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United States and European Union Dairy Farms: Where Is the Competitive Edge?

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The United States (US) and European Union (EU) dairy industries are undergoing rapid structural change as farms become fewer and larger, milk productivity per cow increases, and agricultural policies evolve. This paper examines productivity measures of dairy farms in all dairy production regions of the US and seven member states of the EU. We generally find that larger, more intensively-managed dairy farms experience greater net return on assets and are more scale efficient than smaller, more extensive dairy farms. Efficient farms are found in all farm size and system categories, with many of the smaller farms experiencing relatively high technical efficiency. Overall, we find significant economic forces at work towards more efficient and productive dairy production in both the EU and the United States. With potential efficiency gains that can be made, various EU dairy production regions may significantly strengthen their export positions following the milk quota seizure of 2015.

Keywords: dairy productivity; transformation function; scale efficiency; technical efficiency

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Introduction

The global dairy industry has exhibited significant structural change over the past few decades, including shifts in production location, growth in farm size, and change in farm production systems. These changes are evident in both the United States (US) and the European Union (EU), but the extent to which industry structure has evolved has differed by country. Evidence of structural change has been shown in country-specific analyses by MacDonald et al. (2007), Melhim et al. (2007), Nehring et al. (2009), and Gillespie et al. (2014) for the US and Perrot et al. (2007), Sauer (2010), McDonald et al. and Sauer and Latacz-Lohmann (2015) for the EU.

A new potential impetus for structural change in the EU is expected to be the 2015 elimination of the dairy quota, which should move dairy from the least efficient to the most efficient areas across borders. Furthermore, the current push in Common Agricultural Policy reform is to include payments to farmers to counter the effects of climate change and reduce greenhouse gas emissions, including from dairy animals. No similar payments have been included in US legislation. A potential impact of these changes taken together is that the EU can further enhance its current position as one of the world's top dairy exporters. There are likely, however, to be localized impacts for both the higher and lower-cost regions of Europe, with some regions gaining, and others losing relative dairy competitiveness. The promotion of organic farming has been another important element of national and supranational food policy throughout Europe and is also an important feature of US dairy policy (Breustedt et al. 2011). Thus, there are a number of important policy changes that have the potential to impact dairy industry structure.

Given the current fundamental changes in the EU dairy sector, the purpose of this paper is to provide analyses of the underlying dairy production structure in both the EU member countries as well as in the US, considering policy developments over the last decade. We provide a quantitative comparison of different production systems in the EU and US using a multi-output transformation function approach. Using a common analytical framework allows for insights on the competitiveness of the two regions by production system. Furthermore, future developments given the described policy changes can be discussed. Conclusions can be drawn regarding the EU's low-cost dairy producers' potential to remain and become net dairy product exporters (Bojnec and Ferto 2014), as well as the US's potential to retain its global market share given the changes in the dairy market.

Background

The US and the EU are major players in world trade of dairy products. Of the top five major exporters of dairy products (Argentina, Australia, the EU, New Zealand, and the US), the EU and the US accounted for about 85% of total milk production in 2014 (USDA-FAS 2015). Furthermore, they are the top two producers of milk in the world. In 2014, the EU produced 146.5 million metric tons of milk and the US produced 93.5 million metric tons, with the third-highest production of milk coming from India, at 60.5 million metric tons (USDA-FAS 2015). There are other major players in dairy trade, most notably New Zealand, which ranked first in the export of whole milk powder and butter, second in nonfat dry milk, and third in cheese in 2014 (USDA-FAS 2015). However, New Zealand produced 21.9 million metric tons of milk in 2014, so it was significantly smaller (ranked seventh) than the EU and the US in total milk production.

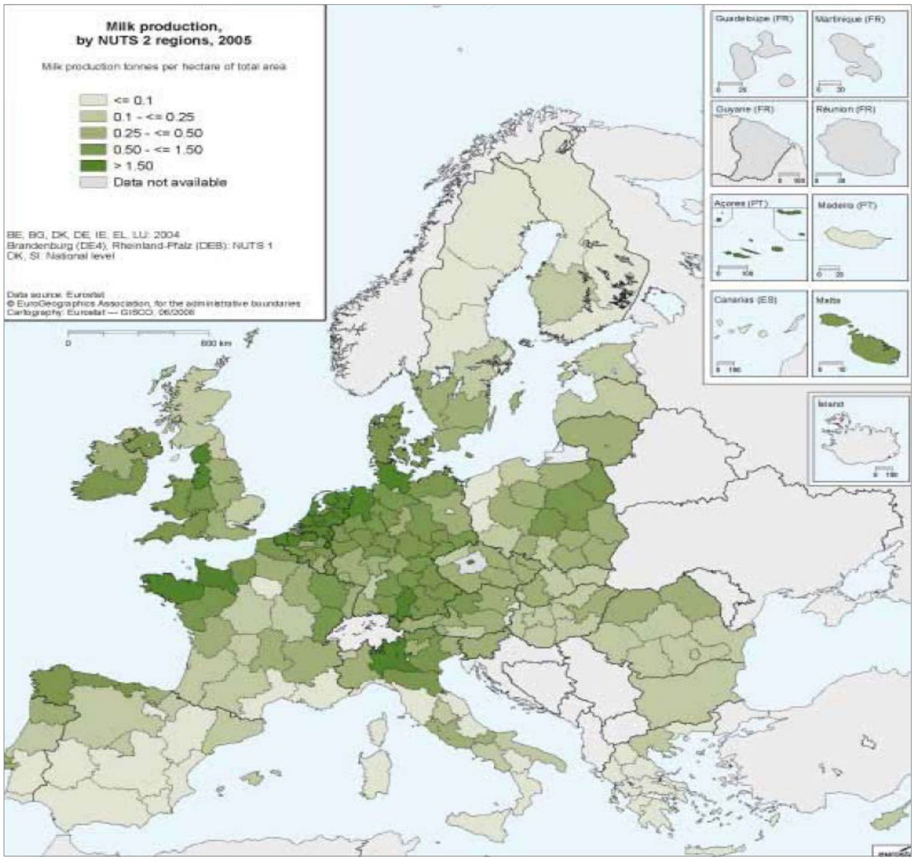

Figure 1. Major dairy producing districts by EU country
Source. Eurostat 2009.

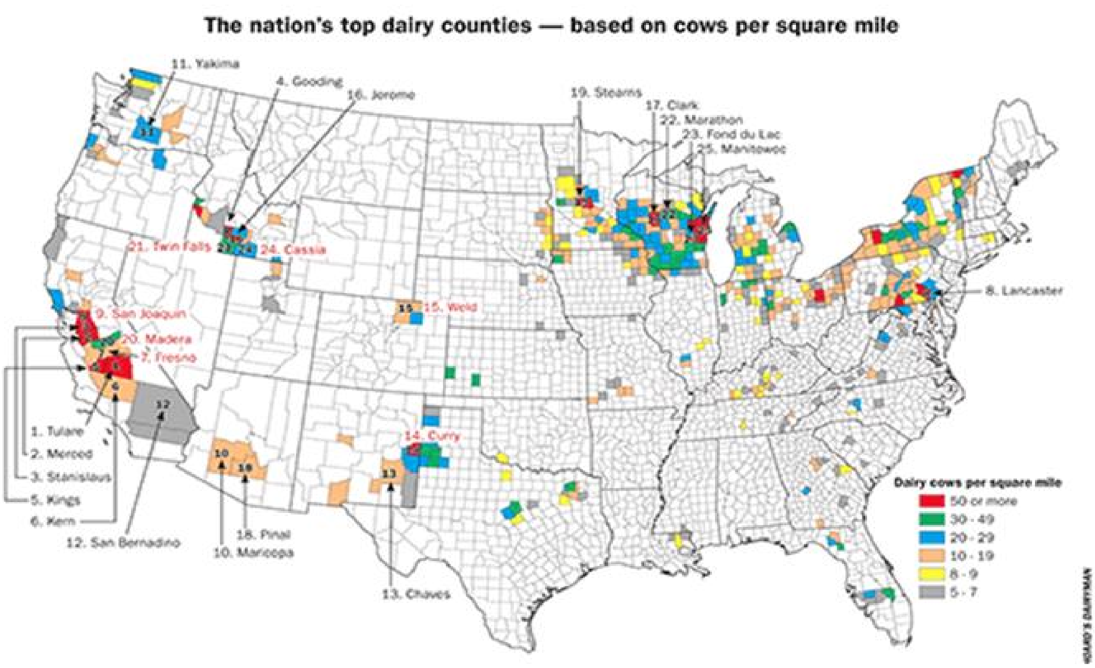

Figure 2. Top dairy counties in the United States in 2012
Source. Hoards Dairyman Staff (2014).

According to MacDonald et al. (2007) the cost advantage of larger farm sizes in the United States allow those farms to be profitable on average, while most small farms are unable to earn enough to replace their capital. Historical survey evidence, including farm financial data, suggests further consolidation is inevitable if current trends continue. Though pasture-based operations generally yield lower milk per cow, their production costs are also lower. Previous work has shown that pasture-based operations tend to be competitive with conventional (no pasture with total mixed ration feeding) operations of similar size (Gillespie et al. 2009; Gillespie and Nehring 2014).

Though several different definitions have been used for pasture-based operations, Gillespie et al. (2009) and Gillespie and Nehring (2014) define these operations as having ≥50% of the forage requirement being met through pasture during the grazing season, and the definition is generally consistent with current organic dairy production rules that require ≥30% of dry matter to be from pasture during the grazing season (Gillespie et al. 2014). Gillespie and Nehring (2014) show that, for 2010, 38%, 37%, and 16% of US dairy farms were conventional, semi–pasture–based (1% – 49% of the forage requirement was met via pasture during the grazing season), and pasture-based, respectively, with the remaining 9% of the operations being organic.

In the EU, milk production takes place in all member states and represents 14% of the value of EU agricultural output. The share of milk in total agricultural production varies between member states, from 6% to 34% in 2006. The share tends to be higher in northern Europe and is below 10% in the Mediterranean countries (EC 2006). During the early 1980s, the EU experienced large production surpluses of milk and dairy products. To prevent further increases and to limit milk production, a country-specific milk quota scheme was introduced to control production. This effectively put a limit on the amount of milk EU dairy farmers produced each year.

Significant structural change and improvements in dairy herd productivity have occurred in several EU countries in recent years. United Kingdom (UK) dairy farms, for example, are developing within the context of agricultural policy which allows for geographical mobility of quotas, low consumer milk prices, and difficulties maintaining production volume. Farms are characterized by strong labor productivity and relatively low investment, enabling one of the highest mean agricultural household incomes among the regions of the EU. In Denmark, dairy farms are characterized by the highest average labor productivity in the EU (Perrot et al. 2007).

In contrast, the larger dairy sectors in the EU, Germany, France, and Italy—with combined farm numbers of nearly four times larger than that of the US—have experienced large reductions in total dairy numbers in recent years while average herd sizes have remained small and milk output has been relatively low (Table 1). In France, for example, low mobility of dairy quotas and high soil quality have led to the prevalence of more traditional, less specialized, dairy farms. Hence, these dairy farms produce less milk than in EU countries with more specialized dairy sectors, with large parts of their output consisting of cereals and beef (Perrot et al. 2007).

Use of a Transformation Function to Measure Dairy Productivity

The dairy farms included in our cross-country sample use multiple factors to produce milk, other livestock products, and crops. Hence, it is desirable to model these processes using a function that accounts for the production of multiple outputs with multiple inputs. Following Sauer and

Morrison-Paul (2013), we use a transformation function to represent the most output producible given the feasible production set. This function in general form can be written as 0=F(**Y,X,T**), where **Y** is a vector of outputs, **X** is a vector of inputs, and **T** is a vector of (external) shift variables, which reflects the maximum output producible from a given input vector and existing external conditions. By the implicit function theorem, if F(**Y,X,T**) is continuously differentiable and has non-zero first derivatives with respect to one of its arguments, it may be specified (in explicit form) with that argument on the left hand side of the equation.

Accordingly, we estimate the transformation function $Y_1 = G(\mathbf{Y_{-1}},\mathbf{X},\mathbf{T})$, where Y_1 is the primary output of dairy farms (milk) and $\mathbf{Y_{-1}}$ is the vector of other outputs, to represent the technological relationships for the dairy farms in our sample. Note that this specification does not reflect any endogeneity of output and input choices, but simply represents the technologically most Y_1 that can be produced given the levels of the other arguments of the transformation function. This is important because in the alternative input (output) distance function approaches, for example, one input (output) is required for normalization in order to impose linear homogeneity. This raises issues not only about what variable should be expressed as ratios with respect to the left-hand side variable, but also about econometric endogeneity because the right-hand side variables are expressed as ratios with respect to the left-hand side variable. See Mas-Colell et al. (1995), page 128–29 for a fuller discussion and a graphical presentation of the transformation function set and transformation frontier.

We estimate the transformation function $Y_{M,it} = F(\mathbf{Y}_{NM,it,}, \mathbf{X}_{it}, T)$, where Y_M is milk production measured in real dollars or Euros for farm *i* in period *t* and $\mathbf{Y}_{NM}$ is non-milk production to include crop production, other non-milk livestock production, and off-farm income measured in real dollars or Euros. Vector **X** indicates inputs to include labor, cows, energy, fodder, capital, livestock-specific expenses, chemicals, machinery, seed, and land (measured in real dollars or Euros[1]). A limitation is that we do not have quality adjustment measures for land, but only measures for land value. For the US, due to some differences in categorization of inputs, the inputs were labor, fertilizer, pesticides, fuel, miscellaneous, land, crop-specific expenses, and livestock-specific expenses. Variable T represents year.

A number of flexible functional forms may be used to represent production technology, such as the translog, quadratic, and generalized linear. As suggested by Diewert (1973), the generalized linear functional form is used for our study to avoid variable calculations that would lead to zero netput values (which would occur with functional forms that include logarithms). As shown by Sauer and Morrison-Paul (2013), for farm *i* in period *t*, the functional form for our study is:

[1]The real input costs used for the U.S. analysis are not cost of production estimates developed by the U.S. Department of Agriculture, Economic Research Service (ERS). Rather they are variables such as cash wages or feed purchased as reported in ARMS that are deflated by prices paid indexes available in the U.S. Department of Agriculture's *Agricultural Statistics*. Similarly, dairy revenues and other outputs are not ERS estimates but variables appropriately deflated using prices paid indexes from *Agricultural Statistics*. The US dairy data are constructed using a whole farm approach, so all outputs, including off-farm income, are considered so that labor used in the dairy enterprise or in another enterprise such as a cow/calf operation are added together. Similarly, other inputs may be used in more than the dairy enterprise. This approach contrasts with a dairy enterprise approach used by, for example, Mosheim and Lovell (2009) where only the outputs and inputs produced or used in the dairy enterprise are considered. Further, we use the hired wage rate as the opportunity cost for labor. ERS publications used a more complicated algorithm based on an index of labor costs and the price of milk (www.ers/data/gov 2011).

1) $Y_{M,it} = F\left(Y_{NM,it}, X_{it}, T\right) = a_0 + 2a_{0NM}Y_{NM}^{0.5} + \sum 2a_{0k}X_k^{0.5} + a_{NMNM}Y_{NM} + a_{kk}X_k + \sum a_{kl}\, X_k^{0.5}X_l^{0.5} + \sum a_{kNM}X_k^{0.5}Y_{NM}^{0.5} + b_T T + b_{TT}TT + \sum b_{KT}X_k^{0.5}T + b_{NMT}^{0.5}T.$

To represent and evaluate the production structure, we compute the first-order elasticities of the transformation function. The first-order elasticities in terms of the milk output Y_M represent the (proportional) shape of the production possibilities frontier (given inputs) for output Y_{NM} and the shape of the production function (given other inputs and Y_{NM}) for input X_K – or output trade-offs and input contributions to milk output, respectively. That is, the estimated output elasticity with respect to the non-milk output, $\varepsilon_{M,NM} = \partial \ln Y_M / \partial \ln Y_{NM} = \partial \ln Y_M / \partial \ln Y_{NM} * (Y_{NM}/Y_M)$, is expected to be negative as it reflects the slope of the production possibilities frontier, with its magnitude capturing the marginal trade-off between milk and non-milk outputs. The estimated output elasticity with respect to input k, $\varepsilon_{M,K} = \partial \ln Y_M / \partial \ln X_K = \partial Y_M / \partial X_K * (X_K/Y_M)$, is expected to be positive, with its magnitude representing the (proportional) marginal productivity of X_K .

Returns to scale (RTS) may be computed as a combination of the Y_M elasticities with respect to the non-milk output and inputs. For example, for a production function, RTS is defined as the sum of the input elasticities to, in a sense, reflect the distance between isoquants. Similarly for a transformation function, such a measure must control for the other output(s). Formally, RTS is defined for the transformation function as $\varepsilon_{M,X} = \varepsilon_K\ \ \varepsilon_{M,K}\ \ /(1-\varepsilon_{M,NM})$. Technical efficiency is defined as the ratio of the observed output to the frontier output that could be produced by a fully efficient firm. Thus, technical efficiency of a farmer is between zero and one and is inversely related to the inefficiency effect. The TE (technical efficiency) "scores" are estimated as TE = $\exp(-u_i)$. It is assumed that the inefficiency effects are independently distributed and u_i arise by truncation (at zero) of the exponential distribution with mean m_i, and variance σ^2.

Data and Methods

For the EU, we use Eurostat data sets for 1999 through 2007 from Denmark (3,744 observations), France (12,180), Germany (15,524), Italy (13,272), Spain (11,315), and the UK (5,970) to represent dairy production (Eurostat 2014). We also use available FADN data for the years covered in the analysis. Organic operations in these dairy surveys are self-identified. The extent of pasture use is determined on the basis of stocking density estimates provided by the survey respondents. These are determined on the basis of number of cows divided by pasture in hectares, with the most intensive operations having ≤0.5 hectares per cow and the most extensive having >1.5 hectares per cow. The EU countries we examine account for about 70% of EU milk production, with Germany accounting for 21%, France 18%, UK 10%, Italy 8%, Spain 4%, and Denmark 3%.

For the US, data on dairy farms is used in the following regions: Appalachia, Corn Belt, Lake States, Mountain West, Northeast, Northern Plains, Southeast, Southern Plains, and Pacific. The data are from USDA's Agricultural Resource Management Survey (ARMS) for 1999-2007, and include 8,233 dairy farms. The states included are Arizona, California, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, New York, New Mexico, Ohio, Oregon, Pennsylvania, Tennessee, Texas, Vermont, Virginia, Washington, and Wisconsin and represent approximately 85% of the US milk production. Our US sample includes the "traditional" US dairy region (the Corn Belt, Lake States, and Northeast), farms that are arguably the most similar in technology usage to those in the EU, with a mix of farms including some that use total mixed rations and others that rely either to limited or extensive degrees on pasture. We also include the bulk of dairy operations in the western, southwestern, and southern US, many of which tend to be larger-scale. We encountered estimation challenges with the transformation function when including California, Oregon, and Washington due to the heterogeneity of dairy operations there, which we solved by including the major producing counties only in these states—accounting for about 70% of production in each state. Thus, our results represent the major dairy production regions for both the US and the EU.

The EU and US micro data sets used are harmonized with outputs and inputs similarly defined, so that cost advantages by country and technology can be identified. Specifically, dairy output data for Eurostat and ARMS were comparable. Non-dairy output was constructed by subtracting dairy output from total output. It was concluded that the ARMS value for off-farm income earned was conceptually the same as that for the EU. For inputs, it was concluded that the expense items were similarly estimated, but in some cases were included in different categories, thus the different numbers of input variables in the US and EU functions. Previous applications have compared farm productivity measures using both US and Eurostat data, including Ball et al. (2008). The net returns, scale efficiency (RTS, defined in the previous section), and technical efficiency (TE) associated with milk production using the multi-output transformation function framework was estimated for each country. Lastly, a financial-performance comparison of the dairy farms was made by country, technology, and size. Table 1 compares the structural trends in the dairy sector for the countries and the dairy production regions in the US analyzed. Figure 1 identifies the major dairy producing districts by EU country.

Since we are interested in estimating economic performance measures associated with pasture-use groupings, we use a stochastic production frontier (SPF) approach to analyze performance within the groups over the nine-year period, using a transformation function. The SPF results allow for determination of TE and RTS. The SPF measurement involves econometric estimation of a four-output (milk, crops, other livestock, and off-farm income), 10 input (as listed earlier, and six for the US) plus time variable transformation or distance function. We use a pooled approach with all dairy farm observations.

Results

The transformation function estimates by country resulted in >50% of the estimated parameters being significant at the $P \leq 0.10$ level. In addition, the calculation of output elasticities (expected negative signs) and input elasticities (expected positive signs) generally resulted in correct signs for all countries. These results are available on request from the authors. This was uniformly so for the EU countries, but for the US traditional dairy states, the chemicals (pesticides) input elasticity was unexpectedly negative, indicating that increased use of pesticides decreased dairy productivity. Overall, the estimated transformation functions fit the data quite well.

Tables 1 through 8 (See Appendix 1) present the summarized scale and technical performance results by size and technology. We present five herd size categories and three technology cow/ha partitions with important technical and financial information by category. We find that large, higher stocking rate farms generally outperformed smaller farms with lower stocking rates using most economic measures. This is particularly the case with respect to profitability and RTS, but not TE. We discuss each of these in more detail as follows.

Returns to Scale

We find that in most of the countries, RTS trended downward as stocking density increased, indicating greater scale efficiency with more intensive land use. In particular, as the stocking density increased from the well-populated categories of >0.5 to ≤1.5 cows/ha to >1.5 cows/ha, RTS decreased strongly in most countries, particularly Italy and the UK. For example, in Italy, RTS declined from 2.01 to 1.67 and in the UK it declined from 1.62 to 1.39. Furthermore, net return on assets for farms with the highest stocking rates were higher than for farms with medium stocking rates, with the exception of Spain. As herd size increased, RTS trended downward in all seven EU countries, indicating greater scale efficiency for the larger operations. For example, RTS in Germany declined from 1.54 to 1.04 as herd size increased from ≤50 cows to >1,000 cows (see Figure 3).

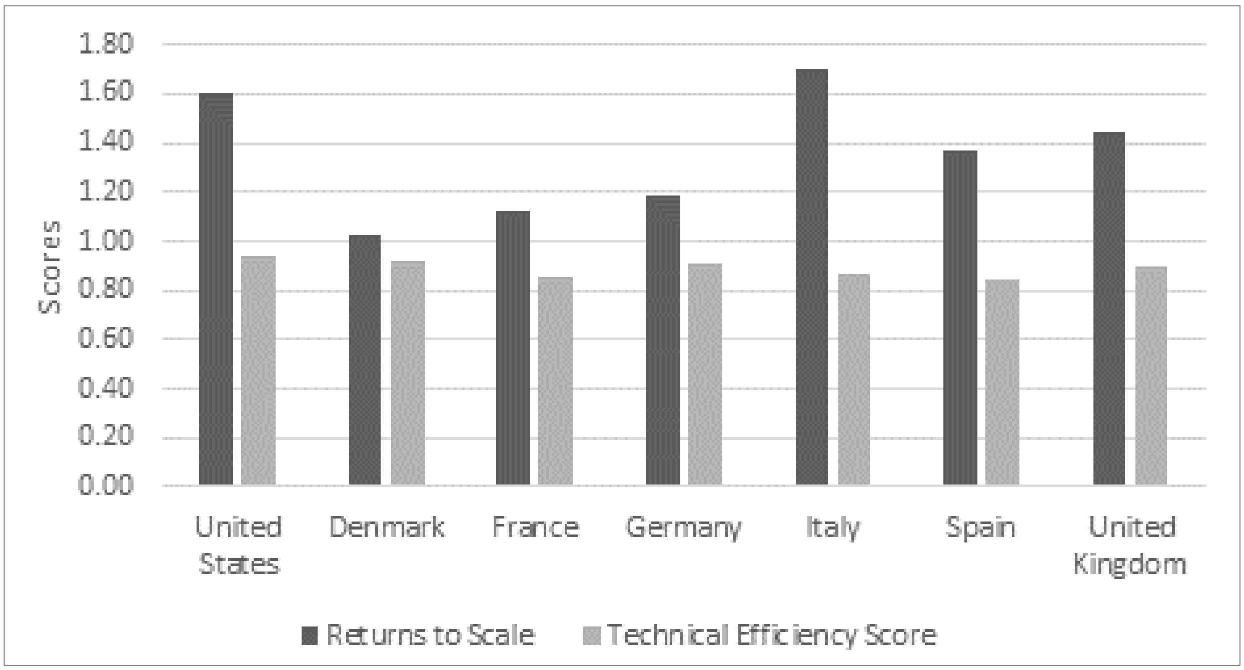

Figure 3. Returns to scale and technical efficiency of dairy operations by country 1999–2007.
Source. USDA–Agricultural and Resource Management Survey (ARMS) and Eurostat

Milk Yield

As herd size increased, milk yields per cow trended upward in all countries. Note, for example, that kg milk produced per cow in Germany increased from 6,070 for the ≤50 cow to 7,843 for the >1,000 cow operations. This is partially due to higher energy feeds used by larger-scale operations, suggested by the increase in feed costs per cow. Note, for example, the US case where feed cost per cow increased from $401/cow for the ≤50 cow operations to $508 for the >1,000 cow operations. Comparing production across countries, the US produced the most milk per cow, with the largest operations (>1,000 cows) producing 11,252 kg/cow, compared with the second-highest large-scale operations (>1,000 cows) in Germany, producing 7,957 kg/cow.

Net Return on Assets

Net return on assets generally trended upward as herd size increased, suggesting greater profitability for larger-scale operations, consistent with economies of scale as shown by MacDonald et al. (2007) for the United States. France had relatively high net return on assets, ranging from 14% to 20% depending upon farm size category. Other regions also having high net return on assets were the UK, Spain, Italy, and Denmark, where net return on assets were >8%. Note that in UK and Germany, the >500, ≤1,000 cow operations experienced 15% net return on assets.

Technical Efficiency

We find no general trend in TE scores by technology or farm size. Farms having the highest TE scores (>0.90) were all sizes of farms in the United States, medium-sized Danish farms, smaller German farms, and the largest Spanish farms, indicating that farms in these categories are producing at levels very close to the stochastic production frontier. The relatively higher TEs among some of the small farms may be the result of their having to pay very close attention to production efficiency in order to remain competitive with larger-scale farms that benefit from economies of scale. United States and Danish farms of all stocking rate categories and more intensive German farms had relatively high (>0.90) TE scores. See Figure 3 for an illustration of TE by country.

Income Diversification

Major differences were not found in farm diversification by country and farm size. The percentage of total farm output from dairy ranged from 66% for Danish >500, ≤1,000 cow operations to 90% for Spanish >500, ≤1,000 cow operations, with the remaining categories falling rather evenly within these boundaries. No clear trends in specialization are noted across all countries, but larger-scale farms tended to be more specialized in Italy, Spain, the UK, and the US. Off-farm income, however, was most important on small-scale (≤50 cows) US farms, accounting for 16% of total income, and larger-scale German farms, accounting for 20% and 17% of household income on >500, ≤1,000 cow operations and >1,000 cow operations, respectively. Off-farm income was least important (contributing ≤1% of household income) on Italian and Spanish farms and on large-scale (>1,000 cows) US farms.

Labor, Feed, and Energy Costs

With the exception of Germany, labor costs per cow generally dropped sharply with farm size as farms became more specialized in dairy and stocking rates increased. Furthermore, milking systems presumably became more automated with farm size. Khanal et al. (2010) showed this to be the case, with larger farms being the greater adopters of four automated technologies. Less clear patterns were seen with feed and energy expenses per cow, though feed expenses in several countries increased with farm size (US, Denmark, Germany, and the UK) along with stocking density and milk production per cow. Figure 4 shows feed and labor costs per cow by country.

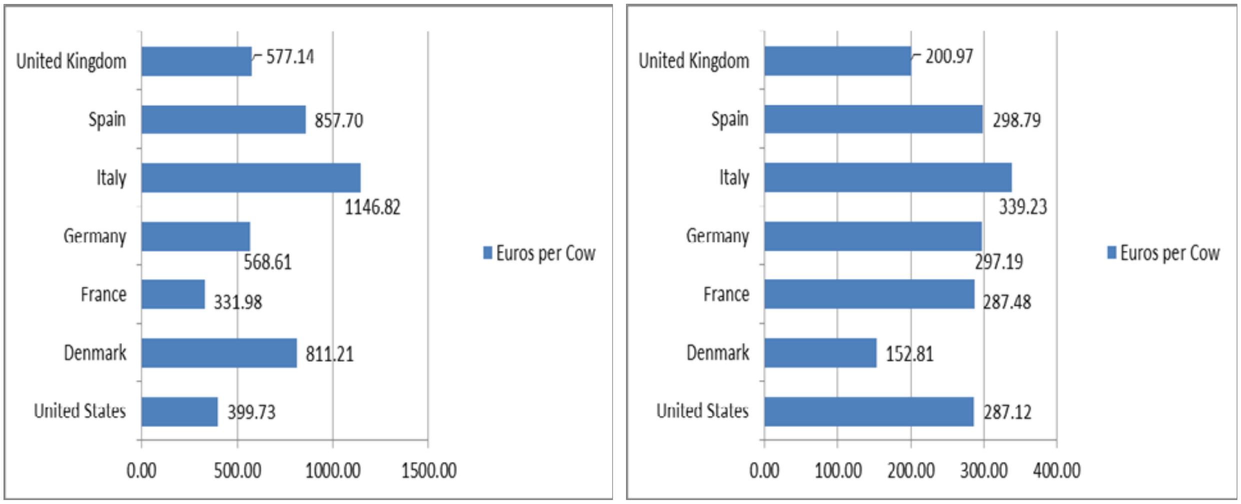

Figure 4. Cost of feed* and labor* per cow on dairy operations by country 1999–2007.
Note. *In Euros; US data converted at an average rate of 1.2 US dollars per Euro.[2]
Sources. Eurostat 2014; ARMS

Conclusions

This study sheds empirical light on dairy production structure in various countries of the EU and the US. Based on a common analytical framework, different quantitative measures derived from an econometrically estimated transformation function are discussed. The aim is to gain insight on the relative competitiveness of the regions by focusing on alternative dairy production systems at the farm level. Dairy industry competitiveness is not solely determined by the competitiveness of the milk production segment, which is the segment on which we focus. Certainly, given that much of trade is in processed or manufactured products, the productive efficiency associated with dairy processing is also important in determining overall industry competitiveness. Further research is encouraged that investigates the competitiveness of the processing segment to gain a fuller picture of dairy industry competitiveness.

The US and most EU countries considered in this analysis show greater dairy farm scale efficiency land is used more intensively, as indicated by increased returns to scale with higher stocking density. Furthermore, an upward trend in farm net return on assets with larger farm size is observed with a few exceptions. Larger dairy operations also show generally greater scale efficiency based on higher milk productivity per cow. In some EU countries, greater degrees of specialization also lead to greater profitability, reflecting economies of scale. The scale of dairy production is positively linked to productivity and profitability over all countries investigated.

However, the empirical analysis also revealed a technically efficient dairy operation does not necessarily require a larger scale or a certain production technology. Highly efficient small scale dairy operations were found in the US and Germany, highly efficient medium-scale dairy operations in Denmark, and highly efficient large scale farms in Spain. This suggests that the relevant competitive edge is still determined to a great deal by regional parameters and structural

[2] https://research.stlouisfed.org /fred2 /data/EXUSEU.txt

conditions in the various countries. The empirical findings for the effects of diversification and off-farm income also point in this direction.

While we have analyzed the productivity of the top two milk producing regions that are also major exporters, we note that several countries outside the EU and the US are also major exporters, most notably New Zealand. Thus, for a full analysis of dairy trade, these countries would need to be included. However, because of the size of the EU and US industries, policies introduced in these regions can have major impacts on dairy trade.

Overall, one can conclude that each of the EU dairy production regions show potential to significantly strengthen their export positions as a consequence of the latest deregulation efforts, namely the milk quota seizure in 2015. Denmark, Germany, Italy, Spain, and the UK show increasing returns to scale and Denmark, Germany, and the UK show higher net return on assets on larger scale farms, suggesting as the farms in these countries expand, they will become more competitive. For the period considered in this study, significant economic forces are at work towards more productive and efficient dairy production throughout the EU. The UK, Germany, and France experienced particularly high net return on assets, returns to scale, and technical efficiency levels that would suggest that increases in farm size and attention to efficiency will significantly influence their productivity. Further deregulation linked with significant milk price fluctuation will likely lead to a reinforcement of these economic linkages between scale, size, cow productivity, and profitability at the farm level as well as total factor productivity and efficiency at the sectoral level. We expect this to result in a faster reallocation of productive resources to more productive and efficient dairy operations, taking into account regional parameters and structural conditions in the various countries. With respect to the US, increasing returns to scale, relatively high milk productivity per cow and technical efficiency, and strong net return on assets among the largest farms will position it to maintain its international competitiveness as a top-five dairy exporter, particularly as farm sizes continue to increase.

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Appendix 1

Table A1. Changing structure of dairy farms in selected EU-27 countries and the United States.

Table A1. Changing structure of dairy farms in selected EU-27 countries and the United States.

Country	Number of Operations			% Change 2000-14	Cows per Farm			% Change 2000-14	Milk per Cow, Kg			% Change 2000-14
	2000	2007	2014		2000	2007	2014		2000	2007	2014	
United States	105,170	75,140	45,344	-56	88	121	204	132	8,257	9,193	10,096	22
Denmark	9,676	4,940	3,622	-63	68	107	151	122	6,930	8,919	9,452	36
France	116,647	97,368	74,397	-36	36	38	50	39	5,623	6,381	6,978	24
Germany	136,000	101,000	77,336	-43	35	41	56	60	6,122	6,944	7,541	23
Italy	97,000	48,487	36,040	-63	35	41	57	63	4,894	5,998	5,623	23
Spain	77,810	37,290	18,798	-75	16	26	46	188	4,964	6,700	7,505	51
United Kingdom	25,944	15,385	14,060	-46	90	130	134	49	6,155	7,175	8,022	30

Sources. USDA Agricultural Statistics, various issues, and Eurostat.

Table A2. US cost of production: means and statistics by pasture usage and herd size.

Table A2. US cost of production: means and statistics by pasture usage and herd size.

Item	**A** *Cows* **≤50**	**B** *Cows* **>50, ≤100**	**C** *Cows* **>100, ≤500**	**D** *Cows* **>500, ≤1,000**	**E** *Cows* **>1,000**	**F** *Stocking* **≤0.5 Cows/Ha**	**G** *Stocking* **>0.5, ≤1.5 Cows/Ha**	**H** *Stocking* **>1.5 Cows/Ha**
Observation	337	1,885	4,548	869	382	1,016	3,285	3,720
% of Farms	9.4	42.0	44.7	2.6	1.3	10.5	50.1	39.3
% Value of Production	3.3	20.9	48.6	12.6	14.6	14.8	37.8	47.4
Farm Size and Pricing Information								
Dairy Cows per Farm	46	75	179	683	1,813	167	117	207
Farm Size, Ha	92	111	193	288	242	206	171	114
Land price, $/Ha	6,193	6,067	5,263	5,370	5,948	7,323	4,960	6,353
Technical and Financial Measures								
Milk/Cow, Kg	9,552	9,151	10,087	11,251	11,015	9,086	8,529	10,657
Net Return on Assets, %	5.6	4.9	5.6	6.9	9.7	6.3	5.0	6.6
Stocking Density, Cows/Ha	1.34	1.43	1.93	3.02	5.81	0.22	0.98	3.53
Off-farm % of Total Output	16.1	12.8	6.3	1.5	1.0	5.1	9.4	4.9
Dairy % of Total Output	72.1	76.9	77.2	89.7	85.3	54.9	76.8	81.6
Labor Cost/Cow, $	772.0	549.5	327.8	212.2	122.8	347.8	432.6	273.3
Feed Cost/Cow, $	433.9	433.7	393.6	698.9	631.1	717.4	356.1	504.0
Energy Cost/Cow, $	48.6	44.5	38.0	28.5	16.1	41.8	45.7	26.4
Performance Measures								
Returns to Scale	2.45	1.95	1.24	0.39	0.19	1.56	1.68	1.54
Technical Efficiency Score	0.95	0.95	0.94	0.92	0.94	0.94	0.95	0.94

Table A3. Denmark cost of production means and statistics by pasture usage and herd size.

Table A3. Denmark cost of production means and statistics by pasture usage and herd size.

Item	**A** *Cows* **≤50**	**B** *Cows* **>50, ≤100**	**C** *Cows* **>100, ≤500**	**D** *Cows* **>500, ≤1,000**	**E** *Cows* **>1,000**	**F** *Stocking* **≤0.5 Cows/Ha**	**G** *Stocking* **>0.5, ≤1.5 Cows/Ha**	**H** *Stocking* **>1.5 Cows/Ha**
Observation	484	1,515	1,735	869			353	3,379
% of Farms	12.9	40.5	46.3	2.6			9.4	90.3
% Value of Production	3.7	36.3	58.1	12.6			9.0	90.6
Farm Size and Pricing Information								
Dairy Cows per Farm	36	76	155	683			99	110
Farm Size, Ha	41	84	152	288			147	108
Rental Rate, Euros/Ha	283	318	495	5,370			173	128
Technical and Financial Measures								
Milk/Cow, Kg	6,629	7,526	7,922	11,251			7,616	7,587
Net Return on Assets, %	6.8	7.8	8.3	6.9			8.1	8.2
Stocking Density	2.95	2.32	2.61	3.02			1.32	2.67
Off-farm % of Total Output	2.8	2.1	3.2	1.5			3.9	2.8
Dairy % of Total Output	78.3	79.7	76.0	89.7			75.3	76.9
Labor Cost/Cow, Euros	258.5	175.1	137.9	212.2			164.7	152.3
Feed Cost/Cow, Euros	700.0	736.8	851.9	698.9			830.3	812.9
Energy Cost/Cow, Euros	74.6	80.4	89.9	28.5			62.3	85.5
Performance Measures								
Returns to Scale	1.56	1.09	0.96	0.82			0.97	1.04
Technical Efficiency Score	0.90	0.93	0.92	0.86			0.94	0.92

Table A4. France cost of production means and statistics by pasture usage and herd size.

Table A4. France cost of production means and statistics by pasture usage and herd size.

Item	A *Cows* ≤50	B *Cows* >50, ≤100	C *Cows* >100, ≤500	D *Cows* >500, ≤1,000	E *Cows* >1,000	F *Stocking* ≤0.5 Cows/Ha	G *Stocking* >0.5, ≤1.5 Cows/Ha	H *Stocking* >1.5 Cows/Ha
Observation	8,074	3,626	480	869		51	6,995	5,134
% of Farms	66.2	29.8	3.9	2.6		0.4	57.4	42.2
% Value of Production	48.3	43.4	8.3	12.6		0.2	51.3	48.5
Farm Size and Pricing Information								
Dairy Cows per Farm	33	67	129	683		28	45	50
Farm Size, Ha	63	110	160	288		99	86	73
Rental Rate, Euros/Ha	128	96	131	5,370		41	80	111
Technical and Financial Measures								
Milk/Cow, Kg	5,798	6,173	6,039	11,251		4,860	5,752	7,587
Net Return on Assets %	13.7	19.9	17.9	6.9		2.1	14.0	8.2
Stocking Density	1.43	1.56	1.56	3.02		0.41	1.14	2.67
Off-farm % of Total Output	3.5	4.3	4.5	1.5		9.1	3.8	2.8
Dairy % of Total Output	67.8	68.8	68.8	89.7		77.5	70.6	76.9
Labor Cost/Cow, Euros	343.8	258.6	170.3	212.2		359.9	293.8	152.3
Feed Cost/Cow, Euros	336.6	339.8	269.8	698.9		322.7	307.7	812.9
Energy Cost/Cow, Euros	93.5	87.7	70.9	28.5		99.0	86.2	85.5
Performance Measures								
Returns to Scale	1.15	1.11	1.11	0.82		1.48	1.13	1.11
Technical Efficiency Score	0.86	0.89	0.86	0.86		0.80	0.86	0.87

Table A5. Germany cost of production means and statistics by pasture usage and herd size.

Table A5. Germany cost of production means and statistics by pasture usage and herd size

Item	**A** ***Cows*** **≤50**	**B** ***Cows*** **>50, ≤100**	**C** ***Cows*** **>100, ≤500**	**D** ***Cows*** **>500, ≤1,000**	**E** ***Cows*** **>1,000**	**F** ***Stocking*** **≤0.5** **Cows/Ha**	**G** ***Stocking*** **>0.5, ≤1.5** **Cows/Ha**	**H** ***Stocking*** **>1.5** **Cows/Ha**
Observation	9,352	4,756	1,253	869	55	20	3,815	11, 689
% of Farms	60.2	30.6	8.1	2.6	0.4	0.1	24.6	75.3
% Value of Production	26.5	32.7	22.5	12.6	8.1	0.2	24.2	75.6
Farm Size and Pricing Information								
Dairy Cows per Farm	31	69	172	683	1.260	74	63	63
Farm Size, Ha	41	86	241	288	1,784	334	125	72
Rental Rate, Euros/Ha	204	238	141	5,370	105	66	99	221
Technical and Financial Measures								
Milk/Cow, Kg	6,070	7,006	7,372	7,843	7,957	5,382	6,237	6,562
Net Return on Assets %	2.1	5.7	4.2	14.7	12.4	0.0	3.4	5.5
Stocking Density	1.90	2.00	2.12	1.97	2.49	0.41	1.21	2.20
Off-farm % of Total Output	10.5	4.9	7.2	19.7	17.3	18.0	12.6	8.7
Dairy % of Total Output	74.9	77.8	78.9	68.8	72.3	70.1	75.1	76.2
Labor Cost/Cow, Euros	360.1	226.5	248.2	404.0	400.2	357.7	353.2	279.1
Feed Cost/Cow, Euros	429.1	470.1	547.8	882.4	746.7	575.6	527.0	529.0
Energy Cost/Cow, Euros	183.3	169.9	191.5	265.8	232.3	291.7	229.0	178.2
Performance Measures								
Returns to Scale	1.54	1.31	1.31	1.12	1.04	1.39	1.26	1.17
Technical Efficiency Score	0.90	0.92	0.91	0.89	0.88	0.87	0.90	0.91

Table A6. Italy cost of production means and statistics by pasture usage and herd size.

Table A6. Italy cost of production means and statistics by pasture usage and herd size.

Item	A *Cows* ≤50	B *Cows* >50, ≤100	C *Cows* >100, ≤500	D *Cows* >500, ≤1,000	E *Cows* >1,000	F *Stocking* ≤0.5 Cows/Ha	G *Stocking* >0.5, ≤1.5 Cows/Ha	H *Stocking* >1.5 Cows/Ha
Observation	9,662	2,251	1,317	29	12	954	2,573	9,744
% of Farms	72.8.	17.0	9.9	0.2	0.4	7.2	19.4	73.4
% Value of Production	29.3	24.4	39.7	2.9	0.1	3.8	8.7	87.5
Farm Size and Pricing Information								
Dairy Cows per Farm	23	71	182	635	1,499	33	25	57
Farm Size, Ha	29	57	82	206	709	172	37	28
Rental Rate, Euros/Ha	67	131	270	520	155	223	733	252
Technical and Financial Measures								
Milk/Cow, Kg	4,824	6,398	7,169	6,449	6,659	3,655	4,520	5,707
Net Return on Assets %	7.8	9.1	10.5	9.9	8.8	11.0	8.1	9.2
Stocking Density, Cows/Ha	3.29	5.53	131.75	10.02	9.78	0.27	1.05	22.08
Off-farm % of Total Output	2.3	0.8	0.4	0.9	---	2.7	2.8	0.1
Dairy % of Total Output	68.8	73.7	76.0	81.5	74.2	79.2	76.3	86.5
Labor Cost/Cow, Euros	586.4	297.7	184.3	153.0	133.1	535.8	577.8	307.0
Feed Cost/Cow, Euros	1024.4	1121.0	1268.0	1172.0	1107.8	920.3	1042.8	1167.0
Energy Cost/Cow, Euros	106.8	112.7	114.4	108.7	123.1	67.9	108.3	114.3
Performance Measures								
Returns to Scale	3.51	1.22	1.30	1.28	1.11	1.61	2.01	1.67
Technical Efficiency Score	0.87	0.88	0.88	0.84	0.82	0.85	0.86	0.87

Table A7. Spain cost of production means and statistics by pasture usage and herd size.

Table A7. Spain cost of production means and statistics by pasture usage and herd size.

Item	**A** *Cows* **≤50**	**B** *Cows* **>50, ≤100**	**C** *Cows* **>100, ≤500**	**D** *Cows* **>500, ≤1,000**	**E** *Cows* **>1,000**	**F** *Stocking* **≤0.5 Cows/Ha**	**G** *Stocking* **>0.5, ≤1.5 Cows/Ha**	**H** *Stocking* **>1.5 Cows/Ha**
Observation	8,438	2,286	587	3	---	553	1,635	9,127
% of Farms	74.6.	20.2	5.2	0.3	---	4.9	14.5	80.7
% Value of Production	47.4	33.3	18.9	0.4	---	7.2	9.8	83.0
Farm Size and Pricing Information								
Dairy Cows per Farm	28	68	182	624	---	70	30	42
Farm Size, Ha	18	31	45	157	---	26	40	18
Rental Rate, Euros/Ha	93	113	111	115	---	62	67	119
Technical and Financial Measures								
Milk/Cow, Kg	5,758	6,842	7,596	6,903	---	6,234	5,561	6,155
Net Return on Assets %	5.6	8.3	10.5	4.5	---	18.0	12.9	7.0
Stocking Density	3.42	7.21	22.25	2.40	---	0.07	1.12	6.19
Off-Farm % of Total Output	0.3	0.5	0.6	---	---	0.6	0.3	0.4
Dairy % of Total Output	79.2	86.2	87.6	90.0	---	87.8	77.9	83.3
Labor Cost/Cow, Euros	393.9	220.1	167.1	163.4	---	196.7	354.2	301.1
Feed Cost/Cow, Euros	804.2	871.2	975.1	572.2	---	636.3	782.4	885.8
Energy Cost/Cow, Euros	60.8	62.0	66.9	25.1	---	48.8	66.8	62.9
Performance Measures								
Returns to Scale	1.45	1.33	1.26	1.00	---	1.29	1.62	1.35
Technical Efficiency Score	0.83	0.84	0.84	0.90	---	0.83	0.82	0.84

Table A8. United Kingdom cost of production means and statistics by pasture usage and herd size.

Table A8. United Kingdom cost of production means and statistics by pasture usage and herd size.

Item	A *Cows* ≤50	B *Cows* >50, ≤100	C *Cows* >100, ≤500	D *Cows* >500, ≤1,000	E *Cows* >1,000	F *Stocking* ≤0.5 Cows/Ha	G *Stocking* >0.5, ≤1.5 Cows/Ha	H *Stocking* >1.5 Cows/Ha
Observation	1,410	2,249	2,290	21	---	9	998	4,963
% of Farms	23.6.	37.7	38.4	0.4	---	0.2	16.7	83.1
% Value of Production	7.5	29.3	63.9	2.0	---	0.01	11.2	90.6
Farm Size and Pricing Information								
Dairy Cows per Farm	36	75	165	629	---	46	68	109
Farm Size, Ha	51	78	138	370	---	329	124	90
Rental Rate, Euros/Ha	239	239	301	308	---	10	167	318
Technical and Financial Measures								
Milk/Cow, Kg	5,411	6,327	7,015	6,892	---	5,222	5,826	6,489
Net Return on Assets %	7.6	8.8	10.7	14.5	---	5.2	8.2	9.8
Stocking Density	1.85	2.09	2.37	2.63	---	0.40	1.22	2.33
Off-Farm % of Total Output	3.6	2.3	2.4	0.9	---	6.3	4.2	2.2
Dairy % of Total Output	73.0	70.2	81.9	89.0	---	62.3	75.2	79.2
Labor Cost/Cow, Euros	306.7	196.0	145.6	100.5	---	372.1	459.3	165.0
Feed Cost/Cow, Euros	473.2.	509.7	561.6	509.4	---	636.9	545.3	537.8
Energy Cost/Cow, Euros	103.8	84.6	93.1	63.1	---	117.5	100.2	78.4
Performance Measures								
Returns to Scale	1.71	1.49	1.35	1.32	---	1.94	1.62	1.39
Technical Efficiency Score	0.86	0.88	0.89	0.84	---	0.83	0.88	0.88