Economies of Scale and Scope among Norwegian Dairy and Crop-producing Farms: a flexible technology approach

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Abstract

The aim in this paper is to investigate economies of scale and scope among Norwegian dairy and crop producing farms, controlling for regional differences. Unlike previous studies in which a common technology was assumed, we estimate economies of scale and scope to account for different technologies for specialized and mixed (diversified) farms. Our analysis is based on translog cost functions using farm-level data for the period 1991-2014. The results suggest that both economies of scale and scope persist in Norwegian dairy and crop producing farms. We also find that dairy farms have an economic incentive to integrate dairy farming with crop production in all regions of Norway.

JEL classification: Q10; M22; D22; D24

Keywords: economies of scale and scope; flexible technology, agriculture; cost function

1. Introduction

Livestock production dominates Norwegian agriculture in all regions. About 30% of the farms in Norway are specialized in dairy farming. Only 3% of the total area is under agricultural cultivation and crop production faces a long winter in most regions (October-March) and a short growing season (April-September). Thus, these farms depend heavily on growing grass during the long summer days (Almås and Brobakk, 2012). Because milk production is subsidized, to avoid overproduction, the government-imposed quotas in 1983 to limit the amounts of milk farmers could sell. Initially, farmers who had no milk quota could not enter the industry and those wishing to expand production could not do so. However, from 1996, the government implemented a system for restricted redistribution of milk quotas using region-based regulated quota sales. Despite this easing of the rules, the ability of a farmer to adjust the scales of their milk production to changes in economic and technological conditions remains somewhat constrained. Agricultural economists have argued that this has come at a cost since the exploitation of scale economies is essential for agricultural productivity growth. Structural change in the Norwegian dairy sector has been slower than in other Nordic countries and quota regulations appear to have slowed the expansion of successful dairy farms, with the result that growth in output and productivity has been held back (Kumbhakar et al., 2008; Flaten, 2002; Løyland and Ringstad, 2001).

In order to exploit the economies of scale and scope, Norwegian farmers may have opportunities to add a dairy enterprise to existing crop production activities or to add crop production to an existing dairy enterprise. Thus, the aim of the study is to analyze the potential economies of scale and scope in terms of cost reduction in the Norwegian dairy and crop farms. The study also addresses the effect of location (region) and farm size on economies of scope. We used Norwegian farm-level data from 1991-2014 to estimate translog cost functions.

Panzar and Willig (1981) and Baumol et al. (1982) introduced the concept of economies of scale (volume of output) and scope (product mix) to characterize the effect of size and output diversification, respectively. Subsequently, estimating economies of scale and scope of the multi-product firm has received much interest in the economics literature in different sectors. For instance, in telecommunications (Bloch et al., 2001), education (Cohn et al., 1989; Worthington & Higgs, 2011), banking (Berger et al., 1987; Awdeh et al., 2016), water (Garcia et al., 2007), healthcare (Given, 1996; Weaver & Deolalikar, 2004), and utilities (Filippini & Farsi, 2008). There are a number of studies estimating economies of scale and scope in agriculture. For instance, Ray (1982) estimated the overall cost reduction in US livestock and crop farms and reported that joint production of the two outputs has an economic advantage. Leathers (1992) found that there were economies of scale and scope between milk and crop outputs in the US State of Wisconsin. Mafoua (2002) estimated the economies of scale and scope of US cash grain farms and suggested that it was less expensive to produce corn, wheat, and soybeans on the same farm than on separate farms. Jin et al. (2005) investigated the economics of scale and scope for China's agricultural research system. Wimmer and Sauer (2016) studied Bavarian dairy farms over the years 2006 and 2014 and reported economies of scale of 1.55 and average cost saving of 77% when milk, crop, and livestock were jointly produced. Using a homothetic production function, Løyland and Ringstad (2001) found that, during the period 1972-1996, there were potential cost reductions by exploiting scale economies and structural changes in Norwegian dairy farming.

These earlier studies give useful insights into the economies of specialization and diversification. Such economies arise from various sources, for example, indivisibilities and the spreading of fixed costs; reducing costs by spreading labor demands over a range of products and reducing the costs by buying larger volumes of inputs. Farms operate more economically when the high fixed costs of specialized machines are spread over a larger output volume (Fernandez-Cornejo et al., 1992).

The most common approach used in previous studies has been to use a quadratic or a translog cost function and to estimate the functions for each farm type jointly. In these studies, estimating a cost function that includes multi-product output of farms jointly has some drawbacks because a common technology among farm types is assumed. The question is whether the specialized farms used technology identical to that used by diversified farms. If the technologies are different, yet a common technology is assumed, the results are likely to be biased. For instance, results suggesting the presence of economies of scope may actually be a result of scale economies (see Triebs et al., 2016 for details). If the technology is different between the farm types, a separate cost function must be estimated for each. Triebs et al. (2016) introduced a method, known as the flexible technology dummy variable approach, which allows us to test for differences in technology between types of farms. For example, by introducing dummy variables for each farm type, we can estimate cost functions for all farm types simultaneously. Another advantage of this method is that it avoids the problem of zero values for output in a translog function.[1] Previous studies have shown that replacing zero values by some arbitrary number can influence the results (see, for example, Pulley and Humphrey, 1993). However, by using the flexible technology dummy variable approach introduced by Triebs et al. (2016), we can replace zero values with any small number without affecting the results and thus avoid the extreme extrapolation problem mentioned in Evans and Heckman (1984).

In this study, we used the flexible technology estimation approach, proposed by Triebs et al. (2016). The study appears to be the first that applies the flexible technology estimation approach for a scale and scope study of agriculture.

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[1] In scope studies, farm output is sometimes zero. This is a problem in the translog function approach because the logarithm of zero is not defined so that missing values will be created, which reduces the number of observations for analysis. The common way to handle this problem is to replace zero values by a small number. We can use a quadratic function, but if the number of zero values represents a large proportion of the total number of sample observations, the parameter estimates may be biased (see for example Battese, 1997).

The rest of the article is organized as follows: in Section 2 we address theoretical approaches to measuring scale and scope while in Section 3 we discuss model specification. Section 4 includes a discussion of the data and definitions of the variables used in the cost function.Section 5 discusses estimation procedure and results. Section 6 concludes the paper.

2. Conceptual framework

2.1. Cost function

This section builds on approaches proposed by Baumol et al. (1982) and Triebs et al. (2016). In this study there are two outputs (dairy and crop) and three farm types: mixed farms (M), which produce both crop and dairy outputs; dairy farms (D), specialized in the dairy sector, and crop farms (P), specialized in crop production.

Let $T = \{M, D, P\}$ be the set of farm types. Mixed farms produce the entire output vector $y = (y_P \; and \; y_D)$, while dairy (D) and crop farms (P) produce output vectors y_D and y_P, respectively. We allow different farm types to have different underling production possibilities. As discussed in detail in Triebs et al. (2016), a flexible cost function for different farm types is defined as:

$$C = \begin{cases} c^m(y, w) \\ c^d(y_D, w) \\ c^p(y_P, w) \end{cases} \tag{1}$$

where C, w, y are the vectors of total cost, input prices and outputs, respectively. Equation (1) allows the cost function to be flexible across farms by allowing technologies to differ across farm types. $c^m(y, w), c^d(y_D, w)$, and $c^p(y_P, w)$ are the costs for mixed, dairy, and crop farms, respectively. This specification allows for potentially distinct technologies associated with the production of each farm type. The technologies in (1) can be written with the use of dummy variables as:

$$C(y, w\,) = mdum * c^m(y, w, \tau_m) + ddum * c^d(y_D, w, \tau_d) + pdum * c^p\big(y_P, w, \tau_p\big) + R \tag{2}$$

where w, y, τ are the vectors of input prices, output, and farm specific unknown technology parameters, respectively. $mdum$, $ddum$, and $pdum$ are dummy variables for mixed, dairy, and crop farms, respectively. The dummy variables $mdum$, $ddum$ and $pdum$ take one if the farm is mixed, dairy, and crop farms, respectively. We also include dummy variables for five regions[2] (R) of Norway to capture location differences with one region dropped during the analysis (to make it possible to estimate).

Equation (2) can be estimated in three different ways. The most straightforward way is to estimate a separate regression for each farm type and estimate the economies scale and scope following the procedure of Färe (1986) (see for example Garcia et al., 2007). The separate estimation means the creation of subsamples with the subsequent problem of reduced degrees of freedom. Moreover, a separate regression approach always assumes the existence of different technologies without allowing the possibility of hypothesis testing with regard to whether this assumption is valid (Triebs et al., 2016). The other possibility is to estimate a single translog or quadratic model for all farm types assuming a common technology in all farm types. As explained in detail in Triebs et al. (2016), the presence of heterogeneous technologies leads to biased estimates of scale and scope economies. For comparison purpose, we first followed the approach used in previous studies and estimated costs under the assumptions that all farms of a given farm type used the same technology (Model 1). Then we estimated costs assuming that all farms of a given type used different technologies (Model 2). Finally, we estimate costs assuming that all farms of a given farm type used flexible technologies (Model 3). For the latter model, we used dummy variables using the approach recently introduced by Triebs et al. (2016) and tested for a common technology.

2.2. Scale economies

Equation (2) can be fitted to quadratic or translog functions (among other function forms) that can be estimated using OLS/GLS. We can compute economies of scale and scope based on the textbook definitions. The coefficient of economies of scale can be calculated based on the inverse relationships between the average cost per unit of dairy and the output level, which is simply the inverse of the cost-output elasticity (Christensen and Greene, 1976). For multiple-output (mixed)

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[2] Norway has five geographical regions: **Northern Norway** (comprising the counties of Finnmark, Troms, and Nordland); **Central Norway** (comprising Nord-Trøndelag , and Sør-Trøndelag); **Western Norway** (comprising Møre og Romsdal, Sogn og Fjordane, Hordaland, and Rogaland); **Eastern Norway (**comprising Akershus, Oppland, Oslo, Telemark, Hedmark, Vestfold, Østfold, Hedmark, and Buskerud); and **Southern Norway** (comprising Vest-Agder and Aust-Agder)

farm the economies of scale are the inverse of the sum of all partial cost elasticities (Panzer and Willig, 1977).

Economies of scale for specialized dairy farms (Scy_d) = $\left[\frac{\partial lnc^d(y_D,w,\tau_d)}{\partial lny_D}\right]^{-1}$ (3)

Economies of scale for specialized crop farms (Scy_p) = $\left[\frac{\partial lnc^p(y_P,w,\tau_p)}{\partial lny_P}\right]^{-1}$ (4)

Economies of scale for mixed farms (Scy_m) = $\left[\frac{\partial lnc^d(y_D,w,\tau_d)}{\partial lny_D} + \frac{\partial lnc^p(y_P,w,\tau_p)}{\partial lny_P}\right]^{-1}$ (5)

Equations (3-5) allow global economies of scale to depends on the technology used in the three farm types in Model 2 and Model 3. However, a further drawback of the conventional common technology approach (Model 1) is that it is not feasible to estimate the economies of scale for single output farms (see Triebs et al., 2016 for details). Therefore, we follow the standard approach of Baumol et al. (1982) and calculate product-specific economies of scale. We first calculated average incremental cost, $AIC\ (y_i)$ for producing output y_i as:

$$AIC\ (y_i) = \frac{(C(y,w) - C(y_{N-i},w)}{y_i} \text{ for } i = D, P \qquad (6)$$

where $C(y,w)$ is the total cost of producing the two outputs and $C(y_{N-i},w)$ is the total cost of producing the units of the i^{th} output and y_{N-i} is a vector with a zero component in place of y_i. Thus, in the case of a single product, the economies of scale are measured by the average incremental cost divided by the marginal cost:

Product-specific economies of scale $Sc(y_i) = \frac{AIC_i(y,w)}{\frac{\partial C(y,w)}{\partial y_i}} = \frac{AIC\ (y_i)}{MC\ (y_i)}$ *for i= D, P* (7)

where $MC\ (y_i) = \frac{\partial C(y,w)}{\partial y_i}$ is the marginal cost of producing y_i units of output. Economies of scale (diseconomies) or constant returns to scale exists when estimated economies of scale in equation 3, 4, 5, and 7 are >1(< 1) or = 1, respectively.

2.3. Scope economies

Scope economies are the benefit that arises from the joint production of the crop and dairy outputs using multi-product technologies. The scope economy can be measured the difference between the cost of producing both outputs on one farm and the cost of producing the same outputs on two specialized farms (see Panzar and Willig,1981 and Baumol et al.,1982), that is:

$$\text{Economies of scope } = \frac{c^{d}(y_D,w,\tau_d) + c^{p}(y_P,w,\tau_p) - c^{m}(y,w,\tau_m)}{c^{m}(y,w,\tau_m)} \tag{8}$$

If joint production is less expensive than separate dairy and crop production, scope economies exist. If economies of scope are > 1, cost savings can be achieved from mixed farming (diversification of output). If economies of scope are < 1, it is cheaper to produce dairy and crop outputs in a separate farm.

3. Model specification

In this section, we describe the specification of our three models (Model 1, 2 and 3) and the estimation method. We used unbalanced panel data, but to simplify the notation, we have dropped the subscripts *i* and *t*, where *i* would denote farm with *i* = 1,…, *n* and *t* time with *t* =1, …, *t*. We chose a translog specification for Models 1 to 3 because of its flexibility (Christensen et al., 1973). Equation (2) can be written in the translog cost function as:

$$\begin{aligned}
\ln C = mdum * {} & \{\propto_0^m + \beta_1^m \ln y_D + \beta_2^m \ln y_P + \textstyle\sum_{j=2}^{k} \gamma_j^m \ln \breve{w}_j + \\
& \textstyle\sum_{j=1}^{m} \theta_{1j}^m \ln y_D \ln \breve{w}_j + \sum_{j=1}^{m} \theta_{2j}^m \ln y_P \ln \breve{w}_j + \rho_{12}^m \ln y_D \ln y_P \\
& \tfrac{1}{2}\left[\rho_1^m \ln y_D \ln y_D + \rho_2^m \ln y_P \ln y_P + \textstyle\sum_{j=2}^{k}\sum_{l=2}^{k} \delta_{lj}^m \ln \breve{w}_l \ln \breve{w}_j\right]\Big\} \\
ddum * {} & \{\propto_0^d + \beta^d \ln y_D + \textstyle\sum_{j=2}^{k} \gamma_j^d \ln \breve{w}_j + \sum_{j=1}^{m} \theta_j^d \ln y_D \ln \breve{w}_j \\
& \tfrac{1}{2}\left[\rho^d \ln y_D \ln y_D + \textstyle\sum_{j=2}^{k}\sum_{l=2}^{k} \delta_{lj}^d \ln \breve{w}_l \ln \breve{w}_j\right]\Big\} + \\
pdum * {} & \Big\{\propto_0^p + \beta^p \ln y_P + \textstyle\sum_{j=2}^{k} \gamma_j^p \ln \breve{w}_j + \sum_{j=1}^{m} \theta_j^p \ln y_P \ln \breve{w}_j \\
& \tfrac{1}{2}\left[\rho^p \ln y_P \ln y_P + \textstyle\sum_{j=2}^{k}\sum_{l=2}^{k} \delta_{lj}^p \ln \breve{w}_l \ln \breve{w}_j\right]\Big\} + \varphi R
\end{aligned} \tag{9}$$

where C is the total cost incur red by the farm *i* in year *t*, w_j represents the price of inputs *j;* $\ln \breve{w}_j = \ln w_j - \ln w_3 \ (\forall j)$ discussed in the next paragraph, y_D is the quantity of dairy output*;* y_P is the quantity of crop output. *m* and *k* shows the number of outputs and inputs used in each farm type, respectively. We include regional dummy variables *R* for five regions of Norway to capture the effect of location. All Greek letters are parameters to be estimated and *m*, *d*, and *p* on the parameters indicate mixed, dairy, and crop farms, respectively. *mdum*, *ddum*, and *pdum* are the dummy variables for mixed (diversified) farms, dairy specialized farms, and crop specialized farms, respectively. The dummy variable approach makes it possible to estimate the three cost functions jointly and test properties of the technology.

We can estimate the models used in previous studies for comparison with the model in (9). If the parameters for each farm type technology are different, we can estimate (9) as three separate translog cost functions and the share equations (Model 2). However, we cannot test the different technology assumption because they are estimated separately and the variance and covariance vary across farm type, thus, it is not possible to impose restrictions on farm type technologies (Triebs et al., 2016). We can estimate one translog cost function (Model 1) assuming common (the same) technology by dropping *mdum*, *ddum*, and *pdum* from equation (9).

Economic theory imposes linear homogenous and symmetry restrictions on the input price parameters. Homogeneity of degree one in input prices is imposed by the restrictions $\sum_j^k \gamma_j = 1, \sum_j^l \theta_{jl} = \sum_{j'}^l \delta_{jl} = 0$; while symmetry implies $\rho_{12} = \rho_{21}, \delta_{jl} = \delta_{lj}$ for farm type *m*, *d*, and *P* and for $\forall\ j$. Given equation (9), the conditional factor demand equations are derived in share equation (10) for input k by using Shephard's lemma as follows:

$$s_k = \frac{\partial lnC}{\partial lnw_j} = \frac{x_j w_j}{C} = mdum * \left[\gamma_j^m + \theta_{1j}^m \mathrm{ln} y_P + \theta_{2j}^m \mathrm{ln} y_D + \sum_{j=2}^k \delta_{lj}^m \mathrm{ln} \breve{w}_j\right] + \\ ddum * \left[\gamma_j^d + \theta_l^d \mathrm{ln} y_D + \sum_{j=2}^k \delta_{lj}^d \mathrm{ln} \breve{w}_j\right] + \\ pdum * \left[\gamma_j^p + \theta_l^p \mathrm{ln} y_P + + \sum_{j=2}^k \delta_{lj}^p \mathrm{ln} \breve{w}_j\right] \tag{10}$$

Since $\sum_{k=1}^k s_k = 1$, the cost share equations must satisfy the adding-up property. However, this property implies the same restrictions as linear homogeneity in the cost function, so we imposed both properties by dividing the quantity of all inputs by the quantity of one of the inputs. Then, in equations (9) we imposed the homogenous restriction by re-defining both the left- and right-hand sides of the equations as follows: $\mathrm{ln}\breve{w}_j = \mathrm{ln}w_j - \mathrm{ln}w_3\ (\forall j)$ and $lnC = \mathrm{ln}(C/w_3)$. This approach also implies that one of the share equations (input 3) is automatically dropped. The parameters of the dropped equation can be recovered from the homogeneity restrictions discussed above.

After adding classical error terms in the cost function and the cost share equations, we estimated a system of the cost function and share equations (9 and 10) using the iterated seemingly unrelated regression (SUR) technique (Zellner, 1962). The advantage of estimating the cost function (9) together with the input demand functions (10) is that the inclusion of more information in the form of share equations makes the estimates more efficient since we add the share equations but do not increase the number of parameters.

We tested whether the restriction of the three farm type technologies to a single common technology (Model 1) is valid with a likelihood ratio (LR) test by imposing the following restrictions:

$$\begin{aligned} \mathrm{H}_0:\quad & \propto^m \equiv \propto^d \equiv \propto^p \\ & \beta^m \equiv \beta^d \equiv \beta^p \\ & \gamma^m \equiv \gamma^d \equiv \gamma^p \\ & \theta^m \equiv \theta^d \equiv \theta^p \\ & \rho^m \equiv \rho^d \equiv \rho^p \\ & \delta^m \equiv \delta^d \equiv \delta^p \end{aligned} \tag{11}$$

4. The Data

The data set used is a farm-level unbalanced panel data set with 14 357 observations from 2219 specialized crop farms, 5929 specialized dairy farms, and 6209 mixed farms during the period 1991-2014. The data include production and economic data collected annually in all regions of Norway by the Norwegian Institute of Bioeconomy Research (NIBIO). Participants are selected randomly from the register of grants distributed by the Norwegian Agricultural Agency. Survey participation is voluntary. No upper limit exists as on the number of years a holding may be involved in the survey. However, a farmer included in the survey may not be more that 70 years old. To accommodate panel features in estimation, we included only those farms for which at least three consecutive years of data were available.

The output includes both dairy production (y_D), which represents total farm revenue from milk and dairy products, exclusive of direct government support, and crop production (y_P), comprising the total farm revenue from crop products of barley, wheat, oats, oilseeds, and forage, also exclusive of direct government support. Silage and hay are considered as input on specialized dairy farms, moreover, grazed grass is not included as a crop for both mixed and specialized dairy farms. All output is valued in Norwegian kroner (NOK), deflated to 2014 revenues using the consumer price index (CPI).

The four inputs used to estimate the share equations are land (both owned and rented) in hectares, labor, variable inputs and capital inputs. Labor (x_2) is measured as the total labor hours used on the farm, including hired labor, owners' labor, and family labor. Variable inputs (x_3) include such as fertilizer, seed, veterinary, medicine, and pesticide, are registered by their costs of purchase in NOK deflated to 2014 price levels by an index for variable cost items figure from NIBIO calculated at 2014 price levels. Capital input (x_4) is maintenance and running (hiring) costs, depreciation and interest costs on the total capital stock (3%) deflated by an index for fixed cost items from NIBIO and calculated at 2014 price levels.

The translog cost function in equation (9) is specified with four input price variables (w_j) for land, labor, materials and capital costs. Land price is the actual or estimated rental value of the land; the price of labor is the wage for hired labor. We computed the implicit prices (opportunity costs) of owned land and family labor based on data for farm-level rents and wages provided by NIBIO. The price of material and capital costs were constructed as Laspeyres indices based on figures provided by NIBIO (Budjettnemnda for jordbruket, 2016). Table 1 provides descriptive statistics by farm type. The table shows that there are important differences across the three farm types and that there are large variances within each group.

Table 1. Descriptive statistics of the three farm types and pooled data, 1991-2014

Variables and symbol	Dairy farms		Crop farms		Mixed farms		All farms	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total cost (NOK), *TC*	1 047 044	556 052	368 048	210 348	841 332	350 693	853 135	489 546
Dairy output (NOK), y_D	877 366	614 157	-	-	455 903	327 927	559 490	544 987
Crop output (NOK), y_P	-	-	310 292	217 154	215 037	126 772	140 956	171 017
Price of land (NOK/hectare), w_1	109	66	138	59	93	50	106	60
Land price (NOK/hour), w_2	115	37	110	35	92	22	104	33
Price of variable inputs (index), w_3	71	21	66	20	58	15	65	19
Price of capital, w_4	83	11	81	11	77	8	80	10
Land in hectare, x_1	26	15	31	18	21	10	25	14
Labour in hours, x_2	3 353	774	908	456	3277	637	2943	1101
Variable inputs (NOK), x_3	314 035	213 430	85 979	58 778	279 128	172 426	263 691	195 529
Capital inputs (NOK), x_4	315 172	210 738	140 039	92 890	240 158	132 309	255 662	175 711
Trend, *t*	1= year 1991							
Sample size, *n*	5 929		2 219		6 209		1 4357	

NOK= Norwegian Kroner

5. Estimation and results

5.1. Cost function and specification test results

The translog cost function was estimated using STATA® version 14. A series of hypotheses about the nature of the model and the consistency of the cost function with its properties were tested using likelihood ratios (LRs). We tested the characteristics of the technology with the result that a Cobb-Douglas technology specification was rejected. Thus, we used the translog production function for our empirical analysis. Table 5 (in the appendix) gives the estimated coefficients and standard errors of the cost functions for the three models. The first three rows in each column give the constants specific to each farm type. Model 1 represents the conventional common technology case. The parameter estimates from this model were derived with arbitrarily small numbers (0.000 001) in place of zeros in the data. For Model 2 the parameters shown were estimated allowing for different technologies for each farm type by using three separate regressions. Finally, the flexible technology model results for Model 3 are shown. Note that, even though the estimates for the three farm types for Model 3 are given in different columns, all the parameters were estimated using a single regression following the dummy variable approach (Triebs et al., 2016)

The goodness of fit measures for the translog cost functions at the bottom of Table 5 are satisfactory for all models, but highest for Model 3. The coefficients, representing estimated cost elasticities are very similar for Models 2 and 3. In contrast, the coefficients for Model 1 are quite different compared to the other two models, supporting the finding of Triebs et al. (2016) that replacing zeros in the data with arbitrary numbers leads to inconsistent results.

We tested whether the restriction of the three farm type technologies to a single common technology (Model 1) is valid. We rejected the null hypothesis in equation (10) at the 1% level that the technologies are the same across the different farm types (Table 6 in the Appendix). In seeming unrelated regression (SUR) models, an often-used specification test is the Breusch-Pagan test of independent errors. The null hypothesis is that there is no contemporaneous correlation, for details see Verbon (1980). The Breusch-Pagan test of whether the residuals from the four equations are an independent indicated that the residuals were statistically independent.

5.2. Economies of scale and scope

Estimates of the economies of scale and scope for the three models are reported in Table 2. The estimates were evaluated at the sample means. All models show increasing returns to scale for all farm types. This result is as expected, given the restriction on the scale of production and it is in line with other research results, for instance, Atsbeha et al. (2015) and Løyland and Ringstad (2001). Rasmussen (2010) reported increasing returns to scale for Danish crop, dairy, and pig farms.

Table 2

Economics of scale and scope at the sample means for the three models

	Model 1* Zero value =0.00 001	Model 2	Model 3
Scale Dairy farms	1.69	2.19	2.17
Scale Crop farms	2.04	1.60	1.68
Scale Mixed farms	2.12	1.98	1.91
Scope	0.38	0.29	0.22

Mode 1 = Common technology (zero values replaced by 0.00001), Model 2 = Separate regressions, and Model 3 = Farm type flexible technology.

Table 2 also shows the economies of scope estimates at the sample means for the three models. All model results indicate the presence of economies scope. Thus, if we consider the flexible technology model (Model 3), a joint production of crop and dairy reduces total cost by 22% on average. The estimated economies of scope from the separate technology assumption (Model 2) show economies of scope of 29%.

The estimated economies of scope from the conventional common technology approach with zeros replaced with small numbers (Model 1) are much higher (38%) than those for Models 2 and 3 and seem somewhat unrealistic. However, it seems that the result may not be sensitive to the value chosen to replace the zero values since we found almost identical results when we replaced the zero values with either 0.001 or 0.00 001 value. Triebs et al. (2016) reported different results for replacing zero values with different small numbers.

There is no research conducted using flexible technology approach in the agricultural sector (Model 3) for comparison. However, our results for Model 1 are broadly in line with other research in the literature estimated using conventional common technology approach. For instance, Melhim and Shumway (2011) reported economies of scope 29% for the US dairy farms and crop farms. Chivas and Aliber (1993), based on results from analysis of 545 Wisconsin farms, recommend the joint production of both crops and livestock on the same farm. Mafoua (2002) reported 27% cost savings from producing corn, wheat, and soybeans on the same farm in the USA.

5.3. Economies of scope for regions and farm size

Table 3 shows the economics of scope for the Norwegian regions for the flexible technology model (Model 3). All regions have an economic advantage joint production of the crop and dairy outputs. The result is in line with other studies. For instance, Chivas and Aliber (1993) reported the existence of economies of scope for nine agricultural districts of Wisconsin. Our lowest economies of scope estimate were for the southern region of Norway (0.17) while the highest economies of scope estimate were for the western region (0.26) followed by the central region (0.25). These results imply that farms located in the western region have a more advantage for the joint production of dairy and crop compared to farms located in the other regions. This could be due to differences in the availability of agricultural land in the Norwegian regions, for example, Rogaland in the Western Norway has a relatively high share of surface cultivated land.

Table 3

Economies of scope for different regions for the flexible technology model (Model 3)

	Mean	Std. Dev.	Sample size
Eastern Norway	0.22	0.32	4874
Southern Norway	0.17	0.33	2292
Western Norway	0.26	0.26	2826
Central Norway	0.25	0.25	2523
Northern Norway	0.21	0.21	1842
Total	0.22	0.22	14357

Table 4 shows the economies of scope for small and larger farms for the flexible technology model (Model 3). The result shows that all farms of all sizes have the incentives for diversification and that the economies of scope appear to increase only slightly with farm size.

Table 4

Economies of scope for farm size using the flexible technology model (Model 3)

	Mean	Std. Dev.	Sample size
Below 30 hectare	0.22	0.36	10552
Above 30 hectare	0.25	0.23	3805
Total	0.22	0.22	14357

Previous studies in the literature have provided mixed evidence on the effect of farm size on the economies of scope. For instance, Mafoua (2002) reported economies of scope of 0.28 for large farms and 0.05 for small farms for mixed farming of three agricultural products. However, Chavas and Aliber (1993) reported the degrees of scope economies decrease with farm size Wisconsin (USA). Our finding might be reasonable because the difference between small and large farms in Norway is small compared to dairy and crop producing farms in other countries such as the USA.

6. Conclusions

We examined the economies of scale and scope in Norwegian dairy and crop farms over the period 1991-2014 using the latest flexible technology approach. Two alternative previous approaches (a common technology and separate technology) were also used for comparison. We obtained the best-fit economies scale and scope and were able to test for differences in technology with the flexible technology approach. The results indicate that economies scale and scope exist in dairy and crop farms in all regions of Norway. The implication of the economies scale result is there is a proportionate saving in cost for farms that are able to increase the output of crop and dairy production. Our findings on scope economies imply that it is less expensive to produce both crop and dairy on the same farm rather than on separate farms. Both dairy and crop farms in all region and all farm sizes have incentives to diversify production. Larger farms appear to have somewhat greater benefits from diversification of production that do smaller farms, and farms located in the western regions have relatively higher scope economies compared to farms in other regions of Norway.

The above conclusions must be tempered by several limitations of our analysis. First, while we estimated the levels of economies of scale and scope, we have not investigated the sources of these economies. However, there is evidence in the literature that multi-output farms lower the cost of production by spreading fixed costs over two or more types of production (see for instance Baumol et al., 1982; Mafoua, 2002). Anderson and Helgeson (1974) reported that sharing of labor and capital resources were the main forms of cost saving from product diversification. A second limitation of our work is that we have limited the scope analysis to two forms of production (dairy and crop). Conceptually, the analysis could include several products. However, there might be some estimation challenges when extending to more kinds of production. Each of the limitations of this study suggests important topics that could benefit from further study.

With these, limitations in mind the estimated economies scale and scope findings, are in according with our expectations since there are policies in place in Norway that restrict opportunities for farms to expand and diversify production. Most notably, milk quota restricts the milk output in all regions and the farm size is too small compared to other countries. Quota regulations and other measures impede output expansion of farms and reallocation of output between farms (Kumbhakar et al., 2008). Structural change in the Norwegian dairy sector is slower than in other Nordic countries owing to government policy that favors small farms and their wide geographic distribution (Atsbeha et al., 2015; Flaten, 2002). Economies of scale are large in the Norwegian dairy farm because of agricultural policy, in particular, the quota system and other regulations, limit farm expansion and structural change in agriculture. Hence, there are likely to be large hidden costs of these policies which the Norwegian society has to pay (Løyland & Ringstad, 2001).

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Appendix

Table 5

Parameter estimates of the translog cost function for the three models

Parameter	**Model 1**	**Model 2**			**Model 3**		
	All farms	Mixed farms	Dairy farms	Crop farms	Mixed farms	Dairy farms	Crop farms
mdum					-0.04***		
					(0.01)		
ddum						0.15***	
						(0.01)	
pdum							-1.22***
							(0.13)
lyD	0.24***	0.43***	0.45***		0.44***	0.45***	
	(0.00)	(0.00)	(0.00)		(0.00)	(0.00)	
lyP	0.23***	0.07***		0.62***	0.09***		0.59***
	(0.00)	(0.00)		(0.01)	(0.01)		(0.01)
$\ln\breve{w}_1$	0.03***	0.03***	0.00***	0.03*	0.00	0.00***	0.10***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.001)	(0.00)
$\ln\breve{w}_2$	0.37***	0.36***	0.32***	0.40***	0.30***	0.31***	0.20***
	(0.00)	(0.00)	(0.00)	(0.03)	(0.00)	(0.00)	(0.00)
$\ln\breve{w}_4$	0.28***	0.28***	0.35***	0.74***	0.45***	0.36***	0.45***
	(0.00)	(0.00)	(0.00)	(0.02)	(0.00)	(0.00)	(0.00)
ly11y1	0.02***	-0.09***	-0.05***		-0.08***	-0.05***	
	(0.00)	(0.01)	(0.01)		(0.01)	(0.01)	
ly21y2	0.02***	-0.02		-0.03*	-0.00		- 0.04**
	(0.00)	(0.01)		(0.02)	(0.02)		(0.01)
ly11y2	-0.00***	-0.12***			-0.13***		
	(0.00)	(0.01)			(0.01)		
lw1lw1	0.02***	0.01***	0.01***	0.08***	0.01***	0.01***	0.07***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
lw2lw2	-0.05***	0.21***	0.21***	0.01	-0.01***	0.21***	0.04*
	(0.00)	(0.01)	(0.01)	(0.02)	(0.00)	(0.01)	(0.02)
lw4lw4	-0.09	0.09***	-0.03***	-0.12***	0.10***	-0.03***	-0.09***
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
lw2w1	-0.00	-0.01***	-0.01***	-0.04***	-0.01***	-0.01***	-0.03***
	(0.00)	(0.00)	(0.00)	(0.0)	(0.00)	(0.00)	(0.00)
lw2w4	0.09***	-0.13***	-0.10***	0.07***	-0.15***	-0.12***	0.09***
	(0.004)	(0.007)	(0.006)	(0.012)	(0.009)	(0.006)	(0.09)

Parameter	**Model 1**	**Model 2**			**Model 3**		
	All farms	Mixed farms	Dairy farms	Crop farms	Mixed farms	Dairy farms	Crop farms
lw1w4	-0.02***	-0.01***	-0.02***	-0.06***	-0.02***	-0.02***	-0.07***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
ly1w1	-0.00***	-0.00***	0.01***		-0.00***	0.01***	
	(0.00)	(0.00)	(0.00)		(0.00)	(0.00)	
ly1w2	0.00***	-0.10***	- 0.11***		-0.10***	-0.11***	
	(0.00)	(0.00)	(0.00)		(0.00)	(0.00)	
ly1w4	-0.00***	-0.00	0.02***		0.00	0.03***	
	(0.00)	(0.00)	(0.00)		(0.00)	(0.00)	
ly2w2	-0.00***	- 0.02***		-0.01***	- 0.02***		-0.04***
	(0.00)	(0.00)		(0.00)	(0.00)		(0.00)
ly2w4	0.00	0.05***		-0.03***	0.05***		-0.00
	(0.00)	(0.00)		(0.00)	(0.00)		(0.00)
Eastern R	0.01	-0.00	-0.01	0.18	0.01	-0.02**	0.311
	(0.01)	(0.01)	(0.01)	(0.18)	(0.01)	(0.01)	(0.13)
Southern R	-0.02**	-0.04***	-0.07***		-0.02	-0.07***	
	(0.01)	(0.01)	(0.01)		(0.01)	(0.01)	
Western R	-0.05***	-0.05***	-0.08***		-0.03***	-0.09***	
	(0.01)	(0.01)	(0.01)		(0.01)	(0.01)	
Central R	0.01	-0.01	-0.01	0.09	0.00	-0.01	0.23
	(0.01)	(0.01)	(0.01)	(0.18)	(0.01)	(0.01)	(0.13)
Constant	0.063***	-0.374***	0.150***	-1.46***			
	(0.01)	(0.01)	(0.01)	(0.18)			
Observations	14357	6209	5930	2219	14357		
Adj R^2	82.02***	76.59	64.67	70.60	93.32		
LM	5746***	2011	2608	1384	4439		
RMSE	0.22***	0.15	0.20	0.27	0.20		

Note: Standard errors in parentheses * $p<0.05$, ** $p<0.01$, *** $p<0.001$, LM (Lagrange multiplier statistic)
Model 1: Common technology; Model 2: Separate regression; Model 3: Farm-type flexible technology.

Table 6

Likelihood-ratio test for common technology

Statistical test	Model 1 Common technology			Model 3 Farm-type flexible technology			Decision
	Chi2	DF	P	Chi2	DF	P	
$\propto^{m} \equiv \propto^{d} \equiv \propto^{p}$ $\beta^{m} \equiv \beta^{d} \equiv \beta^{p}$ $\gamma^{m} \equiv \gamma^{d} \equiv \gamma^{p}$ $\theta^{m} \equiv \theta^{d} \equiv \theta^{p}$ $\rho^{m} \equiv \rho^{d} \equiv \rho^{p}$ $\delta^{m} \equiv \delta^{d} \equiv \delta^{p}$	31732	30	0.0000	270000	19	0.0000	Reject a common technology
Breusch-Pagan test of independence	5837	6	0.0000	4439	6	0.0000	The residuals were independent
Cobb-Douglas cost function =All interaction terms equals zero	67458	15	0.0000	23693	34	0.0000	Reject Cobb-Douglas function