A Comparison of Risk Exposure in Aquaculture and Agricultural Businesses

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Abstract— **Agriculture 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 at the farm level. Results indicate a higher farm-level year-to-year variability in yields, prices and economic returns in salmon farming than in agricultural enterprises. The variability in livestock enterprises was generally lower than for crop enterprises. Return on assets was highest in salmon farming with an average annual return of 9.2%. All of the agricultural farm types exhibited a negative average return on assets on average. Stochastic dominance tests of the distribution of economic returns from aquaculture and agricultural farm types showed salmon farming to be the most risk efficient alternative and salmon farming was most attractive from an investor's perspective.**

Keywords— **Risk analysis, variability, Norway.**

I. INTRODUCTION

Agriculture and aquaculture are both biological production sectors that are exposed to widely varying and unpredictable elements of nature, such as uncertainty in biological processes related to weather, diseases, pests, infertility, etc., which cause yield variability. Weather and spatial dispersion in agriculture particularly affects crops and grazing livestock. In contrast, production risk is generally smaller in indoor production of livestock and green house crops that are less exposed to nature's variations. Modern fish farming is essentially a batch production system, as in chicken or feeder-pig-to-finish operations, but fish are produced outdoors, leading to less control of the biological processes than indoors. The biological variability is one of the fundamental causes of price uncertainty. Consequently, the two sectors face many similar economic risks.

However, there are also notable differences. In contrast to agriculture, 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. The two industries operate in different institutional environments. A large number of government interventions in agriculture are common in many countries. The agricultural sector has built institutions and farmer cooperatives that, among other tasks, mitigate risk. In Norway, on which we focus in this study, less favourable agricultural production environments contribute to high cost of production. 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 in a less regulated international market. The conditions along the Norwegian coast are ideal for rearing of salmon. Norway produces close to half of total world production of farmed salmon 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.

We believe a better understanding of risk exposure can be achieved through a comparative risk analysis of agricultural versus aquaculture businesses. Previous studies have suggested that the high sensitivity of the salmon to its environment, together with the harsh and changing conditions in the ocean environment, lead to higher volatility in salmon farming than in land-based meat production [1]. However, to the best of our knowledge, a cross-industry risk comparison of agriculture and aquaculture has not been done before.

The aim of this paper is to compare risk exposure in salmon farming and agricultural enterprises in Norway. This is accomplished by first computing and comparing the variability of yields, prices and economic returns at the farm level by use of an implicit error component model [2] applied to two sets of panel data. Second, we employ a more general framework for addressing risk exposure, the stochastic efficiency methods, using measures of the economic returns of the different types of farms.

II. MATERIALS AND METHODS

A. Detrending procedures

Improving technology and management influence the yield of most biological enterprises, and deviations from expected yields, as measured by trend, may be said to constitute the random variability. No time trend may overestimate variability, while estimation of individual farm-level trends may result in non-robust trend parameters, in particular in short panel data sets.

Another way is to use an error component procedure that implicitly removes any common regional trend from the farm yields series, described in Atwood et al. [2]. This procedure, error components implicit detrending (ECID), has been shown to better describe the reality in most cases than individually detrending farm-level data.

In this study we used a modified version of the ECID procedure, where we have also included the relationship between the national and the regional yield levels. In our ECID approach the decomposition of yield y_{it} at farm i in year t is expressed as:

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

where $\bar{y}_i$ is average yield of farm i, $\bar{y}_R$ is average output in region R (average yield for all farms in region R over all years), $\bar{y}$ is average national output (average yield for all farms over all years), y_{Rt} is the regional yield in year t and ε_{it} is the residuals for farm i. The four variability components in Eq. (1) can be expressed as:

1. Time-invariant, farm-specific deviations, $(\bar{y}_i - \bar{y}_R)$, the average deviation for a farm 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.
2. Time-invariant, region-specific deviations, $(\bar{y} - \bar{y}_R)$, the average deviation of a region from the national yield level, i.e., variation in yields between regions.
3. 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.
4. Time-variant, farm-specific deviations, ε_{it}, the farm residuals, showing variation in yields between years on a farm caused by time-varying factors such as weather variability and variable annual management decisions.

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 relative yield variability we used the coefficient of variation (CV), which equals the standard deviation (SD) divided by 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. (1).

Variance components were calculated by dividing the variance of a specific component by the sum of the variance of the four components in Eq. (1). A variance component represents the variance of a specific component as a fraction of total yield variance in an enterprise.

Estimation of variability in annual farm-level prices was based on the same error component procedure (ECID). All prices were converted to 2004 real Norwegian kroner (NOK, €1≈NOK 8.00) using the Norwegian consumer price index as price deflator.

The ECID procedure was also used for the examination of variability in economic returns. In the comparison of financial performance we employed the rate of return on assets (ROA), measured as return to assets divided by total value of farm assets (return to assets = Net farm income from operations – opportunity cost of unpaid labour).

ROA is the return on all capital invested in the business, since interest on debt capital is not included in net farm income from operations. To find the return to assets the imputed value of unpaid operator and family labour is deducted. Since the financial measure is already in relative terms, we report SD instead of CV for the analysis of economic variability.

Due to space limitations results of the four variance components for yields, prices and economic returns will not be shown. See Flaten et al. [3] for a discussion of these findings, where also financial performance within agriculture are further examined using even more financial measures.

B. Stochastic efficiency analysis

Hardaker et al. [4] 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. We identified risk efficient solutions using first (FSD) and second (SSD) degree stochastic dominance criteria. In order to determine whether a relation of stochastic dominance holds, the distributions have to be characterised by their cumulative distribution functions (CDFs). Variability in economic returns within farms for each of the farm types, estimated as the sum of component 3 and 4 in Eq. (1), was 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. The empirical economic return variables in this study were smoothed using a kernel density function estimator in the Simetar risk simulation program.

C. 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 1000 farms. These farms are located throughout the country (divided into eight regions) and represent a wide range of farm sizes and types. The total data set available for the analysis included 13,000 observations on 1970 farms from 1992 through 2004. Yield and price data were measured at the product level. Financial performance measures were only available at the whole-farm level. To perform analysis of economic returns at the whole-farm level we included the most common farm types in the survey.

Aquaculture was analysed using data from the Norwegian Directorate of Fisheries, which annually compiles data from salmon farms 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. In aquaculture, region is specified in terms of which county the farm belongs to. Ten of Norway's 19 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 3,600 observations.

Both data sets chiefly follow the rationale of conventional accounting, with its use of historical cost for the valuation of long-term assets. 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.

III. RESULTS AND DISCUSSION

A. Yield variability

Salmon farming showed the highest relative yield variability with a CV within farms of 58% (Table 1). The industry has been through periods where diseases significantly have reduced the output and salmon farmed in sea cages are exposed to extremes of weather and constantly changing conditions in the ocean environment.

Table 1 Yield variability

Enterprise	Average yield	CV within farms[a]
Barley, kg/ha	3859	0.27
Oats, kg/ha	4083	0.28
Wheat, kg/ha	4569	0.25
Potato, kg/ha	18,572	0.51
Forage, feed units/ha	3720	0.38
Milk, litres sold/cow	5686	0.09
Sheep meat, kg/winter fed sheep	26.4	0.27
Goat milk, litres sold/goat	499	0.14
Finisher-hog, kg slaughter weight	75.9	0.08
Salmon, kg/m3 cage volume	27.6	0.58

[a] Means of the farms.

Of the agricultural enterprises, only potatoes reached a CV of more than 50%. Forage followed with a CV of 38%. For grain crops the CVs were within the range of 25% to 30%. Rasmussen [5] found a CV close to 20% for grain yields on Danish farms while the CVs were around 10% among cereal growers in England [6].

Among the livestock enterprises, sheep farms showed the highest CVs. Dairy milk, goat milk and hogs tended to have less variability in yields. Low CVs have also been found for milk and hogs in Denmark [5]. It is reasonable that extensive grazing production such as sheep is likely to have more variable yields than intensive livestock production, since the former is more exposed to the effects of variable weather conditions.

B. Price variability

Table 2 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 CVs around 10% to 20%. Market regulations set by farmer cooperatives within the maximum prices set by the government and supply control in milk production have tempered price fluctuations.

Table 2 Product price variability

Enterprise	Mean prices	CV within farms[a]
Barley, NOK/kg	2.27	0.16
Oats, NOK/kg	2.08	0.16
Wheat, NOK/kg	2.77	0.18
Potato, NOK/kg	2.36	0.68
Milk, NOK/L	4.24	0.15
Lamb, NOK/kg	47.96	0.17
Goat milk, NOK/L	6.77	0.11
Hogs, NOK/kg	25.36	0.15
Salmon, NOK/kg	37.93	0.40

[a] Means of the farms.

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. Much higher relative price variability for potatoes than for other agricultural commodities was also found in Denmark [5].

C. Variability in economic returns

Return on assets (ROA) was highest in salmon farming with an average return of 9.2% (Table 3). All of the agricultural farm types showed a negative average ROA. There were larger within-farm variations between years on salmon farms than in agricultural farm types.

In agriculture, ROA was lowest for sheep, and highest for grain/potatoes and grain/hog. The farm type grain/potatoes showed the greatest economic return variability. Dairying is often believed to have relatively low income variability over time, and the variability was actually lowest for dairy farms.

Table 3 Variability in economic returns (ROA, %)

Farm type	Mean values	SD within farms[a]
Dairy	-9.14	9.96
Sheep	-25.20	14.30
Goat	-12.80	14.18
Grain	-5.14	11.70
Grain and hog	-0.64	13.11
Grain and potato	-2.76	18.23
Salmon	9.19	19.11

[a] Means of the farms.

D. Stochastic efficiency results

We found in general higher variability in yields, prices and economic returns for salmon farms than for agricultural businesses. These findings support earlier suggestions of higher volatility in salmon farming than in livestock production [1]. However, we should not equate higher variability of economic returns with more risk. Fig. 1 shows the empirical CDFs for ROAs in the businesses.

The CDFs show that salmon farming first degree stochastic dominates the sheep, goat and grain/potatoes enterprises, since at every possible probability level the value of returns from salmon farming is greater than that from these agricultural enterprises.

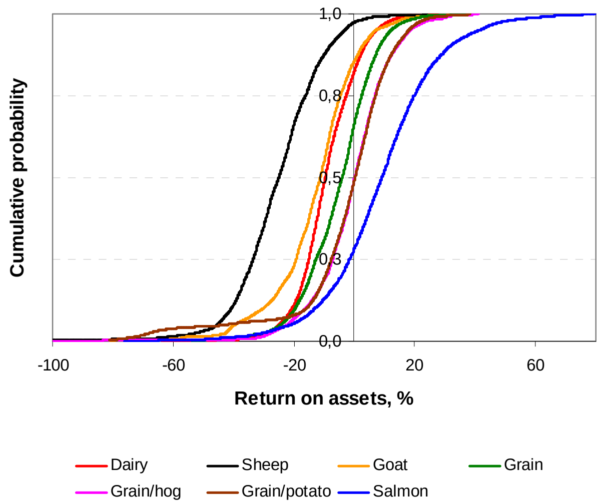

Fig. 1 Cumulative distribution functions for ROA in salmon farming and agricultural businesses

The minimum ROAs for the dairy and grain enterprises were higher than the minimum for salmon farming, implying that salmon farming cannot dominate dairy and grain in the sense of SSD. Salmon farming could not be preferred to grain/hog by SSD, since the accumulated returns from salmon were not greater than the accumulated returns from grain/hog at all of the lower probability levels. However, by inspection of the CDFs, a decision-maker would have to be extremely risk averse (i.e., give extremely high weight to the lower left-tails of the CDF) to rank dairy, grain or grain/hog equally as risk-efficient as salmon farming. Out of, e.g., 100 outcomes salmon farming will have the highest ROA in more than 96 of them, and the upside gains for salmon farming are substantial.

IV. CONCLUSIONS

Our findings suggest that 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 more risk efficient that all agricultural businesses except dairy, grain and grain/hog. The substantial upside gains of salmon farming should also make it more economically attractive than dairy, grain or grain/hog for all except the extremely risk-averse decision-makers.

In summary, it appears that the distribution of economic returns in salmon farming has been preferable (normatively) to that of agricultural businesses. This finding does not imply that agriculturists in Norway 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. The low economic returns to all types of agriculture implies that farming ought to be seen as more than just a way to make money, else few would continue in the agricultural business.

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