A COMPARATIVE STUDY OF VARIABILITY IN AGRICULTURAL ENTERPRISES AND FISH FARMING

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Abstract

Agri- and aquaculture have common features associated with their biological nature affecting risk exposure of the businesses. The aim of this paper is to compare risk exposure in salmon farming and agricultural enterprises in Norway by using an implicit error component model to examine the risk structure of yields, prices and economic returns. Panel data originated from the Norwegian Farm Accountancy Survey and the Norwegian Directorate of Fisheries. Results indicate a higher farm-level year-to-year variability in yields, prices and economic returns in salmon farming than in agricultural enterprises. Return on assets was highest in salmon farming with an average return of 9.2%. All of the agricultural farm types exhibited a negative average return on assets. Stochastic dominance tests of the distribution of economic returns from fish farming and agricultural enterprises showed salmon farming to the most economic viable alternative.

Keywords: risk analysis; salmon farming; livestock production; crop farming; stochastic dominance; Norway

Introduction

Agri- and aquaculture[1] are both biological production sectors and are exposed to widely varying and unpredictable elements of nature, like uncertainty in biological processes related to weather, diseases, pests, infertility, etc., which cause yield variability (production risk). In addition, activities are dispersed on heterogonous soils - or water conditions. Weather and spatial dispersion in agriculture particularly affects crops and grazing livestock. In contrast, confinement production of livestock partially controls production risk. Modern fish farming is essentially a batch production system, as in chicken or feeder-pig-to-finish operations, but fish is produced in open cages leading to less control of the biological processes than indoors. The biological uncertainty is a fundamental cause of price uncertainty. Consequently, the two sectors face many similar economic risks.

However, there are also notable differences. Agriculture has existed for more than 10,000 years, and core agricultural techniques were developed early. Although the practice of aquaculture is ancient, fish farming only recently has become a specialised business. Open-net cage salmon farming in marine waters was pioneered in Norway in the late 1960s; this particular type of aquaculture technology is still a minor part of the production of farmed fish worldwide. It however dominates in salmon farming.

[1] We refer to agriculture as the process of producing food, feed, fibre, fuel and other goods by the systematic raising of plants and animals on land. Aquaculture is the rearing of aquatic organisms under controlled or semi controlled conditions.

The two industries operate in different institutional environments. A large number of government interventions in agriculture are a common feature in many countries. The agricultural sector has built institutions and farmer cooperatives that, among other tasks, mitigate risk. In Norway, which we focus on in this study, agriculture mainly produces goods for the domestic market and receives substantial producer support, chiefly through import tariffs and government payments. The export-oriented aquaculture industry operates with more liberal market and trade regimes, and collective institutions to mitigate risk have not been developed. The current production level in Norway is around 600,000 metric tons of salmon, close to half of total world production, and more than 90% of its salmon production is exported. Finally, small, family-based firms dominate in agriculture, while aquaculture business structures have converted into a mix of medium-sized and large firms.

Since the biological nature affects risk exposure in both sectors, we believe a better understanding of risk exposure can be achieved through comparative analysis of agricultural versus aquaculture businesses. Agri-and aquaculture products may be competitors in food markets and differences in risk exposure may be one important factor for predicting the success of the industries. Good risk estimates may be important for the industries, potential investors and policy makers. Also, the analysis can help to identify sector differences in the need for price and income stabilisation tools and risk management strategies.

The aim of this paper is to compare risk exposure in salmon aquaculture and agricultural enterprises in Norway. First, we compute and compare the variability of yields, prices and economic returns at the farm level. Measures of variability in themselves may not indicate much about riskiness, except under specific probability distribution assumptions, such as normality. Second, we will employ a more general framework for addressing risk exposure, the stochastic efficiency methods, using measures of the farms' economic returns. To the best of our knowledge, a cross-industry risk comparison like the one provided in this paper has not been done before.

Methods

Detrending procedures

Improving technology and management influence the yield of most biological enterprises, and estimates of yield variability are conditional on having an appropriate model of the changes in the mean of output. Atwood et al. (2003) refers to three statistical procedures for detrending of yields:

No time trend adjustment, which is likely to overestimate the variability since no trend is removed.

Estimation of individual farm-level trends. If most or all farms in an area actually have similar underlying trends (which can be reasonable), estimating individual trends for each farm may result in non-robust trend parameters.

An error component procedure that implicitly removes any common regional trend from the farm yields series (Atwood et al., 2003). This procedure, error components implicit detrending (ECID), was shown to better describe the reality in most cases than individually detrending farm-level data.
Atwood et al. (2003) describes the ECID procedure as follows:

Calculate the "regional" yield in year *t*, y_{Rt}, i.e., the area weighted average of farm yields in the region.

Compute each farm's "yield" deviation from the regional yield, as:

$\Delta_{it} = y_{it} - y_{Rt}$, where y_{it} is the yield of farm *i* in year *t*.

3)
Compute farm i's residuals as:

$$\varepsilon_{it} = (y_{it} - y_{Rt}) - (\bar{y}_i - \bar{y}_R) \qquad (1)$$

where $\bar{y}_i$ is farm i's average yield, and $\bar{y}_R$ is the average regional yield in region R for the t_i years of farm output reported by producer i. The first term shows the farms deviation from the regional yield in year t and the second term the farms average deviation from the regional yield.

It can be shown that the resulting farm residual values have been implicitly detrended to the degree that farm yields follows a common regional yield trend. If there are reasons to believe that producers' underlying yield trends could vary widely within a region, it is likely that the ECID procedure might generate biased residuals. However with short-term panel data, it will always be extremely difficult to identify whether a difference in an individually estimated trend occurred because of differences in actual trend or resulted from sampling anomalies.
In this study we will use a modified version of the ECID procedure, where we also have included the relationship between the national and the regional yield level. In our ECID approach the decomposition of yield y_{it} at farm i in year t is expressed as:

$$y_{it} = (\bar{y}_i - \bar{y}_R) + (\bar{y} - \bar{y}_R) + y_{Rt} + \varepsilon_{it} \qquad (2)$$

where $\bar{y}$ is average national output (average yield for all farms over all years) and $\bar{y}_R$ is average output in region R (average yield for all farms in region R over all years). The four variability components in Eq. (2) can be expressed as:

Time-invariant, farm-specific deviations, $(\bar{y}_i - \bar{y}_R)$, a farms average deviation from the regional yield level. In other words, variability that arises from time-consistent, farm-related factors (soil/water properties, farmer skills, topographic position, permanent weather conditions, etc.) showing the variation between farms within a region.

Time-invariant, region-specific deviations, $(\bar{y} - \bar{y}_R)$, a regions average deviation from the national yield level, i.e., variation in yields between regions.

Time-variant, region-specific deviations, y_{Rt}, average output in region R in year t expressing the variation in yields between years in a region.

Time-variant, farm-specific deviations, ε_{it}, the farm residuals, showing variation in yields between years on a farm caused by time-inconsistent factors such as weather variability and variable annual management decisions.

We are particularly concerned with, from the farmers' point of view, how yields vary between years on farms. We examined variability in yields between years within a farm, since this best describes variability in yields at the individual farm level. As a statistical measure of variability we used the coefficient of variation (CV), which expresses the standard deviation (SD) relative to the mean. The SD in yields within farms was estimated by taking the SD of the sum of variability components 3 and 4 in Eq. (2).

Variance components were calculated by dividing the variance of a specific component by the sum of the variance of the four components in Eq. (2). A variance component represents the variance of a specific component as a fraction of total yield variance in an enterprise. The procedure does not take into account correlations between the components. To take notice of the correlations, within-farm correlations of yields were calculated and reported.

Estimation of price variability was based on the same error component procedure (ECID). The aim was to decompose variation in annual farm-level prices. All prices were converted to 2004 real Norwegian kroner (NOK, €1≈NOK 8.10), using the Norwegian consumer price index as price deflator. Also, for the examination of financial variability the ECID procedure was used.

Measures of financial performance

Several measures of financial performance can be computed. When making comparisons across farms, it is useful to control for differences in their resource base. Also, since we are dealing with family farms using unpaid family labour as well as farms organised as corporations with paid labour we have to use a measure which can compare financial variability no matter how the farm business is organised.

In the comparison of financial performance we first employed the rate of return on assets (ROA):

$$\text{Return on assets } (\%) = \frac{\text{return to assets}}{\text{total farm asset values (average)}},$$

where Return to assets = Net farm income from operations – opportunity cost of unpaid labour.
ROA is the return on both debt and equity capital, since interest on debt capital is not included in net farm income from operations. To find the return to assets imputed charges for unpaid operator and family labour is deducted.

Many agricultural businesses do have a negative ROA. Comparing two farms with the same negative return to assets, the one with the lowest asset values will have the most negative ROA. This may be confusing, since is it better to achieve a certain return to assets with the least use of assets. Therefore, we did also calculate a second financial performance measure for agricultural businesses, the profitability quotient (PQ), defined as:

$$\text{PQ} = \frac{\text{Net farm income from operations}}{\text{Opportunity cost of all farm assets} + \text{opportunity cost of labour}} \times 100$$

If PQ equals 100 (or higher) net farm income is sufficient to provide a return to capital and labour equal to (or higher) than their opportunity costs. Since the measures of economic returns already are relative terms, we will report the SD for the analysis of economic variability.

Stochastic efficiency analysis

Risk can be measured as the variation in distribution of possible outcomes, and a risky choice is then one with a wide range of possible outcomes. Most managers do however associate risk with the negative outcomes, and a risky choice is one that contains a threat of a negative outcome (March and Shapira, 1987). Hence, from a managerial perspective, associating lower variability in economic returns with less risk can be misleading.

Hardaker et al. (2004:266) have pointed out that the best route to risk efficiency is by finding strategies that improve the expected values of returns, rather than those that reduce dispersion as measured, for example, by the variance of returns. We isolated risk efficient solutions using stochastic dominance techniques. There are several stochastic dominance criteria, where this study used first (FSD) and second (SSD) degree stochastic dominance criteria.

Stochastic dominance analysis requires comparison of cumulative distribution functions. Variability in economic returns within farms, estimated as the sum of component 3 and 4 in Eq. (2), was for each of the farm types used to generate empirical distributions of financial outcomes. An empirical distribution was chosen because it avoids forcing a specific parametric distribution (such as the normal) on the economic returns.

Data

The data source for agriculture was the Norwegian Farm Accountancy Survey (NFAS) collected by the Norwegian Agricultural Economics Research Institute. The unbalanced panel data set includes farm production and financial data collected annually from about 1,000 farms. These farms are located throughout the country (divided into eight regions) and represent a wide range of farm sizes and types of farms. The total data set used in the analysis included 13,000 observations on 1970 farms from 1992 through 2004.

Financial performance measures were only available at the whole-farm level. Many farms are mixtures of several enterprises. Farms in NFAS are classified according to their main categories of farming. To perform analysis of economic returns at the whole-farm level we included the most common farm types from the survey.

Aquaculture was analysed with data from the Norwegian Directorate of Fisheries, which annually compiles data of salmon farm production data for their profitability survey of Norwegian fish farms. Firm level data for the years 1985-1998 were included. Later data were excluded, as region was only specified until 1998[2]. In aquaculture, region is specified in terms of which county the farm belongs to. Ten of Norway's counties have fish-farms represented in the sample. The sample annually includes 200-300 firms, typically representing over 50% of the total salmon production in Norway. In total the data set included 3600 observations.

The accounting methods used in the data sets chiefly follow the rationale of conventional accounting, with its use of historical cost for the valuation of long-term assets[3]. Following the procedures of the NFAS, a flat labour charge per worked family hour equal to the wage rate for skilled farm workers were used to compute costs of unpaid labour. Opportunity costs of farm assets were set equal to the interest rate used in NFAS.

Results and discussion

Yield Variability and Correlation

Yield variability and the variance components are reported in Table 1. Salmon farming showed the highest yield variability with a CV within farms of 58%. The high yield variability in salmon farming was expected, since the industry is rather young and has experienced rapid growth. The industry has been through periods where diseases and pests significantly have reduced the output and salmon farmed in sea cages are exposed to rough and variable weather conditions.

Of the agricultural enterprises, only potatoes reached a CV of more than 50%. Forage followed with a CV of 38%. For grain crops the CV's were within the range of 25 to 30%. Rasmussen (1997) found a CV

[2] The two sectors are being compared across different time periods and for different length of times. Measures at the national aggregated level show the same mean ROA in aquaculture at 10% for the two periods 1985-1998 and 1992-2004. The CV was 6.3% in the former and 9.0% in the latter period. Even though the essence of problems concerning variability faced by individual producers is lost in the process of aggregation, these numbers suggests only modest impacts on the variability measures of the different time periods.

[3] Market values for assets were not available. Non-farm assets (included the value of the farm dwelling) were not included in the asset values.

close to 20% for grain yields on Danish farms while the CV's was around 10% among cereal growers in England (Webster and Williams, 1988).

Among the livestock enterprises, sheep and hog-farrowing operations achieved the highest CV's. Milk, goat milk and porkers were rather yield stable. Low CV's have been found for milk and pork in Denmark (Rasmussen, 1997). It is reasonable that extensive grazing production like sheep is likely to have more variable yields than intensive livestock production, since the former is more severely exposed to the effects of variable weather conditions. Diseases and infertility may cause variations in herd productivity in hog-farrowing operations.

Table 1 Estimated yield variability

			Variance components			
Enterprise	Average yield[1]	CV within farms[2]	Time-invariant farm-specific	Time-invariant region-specific	Time-variant region-specific	Time-variant farm-specific
Barley, kg/ha	3859	0.27	0.33	0.13	0.24	0.30
Oats, kg/ha	4083	0.28	0.33	0.14	0.22	0.30
Wheat, kg/ha	4569	0.25	0.29	0.15	0.28	0.28
Potato, kg/ha	18572	0.51	0.33	0.13	0.17	0.37
Forage, feed units/ha	3720	0.38	0.27	0.33	0.19	0.21
Milk, litre sold/cow	5686	0.09	0.66	0.02	0.05	0.26
Sheep meat, kg/winter fed sheep	26.4	0.27	0.46	0.04	0.11	0.38
Goat milk, litre sold/goat	499	0.14	0.66	0.07	0.11	0.17
Weaners per sow per year	17.4	0.25	0.46	0.07	0.18	0.29
Finisher-hog, kg slaughter weight	75.9	0.08	0.41	0.02	0.36	0.21
Salmon, kg/m^3 cage volume	27.6	0.58	0.28	0.03	0.27	0.43

[1] Paid or sold crop yields
[2] Mean of the farms

The variance components show that the variability in yield level between the farms within a region was relatively more important for livestock enterprises than for crop enterprises and salmon (column 4 in Table 1). The time-invariant region-specific component was small for salmon and livestock enterprises, i.e., small variations in yields between regions. The larger variation between regions in crop yields is primarily caused by time-consistent differences in climatic conditions for crop production.

The time-variant region-specific component was generally lowest for the livestock enterprises. The higher region-wide variation for crops and salmon may be associated with their heavier influence of widespread weather and pest conditions. The farm-specific shocks were relatively highest for salmon but also for sheep and potatoes the proportion was considerable. Generally, farm-specific randomness may be caused by fluctuating farm-specific weather and disease conditions and variable management decisions.

Table 2 shows estimates of within-farm yield correlations. Weather is the primary factor influencing crop yields and crops within the same growing season experience the same weather. Since crops are susceptible to different insects and diseases and do not react exactly in the same way on the weather crop yield correlations often tend to be moderately positive as found in Table 2. Crop yields and livestock performance were less closely correlated. Production rates among different types of livestock were little correlated. The main findings are in concurrence with a similar study in Denmark (Rasmussen, 1997).

Table 2 Within-farm yield correlations between agricultural enterprises[1]

	Oats	Wheat	Potato	Forage	Milk	Sheep	Goat	Piglets
Barley	**0.53**	**0.43**	**0.39**	**0.33**	**0.18**	**0.26**	0.20	**0.17**
Oats		**0.44**	**0.30**	**0.22**	**0.12**	**0.23**		0.02
Wheat			**0.31**	**0.20**	**0.14**	-0.06		-0.04
Potato				**0.69**	**-0.18**	**0.09**	**-0.31**	0.06
Forage					0.00	**0.08**	**-0.53**	**0.35**
Milk						0.04	-0.13	**0.12**
Sheep							0.02	0.10
Goat								0.51

[1] Bold numbers significantly different from 0 at 5% level

Price variability and correlation

Table 3 shows the price variability results. Potato prices exhibited the largest relative price variability within farms (CV=68%), followed by salmon (CV=40%). The prices of the other agricultural commodities were fairly stable with CV's around 10 to 20%. Farmer cooperatives' market regulations within the maximum prices set by the government and supply control in milk production have tempered price fluctuations.

Why was the potato price more variable than prices for salmon determined in fluctuating world markets? Potato growers face a greater exposure to market prices than other farmers as there are fewer market regulations. Prices are volatile due to the inelastic nature of the demand for potatoes and variations in supply between seasons. A much higher price variability for potatoes than for other agricultural commodities has also been found in Denmark (Rasmussen, 1997).

Table 3 Estimated product price variability

			Variance components			
	Mean prices	CV within farms[1]	Time-invariant, farm-specific	Time-invariant, region-specific	Time-variant, region-specific	Time-variant, farm specific
Barley, NOK/kg	2.27	0.16	0.38	0.09	0.34	0.18
Oats, NOK/kg	2.08	0.16	0.39	0.11	0.29	0.20
Wheat, NOK/kg	2.77	0.18	0.30	0.22	0.31	0.17
Potato, NOK/kg	2.36	0.68	0.22	0.23	0.27	0.28
Milk, NOK/L	4.24	0.15	0.29	0.11	0.37	0.23
Beef, NOK/kg	42.47	0.18	0.34	0.03	0.40	0.22
Lamb, NOK/kg	47.96	0.17	0.29	0.10	0.25	0.36
Goat milk, NOK/L	6.77	0.11	0.30	0.09	0.32	0.29
Piglets, NOK	867	0.15	0.42	0.06	0.29	0.22
Pork, NOK/kg	25.36	0.15	0.35	0.06	0.39	0.21
Salmon, NOK/kg	37.93	0.40	0.22	0.05	0.53	0.21

[1] Mean of the farms

For most products more than 50% of the price variability was attributable to factors that are not consistent in time (Table 3). The time-variant, region-specific component was usually larger than the time-variant, farm-specific component, indicating that variation in prices between years in a region is more important than specific farm shocks. The time-invariant, region-specific component was particularly large for salmon while the farm-specific shocks were highest for lamb.

Table 4 reports the magnitude of price-yield correlations at the farm level. Potatoes exhibited the strongest negative price-yield correlation followed by salmon; cf. their higher exposure to competitive markets for outputs. The price-yield correlations for the other commodities were moderate. The causes of the positive correlations for milk and goat milk may be associated with animal health performance. Animal diseases can result in lower yields as well as deteriorated milk quality implying a reduced milk price.

Table 4 Farm-level price-yield correlations[1]

	Correlation (price - yield)
Barley	-0,02
Oats	**-0,18**
Wheat	**-0,10**
Potato	**-0,58**
Milk	**0,26**
Lamb	**-0,06**
Goat milk	**0,31**
Piglets	**-0,11**
Pork	-0,03
Salmon	**-0,50**

[1] Bold numbers significantly different from 0 at 5% level

Variability in Economic Returns

The variability in return on assets (ROA) is reported in Table 5. ROA was highest in salmon farming with an average return of 9.2%. All of the agricultural farm types showed a negative average ROA. There were larger within-farm variations between years on salmon farms (SD of 19.1%) than in agricultural farm types[4].

It appears that farm-specific factors drive the majority of variations in financial performance of salmon farms. Approximately half of the financial variability was explained by time-variant, farm-specific factors while 30% could be explained by consistent farm-factors. These findings suggest that uncertain factors like variable weather conditions and time-inconsistent management are more important for determining average financial performance in salmon farming than differences between farms in managerial skills, biophysical resources, etc.

The average profitability quotient (PQ) for agriculture in total was 58, i.e., a return to capital and labour far below their opportunity costs (Table 6). PQ was lowest for sheep with 35, and highest for grain/potatoes (70) and grain/hog (76). Hence, substantial variability existed among farm types in terms of PQ's. The farm types grain/potatoes, grain and grain/hog showed the greatest economic return variability at SD within-farms around 40%. Dairying is often believed to have relatively low income variability over time, and the variability was actually lowest for dairy and milk goat farms.

[4] Due to the potential problems with negative ROA's, financial performance within agriculture will be further discussed using the profitability quotient.

Table 5 Variability in economic returns (return on assets, %)

			Variance components			
Farm type	Mean values	SD within farms[1]	Time-invariant, farm-specific	Time-invariant, region-specific	Time-variant, region-specific	Time-variant, farm specific
Dairy	-9.14	9.96	0.59	0.04	0.11	0.25
Sheep	-25.20	14.30	0.33	0.28	0.21	0.18
Goat	-12.80	14.18	0.53	0.10	0.19	0.18
Grain	-5.14	11.70	0.46	0.10	0.22	0.22
Grain and hog	-0.64	13.11	0.13	0.65	0.14	0.08
Grain and potato	-2.76	18.23	0.27	0.29	0.31	0.13
Aquaculture	9.19	19.11	0.30	0.01	0.18	0.51

[1] Mean of the farms

The farm-specific factors did also drive the majority of variations in financial performance of livestock enterprises (Table 6). The regional components was more important for crop farms than for livestock operations, maybe related to the greater dependency of favourable region-wide weather conditions for financial success in cropping. A larger fraction of variability in financial performance for agricultural businesses than for salmon farms was attributable to temporally consistent factors. The difference in financial performance between farms (within a farm type) was thus strongly related to factors associated with permanent farmer skills and location (soil properties, topography, etc.).

Table 6 Variability in economic returns in agriculture (profitability quotients)

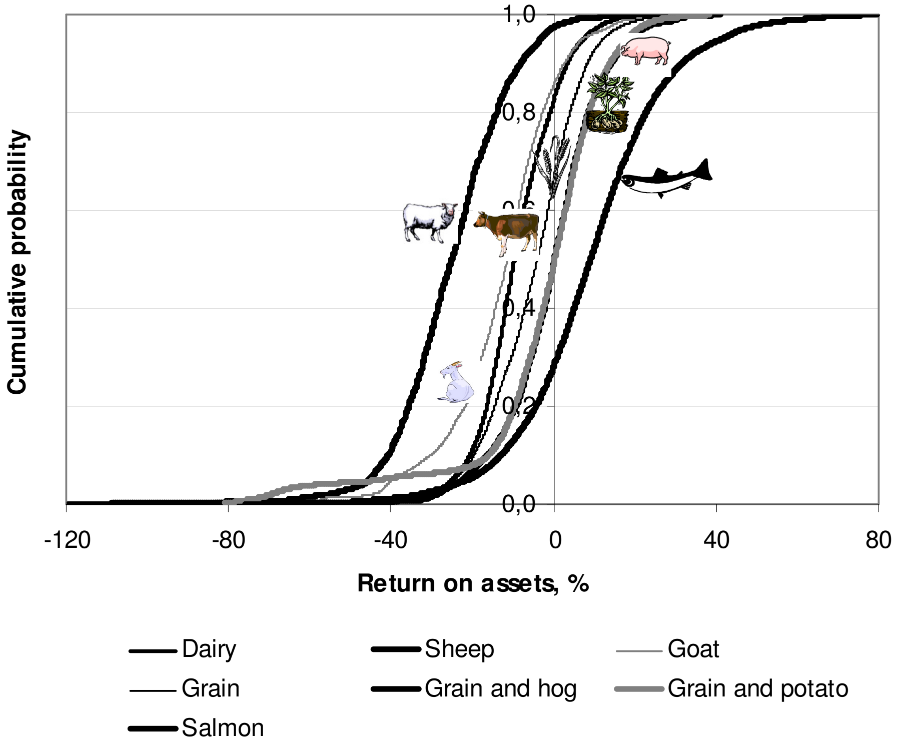
			Variance components			
Farm type	Mean values	SD within farms[1]	Time-invariant, farm-specific	Time-invariant, region-specific	Time-variant, region-specific	Time-variant, farm specific
Agriculture	58	29.4	0.45	0.14	0.07	0.34
Dairy	61	19.2	0.54	0.05	0.12	0.29
Sheep	35	25.1	0.49	0.09	0.17	0.25
Goat	67	21.8	0.44	0.12	0.19	0.25
Grain	53	43.3	0.37	0.28	0.11	0.24
Grain and hog	76	39.0	0.25	0.33	0.19	0.23
Grain and potato	70	43.4	0.31	0.25	0.23	0.21

[1] Mean of the farms

Is Salmon Farming More Risky?

We found in general higher variability in yields, prices and economic returns in salmon farming than in agricultural businesses. But is salmon farming more risky? Fig. 1 shows the empirical cumulative distribution functions (CDF) for ROA's in the businesses.

Fig. 1 Cumulative distribution functions for return on assets in salmon farming and agricultural businesses



ROA from salmon farming was the most variable, since the CDF for salmon is less steep than the agricultural enterprises. However, we should not equate higher variability of returns with more risk. The CDF's show that salmon farming first degree stochastic dominates the sheep, goat and grain/potatoes enterprises, since at any given probability level the value of returns from salmon farming is greater than that from these agricultural enterprises. Salmon farming was preferred to grain/hog by second degree stochastic dominance (SSD), since at any given probability level the accumulated returns from salmon was greater than the accumulated returns from grain/hog. The minimum ROA for the dairy and grain enterprises were higher than the minimum for salmon farming. Then salmon farming cannot dominate dairy and grain in the sense of SSD. However, by inspection of the CDF's, a decision-maker should be extremely risk averse (i.e. give extremely weight to the lower left-tails of the CDF) to rank dairy and grain equally efficient as salmon farming. Out of, e.g., 100 outcomes salmon farming will have highest ROA in more than 96 of them, and the upside gains of salmon farming are substantial.

Conclusions

Results indicate that the year-to-year variability in yields, prices and economic returns at the farm level was larger in salmon farming than in agricultural enterprises. The only exception was higher price variability for potatoes. The variability in livestock enterprises was generally lower than for crop enterprises. Even though salmon farming offered more volatile economic returns than agricultural enterprises, stochastic dominance tests of the distribution of economic returns from the businesses showed salmon farming to be dominant over all agricultural businesses except dairy and grain. The substantial upside gains of salmon farming should also make it more economically attractive than dairy or grain for all except the extremely risk-averse decision-makers. In summary, it appears that the distribution of economic returns in salmon farming was to be preferred to that of agricultural businesses. The findings do not imply that agriculturists should switch to aquaculture. However, since only salmon farming has been attractive from an investor's perspective, it may help to explain why salmon farming has converted from family firms into large corporate ownership, while agriculture has remained in small, family-based firms.

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