migration of this stock. Other demersal species such as haddock, are targeted around the year with no apparent peak season. Anglerfish is mainly caught in the second half of the year. While the overall pattern is stable, there is also is considerable variation from year-to-year in terms of the absolute values that are landed.

2.2 Diversification trends and inter-annual income variability

The Norwegian fishery is highly regulated. The total harvest of many, if not most, species is capped by an annual TAC (total allowable catch) quota. For herring, mackerel, cod, saithe, and haddock, the TAC is distributed to boats as individual vessel quotas. In addition there are a number of gear, area, and seasonal restrictions as well as a general ban on discards.

Kasperski and Holland (2013) raise the question to what extent individual quota regulations have constrained the fisher's ability to smooth income risk by diversifying their catch portfolio. Here, we apply exactly the same method as Kasperski and Holland (2013) so that we can directly compare the results. As measure of diversification we use the Herfindahl index that is computed as $HHI_{i,t} = \sum_n p_{n,i,t}^2$ where $p_{n,i,t}$ is the share of species n that vessel i catches in year t. We then analyze the temporal trends in the average diversification of the

Statistic	N	(n)	Mean	St. Dev.	Min	Max
Coastal conventional fleet						
Length (meter)	9 767	(1 483)	15.58	4.20	10.21	27.99
Boat-age (in years)	9 767	(1 483)	26.52	15.40	0	118
Number of trips	9 767	(1 483)	59.49	30.20	8	232
Median trip (in days)	9 767	(1 483)	2.73	2.41	1.00	57.00
HHI	9 767	(1 483)	0.54	0.20	0.14	1.00
Revenue (1000 NOK)	9 767	(1 483)	4 726.96	7 256.78	12.74	91 867.31
Harvest (in metric tons)	9 767	(1 483)	547.04	1 282.53	0.47	15 778.60
Ocean-going conventional fleet						
Length (meter)	649	(169)	41.35	8.86	28.08	78.39
Boat-age (in years)	649	(169)	19.43	12.10	0	55
Number of trips	649	(169)	27.31	23.91	8	122
Median trip (in days)	649	(169)	17.13	14.16	1.00	59.00
HHI	649	(169)	0.39	0.19	0.18	1.00
Revenue (1000 NOK)	649	(169)	39 900.77	24 914.25	2 832.47	182 374.30
Harvest (in metric tons)	649	(169)	4 642.39	4 467.75	78.14	30 927.52
Pelagic fleet						
Length (meter)	1 570	(346)	45.44	20.69	10.65	94.32
Boat-age (in years)	1 570	(346)	17.83	13.69	0	117
Number of trips	1 570	(346)	25.65	10.56	8	69
Median trip (in days)	1 570	(346)	5.66	2.86	1.00	40.00
HHI	1 570	(346)	0.51	0.15	0.23	1.00
Revenue (1000 NOK)	1 570	(346)	50 732.76	41 895.17	56.98	285 342.20
Harvest (in metric tons)	1 570	(346)	9 761.43	6 989.58	11.04	36 475.94
Trawler fleet						
Length (meter)	595	(147)	48.26	11.20	14.81	75.50
Boat-age (in years)	595	(147)	19.68	11.86	0	57
Number of trips	595	(147)	21.87	12.33	8	99
Median trip (in days)	595	(147)	17.24	10.56	3.00	52.00
HHI	595	(147)	0.43	0.16	0.17	0.94
Revenue (1000 NOK)	595	(147)	59 222.42	45 821.61	283.78	291 512.50
Harvest (in metric tons)	595	(147)	5 847.47	3 668.33	17.17	20 480.65

Table 1: Summary Statistics

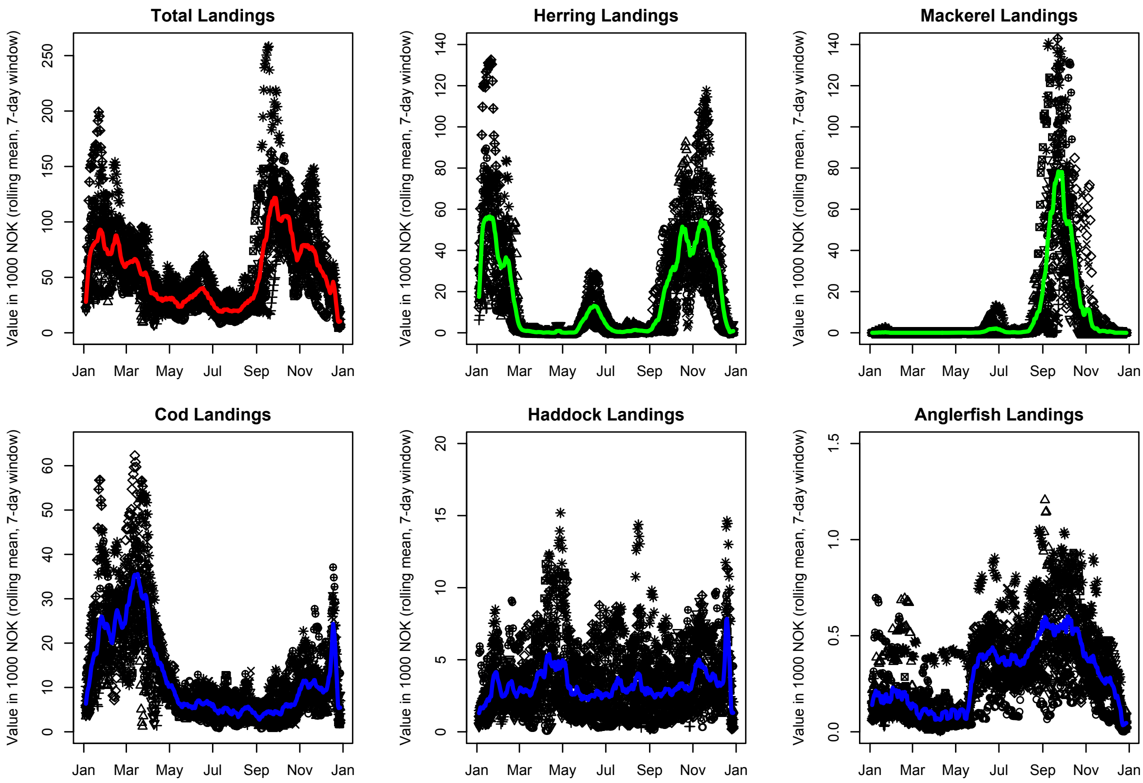

Figure 1: Seasonal pattern of landings (in terms of value, 7-day moving average) for all species combined (upper left panel) and for herring, mackerel, cod, haddock, and anglerfish. The colored lines show the average over 2004-2013. Note the different scales of the y-axis.

entire fleet as well as decomposed in the four categories discussed above.

Additionally, we investigate the relationship between inter-annual income variability (measured as the coefficient of variation of annual income for vessel i) and the average diversification measure for the years that a given vessel is in our data. We probe whether and to what extent more diversification is indeed related to lower income risk. We use the same quadratic functional form as Kasperski and Holland (2013) and estimate the following linear regression model:

$$CV_i = \alpha_0 + \alpha_1 \overline{HHI}_i + \alpha_2 (\overline{HHI}_i)^2 + \varepsilon_i \tag{1}$$

where $CV_i = \frac{\mathsf{sd}[Y_{i,t}]}{\mathsf{E}[Y_{i,t}]}$ is the coefficient of variation (standard deviation divided by mean) of the annual income $Y_{i,t}$ of vessel i in each year t that it is observed. $\overline{HHI}_i$ is the average Herfindahl index for that vessel.

2.3 Measuring risk and risk exposure

As discussed above, the Norwegian fishing fleet consists of vastly different vessels. Annual revenue is the sum of trip revenues, and each trip revenue is the result of a highly idiosyncratic production process: Some vessels have large holding capacities and go on long trips, some vessels deliver their catch daily. Some vessels have freezing facilities on board and land processed products, others target the restaurant market with fresh fish. Some vessels target schooling species where search is an important part of the production process and others target known sedentary populations with traps.

To bring this diversity on a common denominator, we model trip revenue as an (unobserved) stream of daily revenue. Let $Y_{i,t,k}$ be the (observable) revenue of vessel i from trip k in year t. Denote the length of trip k by L_k and let $y_{i,t,k,l}$ be the revenue on day l for $l = 1, ..., L_k$. We then have:

$$Y_{i,t,k} = \sum_{l=1}^{L_k} y_{i,t,k,l}$$

The crux of the problem is that the daily revenue stream is unobserved. We assume that the length of the trip, L_k is exogenous to $y_{i,t,k,l}$ and that the daily revenue is described by the following process:

$$y_{i,t,k,l} = \alpha_k + X_{i,t,k}\beta + u_{i,t,k,l}$$

where X is a trip-specific vector of co-variates (but not day-specific). It controls for the scale of the operation and we additionally include season dummies. Moreover, we assume that $u_{i,t,k,l}$ is an i.i.d. draw from $\mathcal{N}(0, \sigma_u^2)$. It is this entity σ_u^2 that is the main focus of our interest. It measures the standardized variation of harvesting income.

The assumption that L_k is exogenous not unreasonable. Many decisions that determine the trip length have to be taken ex-ante, for example the amount of provisions that are taken on board, the amount of fuel that is bunkered, etc. The trip-fixed effect α_k controls for initial conditions before the trip is started, capturing initial wealth, the current stock of quotas etc. It is modeled explicitly by the AR-1 process $\alpha_k = \rho Y_{i,t,k-1}$. Consequently, we have:

$$Y_{i,t,k} = \sum_{l=1}^{L_k} y_{i,t,k,l} = L_k \rho Y_{i,t,k-1} + L_k X_{i,t,k}\beta + \sum_{l=1}^{L_k} u_{i,t,k}$$

and because X and u are uncorrelated, and u is iid by assumption, we have:

$$\mathsf{var}[Y_{i,t,k}] = \mathsf{var}[L_k \rho Y_{i,t,k-1} + L_k X_{i,t,k}\beta] + L_k \mathsf{var}[u_{i,t,k}]$$

By estimating equation (2) we obtain a distribution of residuals $\hat{u}_{i,t,k}$ and the standard deviation of these residuals is our estimate of σ_u^2.

$$\frac{Y_{i,t,k}}{L_k} = \rho Y_{i,t,k-1} + X_{i,t,k}\beta + u_{i,t,k} \tag{2}$$

Because the standard deviation takes on only positive, we take the log-transformed standard deviation as our measure of risk exposure. We denote it by $x_{i,t}$, that is $x_{i,t} \equiv \ln\left(\mathsf{sd}\left[\hat{u}_{i,t,k}\right]\right)$. To describe the determinants of risk exposure we then regress:

$$x_{i,t} = X_{i,t}\gamma + \varepsilon_{i,t} \tag{3}$$

where γ is the vector of co-variates of interest. In particular, we are interested how risk exposure correlates with annual revenue (to measure the mean-variance tradeoff) and boat characteristics such as vessel length and category. Furthermore, we account for regional differences and we explore whether there are trends in risk exposure, and whether they are different for the different categories.

Finally, we are interested in describing the risk involved in targeting different species. Of course, the target species is an endogenous decision variable of the fisher. Therefore, we compare the risk measure $x_{i,t}^j$ of species j as the log-transformed standard deviation of only those trips where species j made up the largest part in terms of value.

3 Results

3.1 Diversification trends and inter-annual income variability

Figure 2 shows the distribution of the vessel-specific diversification measure (the Herfindahl index, HHI) over time. In addition, we plot the annual average HHI for all boats in a given category. In contrast to the study of Alaskan fisheries by Kasperski and Holland (2013), there is no trend in diversification in the Norwegian fishery sector, neither on the aggregate, nor when differentiating according to vessel categories.

We do see differences in average diversification across categories, however. Ocean going vessels that use conventional gears are the most diversified, while coastal vessels with conventional gear are the least diversified. The latter is due to the overwhelming importance of the valuable cod fishery for this categories. Many of the small boats make almost their entire annual income in the few weeks of the cod season.

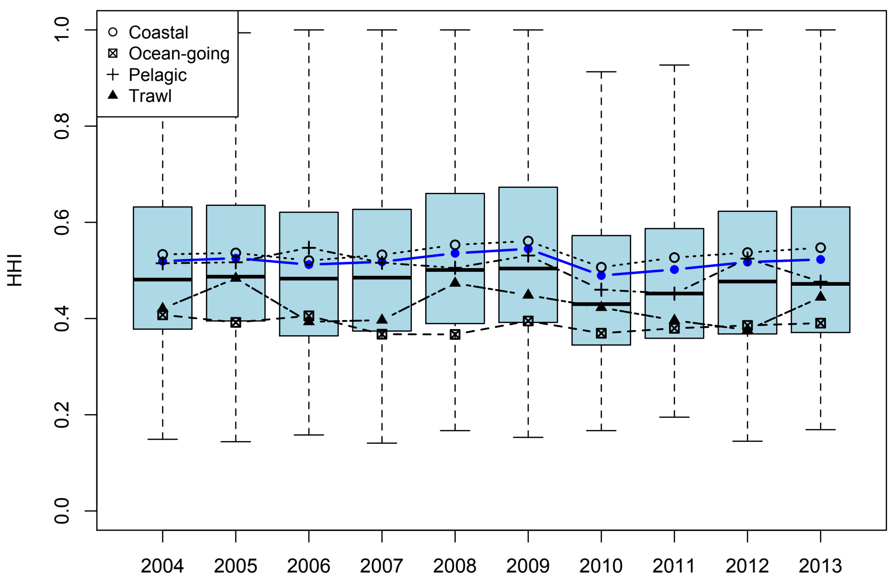

Figure 2: Boxplots of diversification (measured by HHI) for 2004 to 2013. The black lines show the annual average HHI for the different categories.

Table 2 then describes the relationship between income risk and diversification. As Kasperski and Holland (2013), we find evidence for a dome-shaped relationship on average for all categories combined (column 1). However, looking at the category-specific regressions (column 2 to 5), we see that this is stronger for some categories than for others. In fact, for pelagic vessels there is no evidence for a dome-shaped relationship. Through the board – and this is the main message – there is a positive association between a higher concentration of harvest (higher HHI) and more income risk (larger CV_i). Figure 3 gives a visual impression of this relationship and the data.

Table 2: Results of OLS regression of equation (1)

	Dependent variable: CV_i				
	(All vessels)	(Coastal)	(Ocean-going)	(Pelagic)	(Trawl)
$\overline{HHI}_i$	0.442***	0.324***	0.797***	0.455**	0.677*
	(0.048)	(0.057)	(0.160)	(0.206)	(0.369)
$(\overline{HHI}_i)^2$	−0.283***	−0.201***	−0.627***	0.032	−0.711*
	(0.041)	(0.048)	(0.136)	(0.173)	(0.386)
Constant	0.158***	0.195***	0.051	0.084	0.146*
	(0.013)	(0.016)	(0.038)	(0.059)	(0.083)
Observations	12,009	9,447	579	1,445	538
R^2	0.018	0.010	0.046	0.111	0.006
Note:					*p<0.1; **p<0.05; ***p<0.01

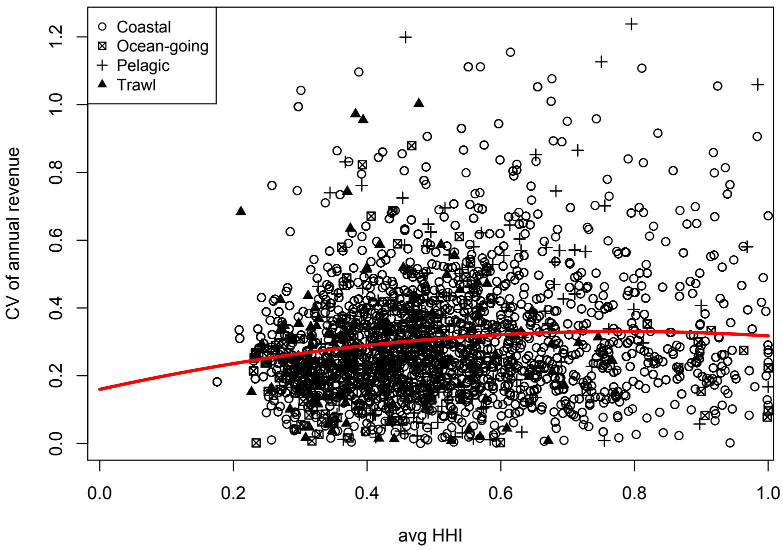

Figure 3: Scatterplot of income risk (measured as CV of annual catch revenue) versus average diversification at the vessel level for the different fleets. Red line shows the fitted function (1) for all categories pooled.

3.2 Description of risk exposure

In section 2.3 above, we define income risk as the deviation of the daily catch revenue from its vessel- and year-specific mean. Table 3 then shows the regression of the log-transformed deviation on a number of covariates. Column 1 shows the result for all boats, and column 2-5 show the results when we split the sample according to vessel categories.

First, we note that through the board there is a significant mean-variance tradeoff (standard errors are clustered at the level of boat-owner combination). As predicted by basic theory, more revenue can only be obtained at the cost of increased risk.

Second, we note that a more diverse catch, a higher number of trips in a given year, and longer trips all are associated with lower risk. The effect of using a larger variety of different gears is not homogenous over the different vessel categories: Using different types of gears increases risk for coastal vessels, but not for ocean-going vessels and purse seiners. Unsurprisingly, there is no effect for trawlers that are defined by their use of trawl gear.

Geographical origin appears to play no role, but length has a positive and significant effect for all categories. The longer a boat, the larger the variation in standardized trip revenues.

Overall, we see that the coastal vessels are exposed to least risk while the ocean going vessels are exposed to most risk, followed by the pelagic fleet and the trawlers. With respect to the trends, however, coastal vessels (and purse seiners) face a trend of increasing risk while the ocean-going vessels and trawlers saw a significant reduction in the risk that they are exposed to over our study period from 2004:2013.

Turning to the species-specific risk for the four different vessel categories (Figure 4), we see that the ordering (in terms of increasing risk) is saithe, cod, herring. This is true for all four vessel categories, but the difference is largest for the coastal vessels. Overall, coastal vessels have the lowest standardized exposure to species-specific risk, confirming the results in Table 3. Figure 4 thus shows that even with today's modern fish finding equipment, targeting herring is more risky than targeting the demersal species cod or saithe.

Table 3: Results of OLS regression of equation (3)

	Dependent variable: $x_{i,t}$				
	(All vessels)	(Coastal)	(Ocean-going)	(Pelagic)	(Trawl)
annualRevenue	0.00001***	0.0001***	0.00002***	0.00001***	0.00001***
	(0.00000)	(0.00000)	(0.00000)	(0.00000)	(0.00000)
HHI.V	−0.831***	−0.340***	−1.411***	−0.802***	−0.439
	(0.094)	(0.083)	(0.401)	(0.183)	(0.385)
length	0.065***	0.101***	0.027***	0.031***	0.042***
	(0.002)	(0.005)	(0.007)	(0.002)	(0.009)
numbgear	0.045***	0.085***	−0.164***	−0.049*	0.019
	(0.014)	(0.011)	(0.055)	(0.026)	(0.086)
medtriplength	−0.050***	−0.152***	−0.026***	−0.062***	−0.011
	(0.006)	(0.013)	(0.007)	(0.013)	(0.012)
numbtrip	−0.007***	−0.007***	−0.008***	−0.003	−0.004
	(0.001)	(0.001)	(0.003)	(0.002)	(0.005)
Hordaland	−0.086	−0.069	−0.022	0.112	0.477
	(0.097)	(0.118)	(0.228)	(0.131)	(0.320)
More & Romsdal	0.040	−0.087	0.161	0.096	0.545***
	(0.069)	(0.059)	(0.224)	(0.129)	(0.210)
Nordland	0.017	−0.049	0.335*	0.016	0.174
	(0.051)	(0.040)	(0.179)	(0.132)	(0.202)
Rogaland	−0.110	−0.168**	−0.345	−0.115	0.423
	(0.083)	(0.084)	(0.241)	(0.154)	(0.264)
Sogn & Fjordane	0.532***	−0.088	0.656***	0.056	0.914***
	(0.111)	(0.107)	(0.209)	(0.147)	(0.277)
Troms	0.063	0.011	0.316	0.134	−0.016
	(0.058)	(0.045)	(0.224)	(0.146)	(0.209)
Trondelag	−0.001	0.024	0.035	0.013	1.238***
	(0.089)	(0.076)	(0.308)	(0.163)	(0.409)
Other counties	−0.174**	−0.278***	−0.154	−0.008	0.366
	(0.088)	(0.076)	(0.300)	(0.195)	(0.340)
trend	0.036***	0.035***	−0.061***	0.016*	−0.053**
	(0.003)	(0.003)	(0.022)	(0.009)	(0.026)
Constant	2.607***	1.814***	5.187***	4.728***	2.586***
	(0.114)	(0.129)	(0.522)	(0.211)	(0.598)
Note:					*p<0.1; **p<0.05; ***p<0.01

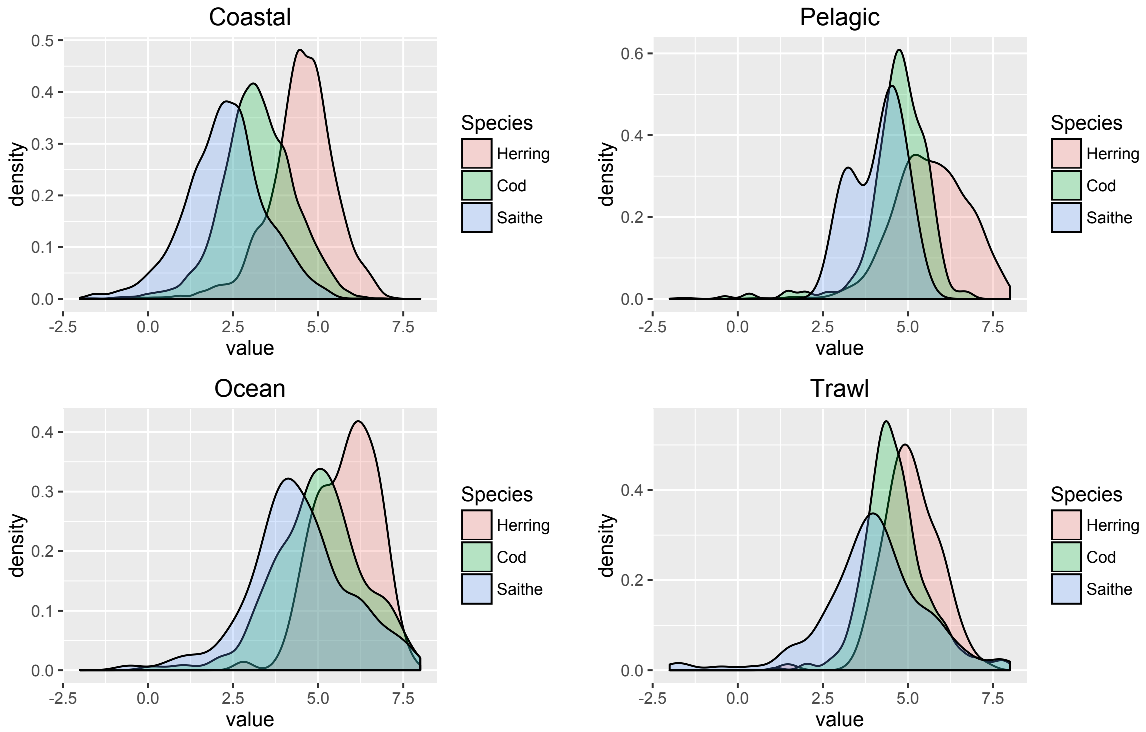

Figure 4: Distribution of species-specific risk for the four different vessel categories

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Fishing is a risky occupation and fishers strive to minimize variance as well as maximize mean profits. In this paper, we present a near complete set of landing tickets between 2004 and 2013 and analyze it to study diversification trends in Norwegian fisheries for different fleet or regulatory types. We find no signs for different trends in diversification as a risk-mitigating strategy across different fleets or regulatory types. Moreover, develop a model of risk exposure by utilizing trip-level landings data to better understand what characterizes the risk exposure of Norwegian fishing vessels.

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