DIVERSIFICATION VERSUS SPECIALIZATION: EMPIRICAL EVIDENCE ON THE OPTIMAL STRUCTURE OF EUROPEAN DAIRY FARMS

Stefan G. Wimmer and Johannes Sauer

stefan.wimmer@tum.de

Department of Agricultural Economics,
Technische Universität München, Munich, Germany

GEWISOLA

2016

Paper prepared for presentation at the 56th annual conference of the GEWISOLA (German Association of Agricultural Economists) „Agricultural and Food Economy: Regionally Connected and Globally Successful“
Bonn, Germany, September 28 – 30, 2016

DIVERSIFICATION VERSUS SPECIALIZATION: EMPIRICAL EVIDENCE ON THE OPTIMAL STRUCTURE OF EUROPEAN DAIRY FARMS

Abstract

This work aims to empirically evaluate economies of scale and scope in the Bavarian dairy sector, representing dairy farms in many other regions of the European Union. Against the background of structural change with the development towards fewer and larger farms, economies of scale and scope are of particular interest because they give an indication about the optimal farm structure. Increasing price volatility and an adverse development of the input-output price ratio have put economic pressure on the agricultural sector. Therefore, there is a strong need to improve farm competitiveness. In this study, a multiple-output quadratic cost function framework is applied to a sample of Bavarian dairy farms covering the years between 2006 and 2014. The results show that Bavarian farms experience overall economies of scale of 1.55, indicating that they are too small from a technological point of view. As expected, economies of scale decrease with farm size, but even the largest farms in the sample operate at increasing returns to scale. Furthermore, considerable economies of scope are evident. The average farm in the sample achieves cost savings of 77 per cent when milk, crop, and livestock are jointly produced compared to a separate production. Furthermore, economies of scope decrease with farm size, indicating that small farms benefit to a greater extent from diversification than large farms. If policy aims to slow down the structural change and to protect traditional family farms, it is recommended to promote farm diversification.

Keywords

Cost function, dairy farms, economies of scale and scope, farm size, structural change

1 Introduction

In recent years, economic pressure has been put on agriculture in the European Union (EU) in two ways. First, the input-output price ratio developed in an adverse direction. In Germany, for example, agricultural input prices increased by an annual average rate of 2 per cent between 1990 and 2015, while producer prices grew only by 0.1 per cent on average (DESTATIS, 2015). Second, as a consequence of the deregulation of agricultural markets through the Common Agricultural Policy, price volatility in European commodity markets has been increasing over the past decades (LEDEBUR and SCHMITZ, 2012). Figure 1 illustrates yearly average farm-gate prices of milk in the EU-15 from 1990 to 2014. It is seen that the average price in 2015 was below the level of the 1990s in nominal terms and that there were enormous price fluctuations in recent years. With the abolishment of the milk quota in April 2015, the milk price is expected to become even more volatile in the future. The price fluctuations caused a tremendous instability in gross margins for dairy producers. Between 2007 and 2009, for example, the EU milk margin declined by 40 per cent. At the beginning of year 2013, the margin was 30 % below the average level of the previous five years, rose up to record levels towards the end of 2013, and by the end of 2014, it dropped back to the levels of the first quarter in 2013. (EC, 2015)

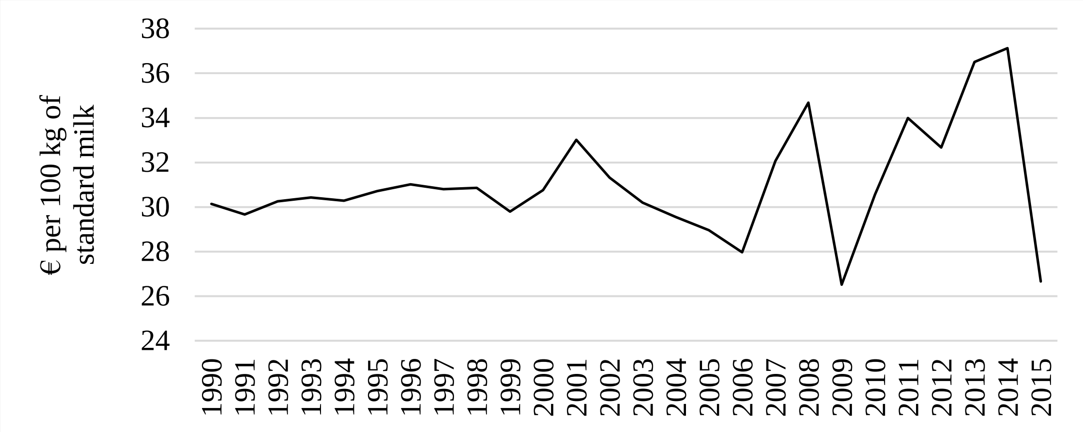

Figure 1: Yearly average farm-gate milk prices in the EU-15 (1990 – 2015)
Source: EC (2016)

Both an adverse price development and a high market uncertainty are challenges that need to be addressed. One way to increase competitiveness is to reduce average costs per unit of output by capturing economies of scale. This economic behavior of farmers is visible in the structural change. In the EU-28, the number of farms decreased by 25 per cent from 14.5 Mio in 2005 to 10.8 Mio in 2013. Within the same time period, the average farm size in-creased by 31 per cent from 21.4 to 28.1 hectares. (Eurostat, 2016)

A second way to increase competitiveness is to reduce costs by farm diversification. Introduced by BAUMOL (1977), BAUMOL et al. (1982), and WILLIG (1979), economies of scope exist if less costs occur for a multiple-output firm than for multiple firms producing the same amount of output separately. WILLIG (1979) explains that these cost savings result from shared or jointly used inputs. TEECE (1982) adds that if high transaction costs exist for these inputs, it is efficient to organize production within a single firm instead of jointly produce the same outputs in multiple firms. Output diversification does not only reduce production costs but it is also a mean to manage risk. This is related to the portfolio problem described by MARKOWITZ (1952) in which combinations of enterprises are efficient if the variance is minimized for a given expected net income. Like all firms and entrepreneurs, farmers – who do not only face yield uncertainty but also considerable price risk – wish to maximize profits while minimizing income variance.

The relative importance of economies of scale and economies of scope determines whether farms are better-off by specializing or diversifying production. If significant economies of scale exist for a particular farm enterprise, specialization would increase farm competitiveness. However if economies of scope outweigh scale advantages, farms are better-off by producing multiple outputs. Therefore the motivation of this paper is to empirically estimate economies of scale and scope in the Bavarian dairy sector as representative region for many other EU countries.

2 Literature on Farm Diversification

There is no consensus on a single definition of farm diversification in the literature. Generally, it can be distinguished between diversification outside and within primary agricultural production. BARBIERI and MAHONEY (2009) find that the most important factors enhancing diversification outside agricultural production in Texas, US, are reduction of uncertainty, achievement of growth, and improvement of financial conditions. MCNALLY (2001) shows that in England and Wales, two major factors that influence diversification outside agricultural production are farm size and farm type; large farms and less intensive farm types are more likely to have a second income pillar, mainly providing contract services or renting out farm buildings, due to the availability of idle resources. HANSSON et al. (2008) finds the same major contributors to diversification outside agricultural production in Sweden. Additionally, they show that farms with favorable financial conditions are more likely to be specialized, arguing that these farms have reasons to expand the production activity that already works out well instead of starting a new business enterprise.

Studies that empirically evaluate scale and scope economies often refer to farm diversification as the production of more than one primary agricultural output. In developing countries, the impact of producing multiple crop species on one farm on productivity and growth of the agricultural sector is of particular interest. For example, COELLI and FLEMING (2004) and RAHMAN (2009) find evidence of diversification economies between various crop combinations in Papa New Guinea and Bangladesh, respectively. Both studies conclude that diversification improves productivity through both cost savings and an increase in technical efficiency.

Studies that measure diversification economies in more economically developed countries usually refer to output diversification as the joint production of crops and livestock. For instance, FERNANDEZ-CORNEJO et al. (1992) detect cost savings from diversification that vary between 21 and 28 per cent for different pairs of the outputs milk, cattle, crops, and hogs in Germany. CHAVAS and ALIBER (1993) finds economies of scope between crop and livestock production varying between 36 and 74 per cent in different districts of Wisconsin, US. These cost savings from diversification are much larger than those found in WU and PRATO (2006). In a sample of dairy farms in Missouri, US, they observe scope economies of 14 per cent on average. While this implies cost savings of 14 per cent when crops and livestock are jointly produced, it is shown that lower allocative efficiency outweighs this advantage of diversified farms. MELHIM and SHUMWAY (2011) incorporate the role of risk into the evaluation of scope economies, showing that ignoring price uncertainty leads to an underestimation of scope economies. According to this study, economies of scope lead to cost savings of 27 per cent when milk, livestock, and crops are jointly produced on the average US dairy farm. As in CHAVAS and ALIBER (1993), the degree of scale and scope economies decrease with farm size, implying that larger farms have less incentives to diversify production than smaller farms.

3 Conceptual Framework

The empirical estimation of economies of scale and scope in this study is based on a cost function framework. Assuming a cost-minimizing behavior of firms, the duality of production and cost functions allows to represent the underlying production technology with a cost function if the cost function meets certain regularity conditions which arise from the theory of production functions. The assumption of cost-minimizing behavior among dairy farms in this work is reasonable because the amount of milk produced was restricted by the milk quota during the whole time period of the study. One great advantage of duality is that cost-minimizing input demand functions can be derived by simply differentiating the function instead of solving constrained minimization problems (DIEWERT, 1974). While production functions give insights into the physical relationships between inputs and outputs, they do not provide information on how firms should decide on the mix of inputs they use. In the classical theory of cost and production, firms face fixed technological possibilities and competitive input markets; the individual firm then chooses a bundle of inputs to minimize the cost of producing each possible output (MCFADDEN, 1978). This cost minimization problem can be mathematically expressed as

$$C(w,y) = \min_{x} w'x \quad \text{such that} \quad T(y,x) = 0, \tag{1}$$

where C denotes costs and w, x, *and* y are vectors of input prices, inputs quantities, and outputs quantities, respectively. $T(y,x) = 0$ defines the technological feasible set of output-input combinations. Thus, the firm is searching over all feasible input-output combinations to minimize costs that depend on input prices and output quantity.

The standard definition of economies of scale is that an increase in all inputs by the factor λ causes the output to rise by a factor larger than λ (PANZAR and WILLIG, 1977). Applied to the cost function framework, economies of scale are present if costs increase by a smaller rate than output: $C(\lambda y) < \lambda C(y)$. Conversely, diseconomies of scale exist when costs increase by a larger rate. Following BAUMOL et al. (1982), economies of scale, product-specific scale, and scope can be expressed by:

$$Sca = \frac{C(w,y)}{\sum_m \frac{\partial C(w,y)}{\partial y_m} y_m} , \tag{2}$$

$$S_i = \frac{AIC_i(w,y)}{\frac{\partial C(w,y)}{\partial y_i}} = \frac{IC_i(w,y)}{\alpha_i C(w,y)} , \tag{3}$$

$$Sco = \frac{\sum_{m=1}^{M} C(w,y_m)}{C(w,y)} - 1 . \tag{4}$$

Economies of scale exist when *Sca > 1*, diseconomies of scale when *Sca < 1*. Constant returns to scale are evident when *Sca = 1*. The evaluation of product-specific economies of scale S_i requires the calculation of the average incremental costs of producing the i-th output rather than total average costs. Incremental costs are defined as the costs of producing all outputs minus the costs of producing all outputs except output i: $IC_i = C(w,y) - C(w,y_{-i})$. Again, product-specific increasing, decreasing, and constant returns to scale are present for $S_i >, <, = 1$, respectively. Finally, equation (4) yields the proportionate change in costs if all outputs are produced separately relative to a joint production. *Sco > 0* indicates that cost savings can be achieved from output diversification. If *Sco < 0*, it is cheaper to produce all products separately.

4 Data

4.1 Description of Data

Farm accounting data were obtained from the Federal Ministry of Food and Agriculture in Germany (BMEL) which annually collects data from a representative rotating sample of German farms. In addition to balance sheets and income statements, the data set contains information on animal stock, land use, farm equipment, inventories, labor, crop yields, and further details on the farm and the farm manager. Since input quantities and prices are not included, price data were collected from other sources. Bavarian average prices for purchased feed were provided by the *Bayerischer Bauernverband*, a farmer's association in Bavaria. Prices for various types of seeds and fertilizer nutrients were obtained from the *Landesanstalt für Landwirtschaft* in Bavaria. For all other inputs, price indices from the *Genesis* database (DESTATIS, 2015) are used. Implicit quantities are calculated by dividing expenses by these price indices.

From the obtained data set, a balanced panel covering nine years from 2006 to 2014 was created. This sample is limited to Bavarian farms because the Bavarian farm sector represents farm sectors of many other regions in the EU: in 2013, the average utilized area per holding of 28 ha in the EU-15 compared to 34 ha in Bavaria. Farms in Belgium, Ireland, Spain, The Netherlands, and Austria operate within +/- 10 ha of the utilized agricultural area of Bavarian farms on average. (EUROSTAT, 2016) The sample has further been reduced to farms that made more than 20 per cent of total revenue from dairy production with a share of at least 20 per cent from milk production on average over the 9 years of the panel. Thus, the data set mainly consists of dairy farms but still contains a wide range of farming activities in order to evaluate diversification economies. The final sample consists of 1278 farms with farming activities in grazing livestock, other livestock production, and crop production. Table 1 summarizes descriptive statistics for these farms over the whole period from 2006 to 2014.

Table 1: Descriptive statistics for selected variables over the whole sample period

	N	Mean	St. Dev.	Min	Max
UAA in ha	11,502	50.81	31.21	0.01	394.17
Cropland in ha	9,213	33.23	26.65	0.48	307.99
Grassland in ha	11,448	24.23	14.85	0.00	135.00
Family labor (FTE)	11,502	1.56	0.439	0.26	3.78
Hired labor (FTE)	1,239	0.48	0.41	0.01	3.1
Dairy cows per farm	11,502	38.42	19.45	0.50	233.96
Milk production per cow	11,502	6,155.40	1,233.88	0.00	10,427.74
Revenue from grazing livestock	11,502	118,413.30	72,162.12	3,432.00	1,070,831.00
Revenue from crop production	6,802	20,155.81	30,188.68	4.89	307,356.30
Revenue from other livestock production	2,641	19,887.18	56,150.57	0.22	829,224.20

UAA = utilized agricultural area
FTE = full-time equivalent worker

The average utilized agricultural area per farm in the sample is 48 ha in 2006 and increases to 53 ha in 2014. The share of rented land in 2014 is 57 per cent. The average number of dairy cows per farm increased from 35.2 in 2006 to 41.9 in 2014. Milk production per cow varies between 5,444 liter per year on farms with less than 20 cows (n = 1474) and 7,160 liter per year on farms with more than 80 cows (n = 427), indicating that large farms are more productive than small farms. In 2014, 749 of 1278 farms produced crops for sale in addition to milk and livestock production. Over the whole period of 9 years, the vast majority (87 per cent) of farms make more than 66 per cent of revenue with grazing livestock. The remaining 13 per cent of farms do not exceed 66 per cent revenue share with any of the enterprises grazing livestock, livestock production, and crop production and are therefore considered to be diversified. Within the farm type grazing livestock, dairy production – including calves, heifers, dairy cows, cow's milk and dairy products – accounts for 93 per cent and cow's milk alone for 77 per cent of the total revenue.

4.2 Construction of Variables

The dependent variable *costs* is the sum of all expenses for plant production, livestock production, other expenses, depreciation, interest costs, maintenance of capital, land rental, labor, and insurance. Plant production comprises costs for seed, fertilizer, pesticides, other material, and purchased services. Costs for livestock production consist of side costs of animal purchasing (e.g. transport costs), purchased feed, veterinary expenses, insemination, other material, and purchased services. Other expenses are costs for fuel, heating fuel, electricity, water, contract services and machinery leasing. Labor costs include wages and salaries, pensions, social security, and operational accident insurance. Variable inputs are divided into four input categories: (1) *purchased feed*, (2) *crop-specific inputs*, (3) *other intermediate inputs*, and (4) *land*. Purchased feed include concentrates, roughage, and feed for hogs. Crop-specific inputs are seed, fertilizer, and pesticides. Other intermediate inputs comprise electricity, fuel, heating fuel, capital, and maintenance of capital. As in HENRY DE FRAHAN et al. (2011), farm level price for capital is defined as the sum of the rental price of acquisition and the rate of depreciation, where rental price of acquisition is measured by dividing the financial expenses by the debt and the rate of depreciation is obtained by dividing depreciation by the initial value of capital. Regional average prices for capital is then calculated for each administrative district in Bavaria. Regional rental rates for land are also calculated from the database.

Input prices for purchased feed, crop-specific inputs, and other intermediate inputs are expressed as Tornqvist price indices at the farm level. The Tornqvist price index is the geometric average of prices that uses the averages of expenditure shares in two periods as weights:

$$w_{ift} = \prod_{j=1}^{N_i} \left(\frac{w_{jft}}{w_{jrt_o}} \right)^{\frac{g_{jft}+g_{jft_0}}{2}}$$
$$g_{jft} = \frac{E_{jft}}{\sum_{k=1}^{N_i} E_{kft}} \quad , \tag{5}$$

where w_{ift} denotes the Tornqvist price index for input category i and farm f in and year t. N_i is the number of components of input category i and E_{jft} represents total expenses for the j^{th} input in farm f at year t. Year 2014 is selected to be basis year t_0. Since all prices available for purchased feed, crop-related inputs, and other intermediate inputs except capital are average prices for either Bavaria or Germany, the different shares of expenses are the only source of price variability across farms. Tornqvist price indices have also been calculated with regional expense shares, but the econometric estimation then failed to converge. Price variability across farms seems too little with this approach.

Output is divided into the three categories *milk production*, *crop production*, and *livestock production*. Milk output is measured in liter and crop and livestock production in sales revenues, deflated to 2014 prices using Destatis price indices as deflators. Deflation is necessary to control for changes in prices that would otherwise be reflected in the output measure. With this classification, part of the revenues made with the dairy enterprise such as the sale of calves is assigned to the category of livestock production. This is a desired effect when diversification activities are to be evaluated, since the longer a dairy farm raises newborns the higher is the received price, for example. Therefore, revenue in livestock production reflects a type of diversification of dairy farms. A summary description of all variables used in the estimation of the cost function is provided in the appendix (Table A 1).

5 Empirical Estimation

It becomes obvious from equation (4) that the calculation of economies of scope requires the functional form of the cost function to accommodate zero outputs. Thus, the quadratic form is chosen instead of a transcendental logarithmic form. A disadvantage of quadratic forms is that linear homogeneity in input prices cannot be imposed by parametric restrictions without sacrificing the flexibility of the form (CAVES et al., 1980). DIEWERT (1974, p. 113) defines a flexible functional form for a cost function as one which “could provide a second order differential approximation to an arbitrary twice continuously differentiable cost function *C* that satisfies the linear homogeneity in prices property at any point in an admissible domain”. If the functional is not flexible, own and cross price elasticities will be a priori restricted in some arbitrary way which is not in line with economic theory. Therefore, price homogeneity of degree 1 is imposed by the normalization of costs and all input prices by one common input price rather than using parametric restrictions.

The second order Taylor series approximation with *m* outputs and *n* variable inputs takes the following form:

$$C(w,y) = \beta_0 + \sum_{k=1}^{m} \beta_k\, y_k + \sum_{i=1}^{n} \beta_i w_i + \frac{1}{2}\sum_{k=1}^{m}\sum_{l=1}^{m} \beta_{kl}\, y_k y_l$$
$$+\frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} w_i w_j + \sum_{k=1}^{m}\sum_{i=2}^{n} \beta_{ki}\, y_k w_i \qquad (6)$$
$$+\beta_t\, t + \sum_{k=1}^{m} \beta_{kt}\, y_k t + \sum_{i=1}^{n} \beta_{it}\, w_i t \ ,$$

where *y* and *w* denote output quantities and input prices, respectively. The time trend variable *t* and its interaction terms serve as a proxy for neutral and non-neutral technical change. The βs are parameters to be estimated.

Applying SHEPHARD's (1954) lemma, the cost function is supplemented by cost-minimizing input demand functions. The system of conditional input demand functions is represented by

$$Q_i(w,y) = \frac{\partial c(w,y)}{\partial w_i} = \beta_i + \sum_{j=1}^{n} \beta_{ij}\, w_j + \sum_{k=1}^{m} \beta_{ik}\, y_k + \beta_{it} t \,. \qquad (7)$$

Symmetry constraints are imposed to ensure β_{ij}=β_{ji}. The system of equations (6) and (7) is estimated using ZELLNER's (1962) seemingly unrelated regression, which assumes the error terms to be jointly distributed with zero means and a constant covariance matrix. The advantage of estimating the cost function (6) together with input demand functions (7) is the inclusion of more information in form of input demands without adding any new parameters. Hence, the degrees of freedom are increased and the parameter estimates become more efficient. Unobserved farm characteristics are accounted for by deviating all variables with respect to their farm-specific mean.

6 Results and Discussion

6.1 The Estimated Cost Function

Equations (6) and (7) are estimated with outputs milk, crop, and livestock, and inputs feed, crop-specific inputs, other intermediate inputs, and land. The price for other intermediate inputs is used as the normalizing factor to impose price homogeneity. The adjusted R^2 is 0.77 for the cost function and ranges between 0.19 and 0.56 for the conditional input demand functions. The vast majority of the estimated parameters are statistically significant at the 1 % level (see Table A 2 in the appendix). Table 2 shows the de-normalized marginal costs and cost elasticities evaluated at the sample mean.

Table 2: Marginal costs and cost elasticities at the sample mean

Variables	Marginal Costs	Elasticity
Output milk in liter	0.202	0.447
Output crops in €	0.104	0.015
Output livestock in €	0.616	0.182
TPI purchased feed	356.07	0.287
TPI crop-specific inputs	226.49	0.190
TPI for other intermediate Inputs	341.43	0.363
Rental price for land	71.29	0.198

TPI = Tornqvist price index

At the sample mean, a one percent increase in milk production causes a 0.45 per cent increase in costs all other things equal. The marginal costs of milk are 0.20 € at the sample mean. The average received milk price in the sample is 0.38 € and therefore above marginal costs, which implies that farms could increase profit by an expansion of milk production. This is an expected result because milk production has been limited by the milk quota until April 2015. The monotonicity condition of cost functions requires marginal costs and elasticities to be positive. At the sample mean, this is true for all outputs and inputs. For milk and livestock production, marginal costs are positive for all observations. Marginal costs of crop production are positive for 86 per cent of the observations. The function is also monotonically increasing for all input prices except the price for other intermediate inputs, which positive in at 81 per cent of the observations.

Concavity in prices, another regulatory condition of cost functions, is examined by calculating the eigenvalues for the Hessian matrix of the function. It turns out that the Hessian is not semidefinite, indicating that the estimated cost function does not satisfy the condition of concavity. Concavity in input prices requires cross-price elasticities of input demands to be negative. As Table 3 shows, this is true for feed, crop-specific inputs, and other intermediate inputs. For example, the demand for purchased feed decreases by 0.55 per cent if price for feed increases by 1 per cent. However the cost-minimizing input demand for land is shown to increase as a respond to a rise of land prices.

Table 3: Price elasticities of input demands at the sample mean

Inputs	Input price			
	Purchased Feed	Crop-specific inputs	Land	Other intermediate inputs
Purchased Feed	-0.546	0.152	0.012	0.382
Crop-specific inputs	0.261	-0.304	0.010	0.033
Land	0.014	0.007	0.036	-0.057
Other intermediate inputs	0.139	0.007	-0.017	-0.129

The fact that a change in the rental price for land does not change the demand for any of the inputs by more than 0.05 per cent might indicate that the input land is fixed for Bavarian farms even for a time period of 9 years. However since most price elasticities of input demands have the expected sign and the regulatory conditions of monotonicity, non-negativity, and price homogeneity are satisfied, the production technology is assumed to be well represented by this specification of the cost function.

6.2 Scale and Scope Economies

The evaluation of overall economies of scale, product-specific economies of scale, and economies of scope with equations (2), (3), and (4) yields results at a local point of the sample. In order to analyze how diversification economies vary with farm size, farms in the sample have been grouped into 10 size classes according to their production value. Each size class includes 10 % of the observations in the data set. The estimates of economies of scale and scope for each size class and at the sample mean are presented in Table 4.

Table 4: Economies of Scale and Scope

Size class	Mean value of production	Product specific economies of scale: Milk	Crops	Other Live-stock	Economies of scale (Overall)	Economies of scope	Revenue shares milk/crops/live-stock
1	43,709	0.976	0.988	0.991	2.782	1.293	0.72/0.03/0.25
2	65,247	0.965	0.976	0.986	2.194	1.110	0.72/0.04/0.24
3	80,456	0.958	0.967	0.984	1.967	1.012	0.72/0.05/0.23
4	94,422	0.952	0.954	0.982	1.825	0.940	0.72/0.05/0.22
5	109,192	0.946	0.932	0.979	1.706	0.871	0.71/0.06/0.22
6	127,072	0.938	0.920	0.975	1.597	0.800	0.70/0.07/0.23
7	148,234	0.931	0.886	0.971	1.511	0.738	0.68/0.09/0.23
8	175,576	0.920	0.858	0.964	1.415	0.663	0.68/0.09/0.23
9	218,662	0.907	0.794	0.956	1.328	0.590	0.66/0.11/0.23
10	355,349	0.876	0.595	0.924	1.191	0.463	0.62/0.13/0.26
Mean	141,782	0.935	0.893	0.972	1.553	0.768	0.68/0.09/0.23

n per size class is either 1150 or 1151

It is seen in Table 4 that the average farm in this sample experiences scale economies of 1.55, indicating that long run average costs can be considerably decreased by expanding production. As expected, the smallest farms in the sample are operated at the largest overall economies of scale. With increasing farm size, economies of scale become smaller, but the largest 10 per cent of dairy farms in this sample are still operated at increasing returns to scale (1.19). Product-specific economies of scale show that the average farm operates close to constant returns to scale in its individual enterprises. As overall economies of scale, product-specific economies of scale decrease with farm size. The largest farms experience considerable diseconomies of scale in the crop enterprise. Since none of the individual enterprises is operated at increasing individual returns to scale in any of the size classes, increasing overall returns to scale must be attributed to economies of scope. In other words, cost savings from output diversification outweigh cost disadvantages from decreasing returns to scale in the individual enterprises.

Considerable economies of scope between milk, crops, and livestock production are evident in this sample. Farms that jointly produce the average output quantities of milk, crops, and livestock achieve cost savings of 77 per cent compared to three hypothetical farms that produce the same amount of outputs separately. As overall and product-specific economies of scale, economies of scope decrease with farm size. These results are consistent with MELHIM and SHUMWAY (2011) who find a negative correlation between farm size and economies of scope in US dairy farms. The implication is that small farms benefit to a greater extent from output diversification than larger farms. This is in line with TEECE (1982) who states that if high transaction costs exist for shared inputs, it is efficient to organize production within a single firm instead of jointly produce the same outputs in multiple firms. Since transaction costs account for a higher percentage of production costs for small farms than they do for large farms, joint production is an effective strategy especially for smaller farms to increase competitiveness. Furthermore, it is seen in Table 4 that the level of economies of scope decreases with more balanced revenue shares. The optimal production structure in terms of economies of scale and scope is where scope economies equal zero and scale economies equal one. At this point, there would be no further gain neither from increasing production nor from diversifying production. The fact that these values are not found in this sample of Bavarian dairy farms implies that they are too small and too little diversified.

However, the degrees of scope economies in this study seem to be too high in absolute terms. Economies of scope higher than one, as observed in farms below the 30th percentile of size distribution, indicate an increase in costs of more than 100 per cent when outputs are separately produced in different firms relative to costs that arise when they are jointly produced. A possible reason for the high values of economies of scope found in this study is the sample construction. Since the sample consists of farms that make at least 20 per cent revenue with the dairy enterprise, it contains heterogeneous farms with different production technologies. Economies of scope have also been evaluated for a sample that contains farms with more than 80 per cent revenue from the dairy enterprise in order to achieve a greater homogeneity of production technologies. Farms in the new sample experience economies of scope of 44 per cent on average. This finding clearly reveals that economies of scope depend on sample construction and technology definition.

Irrespective of the sample construction, scope economies decrease with farm size. Therefore, if policy aims to slowdown the structural change, farm diversification should be especially supported among small farms. For example, educational training should be promoted since the management of more than one farming activity requires a broad range of skills. Subsidizing small-scale investments and relaxing environmental and animal welfare regulations for small farms would further promote farm diversification.

7 Conclusions

This study examined diversification economies in the Bavarian dairy sector between 2006 and 2014 based on a cost function approach. The assumption of cost-minimizing behavior is reasonable regarding production restrictions imposed by the milk quota during the period of the study. The cost function satisfies the regularity conditions of non-negativity, monotonicity, and price homogeneity. Global concavity is failed, but most price elasticities of input demands have the expected sign. Hence, the cost function is assumed to properly represent the underlying production technology.

Scale and scope economies derived from the estimated cost function show that diversification economies highly depend on farm size. The average farm in the sample experiences overall economies of scale of 1.55. Overall economies of scale decrease with farm size, but even the largest farms in the sample operate at increasing returns to scale. Since none of the individual enterprises is operated at increasing returns to scale, overall scale economies must be attributed to economies of scope. On average, economies of scope are 77 % in this sample. Since small farms have larger cost savings from diversification than larger farms, the structural change with the trend towards larger farms could be slowed down by the promotion of farm diversification among small farms. However from a technological point of view, the structural change should be enhanced because larger farms operate closer at the optimal point of scale.

This work leaves much space for further research. For example, it is known from the literature that off-farm income affects scale economies (PAUL and NEHRING, 2005) and ignoring price uncertainty leads to an underestimation of scope economies (MELHIM and SHUMWAY, 2011). Finally, there is also evidence that cost inefficiencies can counteract cost savings from diversification (OUDE LANSINK et al., 2015; WU and PRATO, 2006). To provide more comprehensive management and policy recommendations, these aspects should be included into the model in further research.

References

BARBIERI, C. and MAHONEY, E. (2009): Why is diversification an attractive farm adjustment strategy? Insights from Texas farmers and ranchers. In: Journal of Rural Studies 25 (1): 58–66.

BAUMOL, W. J. (1977): On the Proper Cost Tests for Natural Monopoly in a Multiproduct Industry. In: The American Economic Review 67 (5): 809–822.

BAUMOL, W. J., PANZAR, J. C. and WILLIG, R. D. (1982): Contestable markets and the theory of industry structure. Harcourt Brace Jovanovich, New York.

CAVES, D. W., CHRISTENSEN, L. R. and TRETHEWAY, M. W. (1980): Flexible Cost Functions for Multiproduct Firms. In: The Review of Economics and Statistics 62 (3): 477.

CHAVAS, J.-P. and ALIBER, M. (1993): An Analysis of Economic Efficiency in Agriculture: A Nonparemetric Approach. In: Journal of Agricultural and Resource Economics 18 (1): 1–16.

COELLI, T. and FLEMING, E. (2004): Diversification economies and specialisation efficiencies in a mixed food and coffee smallholder farming system in Papua New Guinea. In: Agricultural Economics 31 (2-3): 229–239.

DESTATIS (2015): Genesis-Online Datenbank, Statistisches Bundesamt. Wiesbaden, Germany. Retrieved from https://www-genesis.destatis.de/genesis/online

DIEWERT, W. E. (1974): Applications of duality theory. Intriligator, M., Kendrick, D. (Ed.): Frontiers of Quantitative Economics: Volume II. North-Holland Publishing Company.

EC (2015): EU Milk Margin Estimate up to 2014: *An overview of estimates of costs of production and gross margins of milk production in the EU*: EU Agricultural and Farm Economics Briefs, European Commission. Retrieved from http://ec.europa.eu/agriculture/rica/pdf/Milk_margin_estimate_2014.pdf

EC (2016): Milk Market Observatory, European Commission. Retrieved from http://ec.europa.eu/agriculture/milk-market-observatory/index_en.htm

EUROSTAT (2016): Statistical Database, Statistical Office of the European Communities. Luxembourg.

FERNANDEZ-CORNEJO, J., C. M. GEMPESAW, ELTERICH, J. G. and STEFANOU, S. E. (1992): Dynamic Measures of Scope and Scale Economies: An Application to German Agriculture. In: American Journal of Agricultural Economics 74 (2): 329.

HANSSON, H., FERGUSON, R. and OLOFSSON C. (2008): Understanding the diversification and specialization of farm businesses. In: Agricultural and Food Science 19 (4): 269–283.

HENRY DE FRAHAN, B., BAUDRY, A., BLANDER, R. de, POLOME, P. and HOWITT, R. (2011): Dairy farms without quotas in Belgium: Estimation and simulation with a flexible cost function. In: European Review of Agricultural Economics 38 (4): 469–495.

LEDEBUR, O. v. and SCHMITZ, J. (2012): Price volatility on the German agricultural markets. Paper prepared for the 123rd EAAE Seminar Price Volatility and Farm Income Stabilisation; Moddeling Outcomes and Assessing Market and Policy based Responses. Retrieved from http://econpapers.repec.org/paper/agseaa123/122534.htm

MARKOWITZ, H. (1952): Portfolio Selection. In: The Journal of Finance 7 (1): 77.

MCFADDEN, D. (1978): Production Economics - A Dual Approach to Theory and Applications: Cost, Revenue, and Profit Functions. North-Holland Publishing Company, Amsterdam.

MCNALLY, S. (2001): Farm diversification in England and Wales — what can we learn from the farm business survey? In: Journal of Rural Studies 17 (2): 247–257.

MELHIM, A. and SHUMWAY, C. R. (2011): Enterprise diversification in US dairy: Impact of risk preferences on scale and scope economies. In: Applied Economics 43 (26): 3849–3862.

OUDE LANSINK, A., STEFANOU, S. E. and KAPELKO, M. (2015): The impact of inefficiency on diversification. In: Journal of Productivity Analysis 44 (2): 189–198.

PANZAR, J. C. and WILLIG, R. D. (1977): Economies of Scale in Multi-Output Production. In: The Quarterly Journal of Economics 91 (3): 481–493.

PAUL, C. J. M. and NEHRING, R. (2005): Product diversification, production systems, and economic performance in U.S. agricultural production. In: Journal of Econometrics 126 (2): 525–548.

RAHMAN, S. (2009): Whether crop diversification is a desired strategy for agricultural growth in Bangladesh? In: Food Policy 34 (4): 340–349.

SHEPHARD, R. W. (1954): Cost and production functions. By Ronald W. Shephard, Princeton University Press, 1953, 104 pp. In: Naval Research Logistics Quarterly 1 (2): 171.

TEECE, D. (1982): Towards an economic theory of the multiproduct firm. In: Journal of Economic Behavior & Organization 3 (1): 39–63.

WILLIG, R. D. (1979): Multiproduct Technology and Market Structure. In: The American Economic Review 69 (2): 346–351.

WU, S. and PRATO, T. (2006): Cost efficiency and scope economies of crop and livestock farms in Missouri. In: Journal of Agricultural and Applied Economics 38 (3): 539–553.

ZELLNER, A. (1962): An Efficient Method of Estimating Seemingly Unrelated Regressions and Tests for Aggregation Bias. In: Journal of the American Statistical Association 57 (298): 348.

Appendix

Table A 1: Summary description of variables used in the cost function

Variables	Mean	St. Dev.	Min	Max
Total costs in 1,000 €	122.97	84.27	11.03	1,182.31
Inputs				
TPI purchased feeds	92.76	13.01	65.17	134.93
TPI crop-specific inputs	96.59	13.58	53.52	128.13
TPI other inter-mediate inputs	108.77	8.71	77.86	152.35
Rental price for land	319.86	88.27	164.31	527.97
Outputs				
Milk in 100 liter	2448.86	1516.28	3.20	18,593.81
Crop sales in 1000 €(*) (*n* = 6802)	34.62	38.60	0.35	895.07
Livestock sales in 1000 €(*)	21.88	32.00	7e-03	325.27

n = 11502; Livestock and crop output in nominal values of the year 2014
TPI = Tornvqvist Price Index
(*)in 2014 prices

Table A 2: Regression results of the estimated cost function

Variable	Coefficient	z-statistic
Milk output	0.0003891 ***	5.40
Crops output	-0.0019238 ***	-5.34
Livestock output	0.0019559 ***	8.48
TPI for purchased feed	85.8733 ***	4.97
TPI for crop-specific inputs	161.3564 ***	10.41
Rental price for land	59.08693 ***	14.32
Milk output^2	1.01e-09 ***	7.40
Crop output^2	2.08e-08 ***	8.36
Livestock output^2	9.15e-09 ***	15.57
TPI for purchased feed^2	-134.3734 ***	-20.49
TPI for crop-specific inputs^2	-40.2743 ***	-12.15
Rental price for land^2	0.6180431 ***	5.38
Milk output * crop output	3.49e-11	0.06
Milk output * livestock output	-1.17e-09 ***	-2.73
Milk output * TPI feed	0.0010032 ***	77.49
Milk output * TPI crop-specific inputs	0.00001384 ***	18.50
Milk output * rental price for land	0.0000207 ***	20.69
Crop output * livestock output	-1.49e-08	-1.83
Crop output * TPI feed	0.0007877 ***	14.02
Crop output * TPI crop-specific inputs	0.0013072 ***	40.30
Crop output * rental price for land	0.0000841 ***	19.48
Livestock output * TPI feed	0.0019763 ***	58.66
Livestock output * TPI crop-sp. inp.	0.0002759 ***	14.21
L. output * rental price for land	0.000047 ***	18.20
TPI feed * TPI crop-spec. inputs	36.07263 ***	11.13

(continued)

Table A 2 (continued)

Variable	Coefficient	z-statistic
TPI feed * rental price for land	0.822743 *	1.70
TPI crop-specific * rental p. for land	0.3867636	0.95
Time variable	-65.57671***	-25.71
$Time^2$	11.85924	24.49
Time * output milk	0.0000575 ***	12.01
Time * output crops	0.0002672 ***	12.62
Time * output livestock	0.0003401 ***	19.65
Time * TPI purchased feed	5.22303 ***	14.87
Time * TPI crop-specific inputs	1.726352 ***	8.66
Time * Rental price for land	0.3144469 ***	10.91
Constant term	-5.51e-06	-0.00
Number of observations	11,502	
Adjusted R^2	0.7698	

*** significant at 1 %, ** significant at 5 %, * significant at 10 %

TPI = Tornqvist price index