Exploring competitiveness of low input dairy farms across European regions with efficiency analysis

Jef Van Meensel[1], Ludwig Lauwers[1], Jo Bijttebier[1], Jolien Hamerlinck[1]

[1] ILVO, Social Sciences Unit, Burg. Van Gansberghelaan 115, B-9820 Merelbeke, Belgium

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Abstract

This paper explores the competitiveness of low input dairy farms. Efficiency scores and underlying key performance indicators are used to compare the performance of low input and conventional farms in Europe and to account for regional differences. Results show that low input dairy farms can be competitive with conventional ones, but regional differences exist. In order to be competitive, low input farms should transform their external inputs, land, labour and cows into milk revenues more technically efficiently compared to conventional farms, because they use inputs in a less cost minimizing proportion compared to conventional farms.

Keywords: dairy farming, low input, competitiveness, efficiency analysis, Europe

1 Introduction

Conventional dairy farms increasingly use so-called external inputs like concentrates, fertilizer or crop protection products. Pretty and Bharucha (2014) report a doubling of agricultural area under irrigation and a fourfold increase of fertilizer use over the last century on agricultural land in the world. Dairy farmers apply this high input (HI) production method because it entails a higher productivity, resulting in a better economic performance (Wilson and Tisdell, 2001, Hodgson et al., 2005). Nevertheless, abundant input use also results in environmental problems like nutrient imbalances, water and air pollution and biodiversity losses (Hodgson et al., 2005; Stoate et al., 2009; Pretty and Bharucha, 2014; Kleijn et al., 2015). Alternative farming systems, with a lower external input use, can cope with these problems (Bignal and McCracke, 1996; van Grinsven et al., 2015). A typical example is low input (LI) farming, as a response to HI farming. Although the concept of LI farming is not commonly defined, it can be characterized as relying less on external and non-renewable resources and more on locally generated resources (Poux, 2007). Moreover, it is associated with a reduced environmental impact and a higher nature conservation value.

While LI farming is based on environmental considerations, the question is whether it is also attractive from an economic point of view? Are low input (LI) farming systems competitive and can LI farms compete with conventional dairy farms? The worry about competiveness can be translated into a concern about efficient input use on LI dairy farms. Do LI farms convert inputs efficiently into outputs? What is the effect on the technical efficiency of farms of using low levels of external inputs together with high levels of other inputs like land or labor. Moreover, substituting external inputs for other inputs may affect not only the technical efficiency of farms, but also the extent to which inputs are used in a cost minimizing proportion, given the input prices. Another question concerns the optimal scale of LI dairy farms. Does a farm needs to be preferably larger or smaller when adopting a LI or HI strategy?

For answering these questions, frontier methods can be used. These methods compare in an integrated manner the transformation of inputs into outputs on a certain farm with the optimal transformation at a certain point in time (Farrell, 1957). Different efficiency scores can be calculated. Technical efficiency (TE) represents the extent to which a given amount of outputs is generated with a minimum amount of inputs (input oriented), or the extent to which a given amount of inputs can be used to produce a maximum amount of outputs (output-oriented). Cost allocative efficiency (CAE) represents the ability to use optimal input proportions given input prices and the production technology. Cost efficiency (CE) combines input oriented TE and CAE. Finally, scale efficiency (SE) indicates if a farm is producing at an optimal scale (Coelli et al., 2005).

In order to examine their competitiveness, LI dairy farms need to be defined. Since there is no clear-cut description for LI dairy farms, analyzing their competitiveness is not straightforward. Contrary to organic farms, LI dairy farms have no legal definition in the European legislation and remain hidden in the group of conventional farms in the European Farm Accountancy Data Network (FADN). Different concepts to define LI farms have been designed. These are mainly based on input ratios. The CEAS/EFCN classification (CEAS/EFNCP, 2000), for example, is constructed based on different indicators like fertilizer use, concentrate use, farm size, herd size, breed, milk yield and livestock density. The intensification indicator in the IRENA indicator report (EEA, 2006) is defined as external input costs divided by utilizable agricultural area. Andersen et al. (2007) also include an output in their definition. They describe farm intensity as the total monetary value of agricultural products per hectare and adopt it in combination with a land use dimension. In this our paper the concept designed by Bijttebier et al. (2016) is used to distinguish LI from HI farms. This country-specific ratio is based on external input costs (EIC) divided by grazing livestock units (GLU).

The objective of this paper is to examine the competitiveness of LI dairy farms in Europe with efficiency analysis. European data from the Farm Accountancy Data Network (FADN) are used in order to reveal insights in the competitiveness of LI dairy farms in Europe and regional differences are analysed.

2 Materials and methods

The LI concept designed by Bijttebier et al. (2016) is used to distinguish between LI and HI dairy farms. This ratio is based on EIC divided by GLU and is applied to the dairy farms in the FADN dataset. EIC comprise of costs for fertilizer, crop protection, fuel, electricity and purchased feed while GLU cover all animals producing milk and milk products and their replacement cattle. Based on this ratio, LI farms are selected for each country and year separately. In each country the 25% dairy farms with the lowest value for the ratio are defined as LI and the 25% farms with the highest value are specified as HI. The farms in between represent the medium input (MI) group. The 25% cut off value is selected arbitrarily to create more distinct LI and HI groups which are less influenced by the MI farms and consequently allow for better comparisons between the groups, looking at competitiveness and strategies applied.

Efficiency analysis, a technique based on production theory, is used to explore the competitiveness of LI dairy farms. This technique enables comparing the production level of a farm to a theoretical optimal production level (frontier) at a certain time taking into account different inputs and outputs (Farrell, 1957). Two methods are commonly used: data envelopment analysis (DEA) and stochastic frontier analysis (SFA). The former uses mathematical programming to establish a piece-wise frontier over the data. The latter applies econometric methods using a parametric function to estimate the frontier (Coelli et al., 2005). Contrary to SFA, DEA has the advantage that no functional form is presumed a priori to determine the frontier. However, because the frontier is established deterministically, DEA is sensitive to outliers. In this research DEA will be applied. Efficiency scores range between zero and one, zero being fully inefficient and one being fully efficient (Coelli et al., 2005).

Input oriented technical efficiency (TE) for transforming K inputs into M outputs for the i^{th} farm is calculated as follows:

$$\begin{aligned} & min_{\theta,\lambda}\,\theta \\ & subject\ to \quad -y_i + Y\lambda \geq 0 \\ & \qquad\qquad\quad \theta x_i - X\lambda \geq 0 \\ & \qquad\qquad\quad \lambda \geq 0 \end{aligned} \tag{1}$$

With θ a scalar for TE and λ a Nx1 vector of constants where N represents the number of farms in the dataset, X a KxN input matrix and Y a MxN output matrix and column vectors x_i and y_i the input and output quantities for the i^{th} farm.

The model assumes constant returns to scale (CRS). In order to account for variable returns to scale (VRS), the following restriction is added:

$$N1'\lambda = 1 \tag{2}$$

Based on the technical efficiency scores under CRS and VRS, scale efficiency (SE) is calculated for the i^{th} farm:

$$SE_i = TE_{i,CRS}/TE_{i,VRS} \tag{3}$$

By altering constraint (2) a third DEA model verifies if it concerns increasing or decreasing returns to scale when SE scale inefficiency occurs:

$$N1'\lambda \leq 1 \tag{4}$$

Assuming variable returns to scale, cost efficiency (CE) for the i^{th} farm is determined by solving the following linear program:

$$\begin{aligned} & min_{\lambda,x_i^*} w_i' x_i^* \\ & subject\ to \quad -y_i + Y\lambda \geq 0 \\ & \qquad\qquad\quad x_i^* - X\lambda \geq 0 \\ & \qquad\qquad\quad N1'\lambda = 1 \\ & \qquad\qquad\quad \lambda \geq 0 \end{aligned} \tag{5}$$

With w_i a Nx1 vector of input prices and x_i* the cost-minimizing Kx1 vector of input quantities given the input prices w_i and output quantities y_i.

The CE_i is calculated as the ratio between minimum cost and observed cost:

$$CE_i = w_i' x_i^* / w_i' x_i \tag{6}$$

Finally, CAE for the i^{th} farm is calculated residually as:

$$CAE_i = CE_i/TE_{VRS,i} \tag{7}$$

To account for the differences in efficiency between LI, MI and HI dairy farms, EIC (euros), labor (hours) and hectares of utilized agricultural area (UAA) are chosen as three main operational inputs. Number of dairy cows is selected as a fourth input to include farm size. Although labor is rather difficult to estimate for farmers, we include it because of its importance as a possible substitution element for EIC on LI farms. Only one output, economic output of milk production (euros), is included, considering it as the main operational output of the dairy farm. The output generated from production of beef and veal is taken into account in the input price as explained in the next paragraph.

Corresponding input prices are selected to calculate CAE and CE. For EIC this price is 1 for every farm because this input is already expressed in euros. Rent paid per ha is linked to UAA including owned land, because there is no other land cost available in FADN which is not already included in EIC. Paid labor price per hour is associated with total hours of labor since there are no convenient labor costs associated with family labor. A price per dairy cow is associated with the number of dairy cows. This price consists of all costs not included in the other input costs. As mentioned before economic output from beef and veal is not considered as an output in this study. Therefore it is subtracted from the costs that determine the dairy cow price. After all, beef and veal is also produced with the considered inputs, so it has to be taken into account in the efficiency analysis.

Obtained efficiency scores are compared between LI, MI and HI farms and underlying input-output ratios, input-input ratios and frequently used key performance indicators are used to explain differences in efficiency scores. This is done at European level. In addition, efficiency scores are also compared at a regional level, in order to account for regional differences. Countries are grouped in regions in order to have sufficient observations per region, based on geographical characteristics and based on similarities in prices of inputs. Table 1 provides an overview of the countries that are taken together in a region and the number of farms per region used in the analysis.

Average input prices per region are used to assess the efficiency scores. For dairy cows, a corresponding price can be calculated for each farm in the dataset and an average price per region can easily be calculated. The price for land and labor is only available in the dataset for farms that have rented land and paid labor. This creates the need for using average prices, because some farms do not rent land or do not use hired labor, resulting in no price figure available for these farms. Before average input prices are calculated, a boxplot analysis is executed per region for each input price. Input prices outside the range of more than 3 times the interquartile range are not considered for calculating the average. The average prices are calculated for every region for different years.

The European FADN dataset includes farm accountancy data of 27 member states of the European Union (EU) for the period from 2004 until 2012. We focus on the data of 2011 because the value of ratio indicator (EIC divided by GLU) used for distinguishing between LI, MI and HI farms is representative in 2011 for the observed trend between 2004 and 2012. In addition, data from the years 2009 until 2012 are used to get a view on the evolution of the efficiency scores in time. FADN data have the advantage that they cover more or less representatively professional farming over the EU, however at the expense of details. The dataset primarily consists of financial data and some structural data. Physical input values are not recorded in each country and are not available in FADN. Moreover, there is no distinction between costs for the different branches on the farm. Therefore specialist dairy farms are selected based on the standard output of the farms (Commission Regulation (EC) No 1242/2008). Farms with buffaloes were excluded from the dataset based on the method described in the EU dairy farms report 2013 (EC, 2014).

Outliers are excluded from the dataset, on the one hand to confirm that the selected farms are indeed specialist dairy farms and on the other hand to prevent bias in the DEA results. Specialized dairy farms are retained by analysing the dataset economically and structurally by using raw data and variables defined for the FADN standard results (FADN, 2011). These variables include economic output of milk, beef and veal on total economic output of the farm, value change of the dairy herd, hectares forage per UAA and the ratio of GLU and livestock units. Also the different input and output values used in our DEA are analysed. Farms with a negative price per dairy cow are excluded from the dataset. This applies to 255 farms which are considered to produce too much beef and veal in comparison with milk. Boxplots are constructed for the partial productivities and different input proportions. Farms with values outside three times the interquartile range are considered as outliers and are removed. As the distribution for the different ratios remains high after the first analysis, the boxplot analysis is executed twice. Finally a SFA, a Cobb-Douglass function is estimated with Stochastic Frontier Analysis (SFA) in order to detect final outliers. This results in a final dataset consisting of 4460 specialized European dairy farms: 1106 LI, 2228 MI and 1126 HI farms. Table 2 provides descriptive statistics for the sample of LI, MI and HI farms.

3 Results

a. Competitiveness at European level

In Table 3 the average efficiency scores are presented for the whole sample of LI, MI and HI farms. Explaining input-output ratios, input-input ratios and frequently used key performance indicators are shown in Table 2.

The TE of LI farms is not significantly different from the TE of MI and HI farms in Europe. LI farms use significantly more UAA, labour and dairy cows per unit of output, but this is compensated by significantly lower EIC per unit of output. TE differs significantly between MI and HI farms. Although MI farms have significantly lower EIC per unit of output compared to HI farms, the higher use of the other inputs results in a lower TE score. Despite the significantly lower milk production per cow and lower milk price, LI farms succeed in obtaining a similar TE score compared to HI farms by lowering EIC per unit of output and using more labor, land and dairy cows per unit of output. Contrarily, MI farms do not succeed in obtaining a similar TE score compared to HI farms.

Given the input prices, which do not differ between the different farm types, HI farms have an allocation of inputs that results in the highest CAE, followed by MI farms and LI farms. Compared to other farm types, HI farms use relatively more EIC per unit of other input, but less labor per dairy cow (only significantly different from LI farms, not from MI farms) and they have also more dairy cows per UAA. The better input allocation from an economic perspective is not only the case for our reference year 2011, but also for the years 2009, 2010 and 2012. The prices of the different inputs do not vary enough throughout the years to change the optimal input allocation. This is also confirmed by the farms with a CAE-score 1, which stay the same for the different years.

CE, combining TE and CAE, differs significantly between the farm types, being highest for HI farms and lowest for LI farms. This is not fully reflected by the total cost per kg milk, which is significantly lower for HI farms and MI farms compared to LI farms, but not significantly different between HI and MI farms. Nevertheless, HI farms have a significantly higher milk price, resulting in more euros obtained from milk production, which is the output in our efficiency analysis. Consequently, CE is significantly higher for HI farms. Although the TE of LI farms is not significantly different from the TE of MI and HI farms, their CE is significantly lower. This is caused by the significantly lower CAE of LI farms, meaning that at given input prices, LI farms use their inputs in a proportion that minimizes input costs to a lesser extent compared to MI and HI farms. LI farms use relatively less EIC compared to the other inputs, but more labor per dairy cow and they have also less dairy cows per UAA.

Scale efficiency is not significantly different between the different types of farms. The majority of farms in the sample can increase scale to become more scale efficient. In the HI group more farms should decrease their scale than in other groups.

b. Regional differences: example of BNL and BPR

Results at European level may hide differences in results between regions, due to different regional conditions or farming systems. In this section, we therefore analyse results at a regional level, taking the regions BNL (Belgium, Netherlands, Luxembourg) and BPR (Bulgaria, Hungary, Poland, Romania) as an example. In order to give insights in the regional differences in the performance of the same farm types, Table 4 compares the performance of LI, MI and HI farms, respectively, between the regions BNL and BPR. For each farm type, it is shown that the performance is significantly different in the two regions. Each type of efficiency is significantly higher in the BNL region, compared to the BPR region, and this for each farm type. Farms in the BNL region succeed better in transforming inputs into output (higher TE): they use significantly less of each input per unit of output. They also use an input proportion that is closer to the cost minimizing input proportion, given the input prices (higher CAE). Both input proportions and input prices differ significantly for each farm type between the regions. Compared to the BPR region, farms in the BNL region use proportionally more EIC per unit of other input, they use less labour per hectare and per dairy cow and they have more dairy cows per hectare. Also the input prices are higher in the BNL region. For each farm type, milk production per cow is higher in the BNL region.

The cost per kg milk production is also significantly higher, for each farm type, in the BNL region. The same applies for the milk price. When considering the margin (milk price minus total cost per kg milk), Table 4 shows that farms in the BPR region obtain a higher and positive margin, while the margin in the BNL region is negative. This is not reflected by the efficiency analysis, yielding higher efficiency scores for farms in the BNL region. The reason is that efficiency analysis only considers input price proportions to account for cost allocative efficiency, while absolute input price levels are not taken into account. This means that, when prices for all inputs are lower, similar cost allocative efficiency scores are obtained when input price proportions remain the same, despite the better economic margin.

The observed differences in performance of each farm type between regions and the differences in input prices urge for analysing the competitiveness of LI, MI and HI farms within separate regions. Table 5 provides results for the BNL region. TE is significantly lower for LI farms compared to HI farms, but not significantly different between LI and MI farms on the one hand, and between MI and HI farms on the other hand. LI farms have significantly less EIC per unit of output, but use more of all other inputs compared to MI and HI farms. Despite the significantly lower milk production per cow, LI farms succeed in obtaining a similar TE compared to MI farms, by having les EIC per unit of output and using more labor, land and dairy cows per unit of output. CAE is significantly lower on LI farms, compared to MI and HI farms. LI farms use relatively less EIC compared to the other inputs, they use more labour per dairy cow compared to MI farms and have less dairy cows per ha compared to HI farms. CE is significantly lower on LI farms and not significantly different between MI and HI farms. This is also reflected by the total cost per kg milk production. Despite a significantly lower milk production per dairy cow, MI farms succeed in obtaining a similar cost efficiency compared to HI farms by using relatively less EIC. Scale efficiency does not differ significantly between the different farm types.

In the BPR region (Table 6), TE is significantly higher for LI farms compared to the other farm types, despite the lower milk production per cow, and not significantly different between MI and HI farms. On LI farms, the use of more labor, land and dairy cows per unit of output is more than compensated by having less EIC per unit of output, resulting in a higher TE. CAE is similar between LI and MI farms, but significantly higher on HI farms. Compared to HI farms, LI farms use proportionally less EIC per unit of each of the other inputs, similar amounts of labor per hectare and per dairy cow, and a similar number of dairy cows per hectare. In the BPR region, CE is not significantly different between LI farms and MI farms on the one hand, and between LI farms and HI farms on the other hand. Also the total cost per kg milk does not differ significantly between LI farms and the other farm types. HI farms have a significant better CE than MI farms, which is mainly due to a better input allocation at given input prices.

In the BPR region, LI farms succeed in obtaining a similar CE compared to MI and HI farms, while in the BNL region, CE of LI farms is significantly lower. Both in the BPR and BNL region, CAE is significantly lower on LI farms compared to HI farms. Consequently, it is mainly the high TE that drives LI farms in the BPR region to obtain a similar CE compared to HI farms. In the BNL region, TE is lower on LI farms compared to HI farms. When comparing LI and HI farms in the BPR region, LI farms have on average 34% EIC less per unit of output, while they use 53% more land, 47% more labor and 50% more dairy cows per unit of output. The same comparison in the BNL region shows that LI farms have only 23% EIC less per unit of output, while they use 77% more land, 60% more labor and 41% more dairy cows per unit of output. Consequently, LI farms achieve a higher TE compared to HI farms in the BPR region, but not in the BNL region.

4 Conclusion

In Europe, low input (LI) dairy farms can be competitive with conventional dairy farms. Much depends on the region where the farm is situated. This paper shows that, in general, LI dairy farms are less cost efficient compared to their conventional counterparts. They use an input allocation, containing proportionally less external inputs and more labour, land and cows, which is less optimal from a cost minimizing perspective compared to conventional farms. In order to be competitive, LI farms have to transform their inputs into milk revenues in a more technically efficient way compared to conventional farms. While our results indicate that, on average, technical efficiency is not significantly better on LI farms, regional differences exist. The comparison between Belgium, the Netherlands, Luxembourg, on the one hand, and Bulgaria, Hungary, Poland, Romania, on the other hand, shows that in the latter region, LI farms succeed in obtaining a higher level of technical efficiency compared to conventional farms, resulting in a similar competitiveness of both farm types. In the first region, technical efficiency is lower on LI farms than on conventional farms, resulting in less competitive LI farms.

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6 Appendix

Table 1. Countries in a region and number of farms per region included in the analysis

Region	Countries included	Number of farms
BNL	Belgium, Netherlands, Luxembourg	415
BPR	Bulgaria, Hungary, Poland, Romania	341
DAN	Denmark	187
DEU	Germany	1081
FRA	France	536
IRE	Ireland	179
ITA	Italy	205
LEL	Latvia, Estonia, Lithuania	104
MED	Spain, Portugal, Malta, Cyprus, Greece	516
OSC	Austria, Slovakia, Slovenia, Czech Republic	347
SUV	Finland, Sweden	271
UKI	United Kingdom	278
EU		4460

Table 2. Descriptive statistics of the sample of 1106 LI, 2228 MI and 1126 HI farms

Characteristic	LI	MI	HI
EIC per output milk (€/€1000)	349^{a}	419^{b}	496^{c}
UAA per output milk (ha/€1000)	0.58^{a}	0.46^{b}	0.38^{c}
Hours per output milk (h/€1000)	50^{a}	39^{b}	32^{c}
Dairy cows per output milk (#/€1000)	0.52^{a}	0.43^{b}	0.37^{c}
EIC per UAA (€/ha)	756^{a}	1155^{b}	1642^{c}
EIC per hour (€/h)	10^{a}	16^{b}	22^{c}
EIC per dairy cow (€/cow)	701^{a}	1007^{b}	1393^{c}
Hours per UAA (h/ha)	96	95	94
Hours per dairy cow(h/cow)	94^{a}	88^{b}	86^{b}
Dairy cow per UAA (cow/ha)	1.08^{a}	1.15^{b}	1.20^{c}
Wages (€/h)	10	10	10
Rent price (€/ha)	201	201	200
Cow price (€/cow)	1059	1059	1058
Milk production per cow (kg/cow)	6120^{a}	7220^{b}	8240^{c}
Milk price (€/kg)	0.340^{a}	0.342^{a}	0.348^{b}
Forage (ha)	58^{a}	65^{b}	79^{c}
Concentrates cost per cow (€/cow)	379^{a}	604^{b}	881^{c}
Total cost per kg milk (€/kg)	0.471^{a}	0.425^{b}	0.419^{b}

^{a,b,c} Values within a row with different superscripts differ significantly at $P \leq 0.05$

EIC: external input costs; UAA: utilized agricultural area; LI: low input; MI: medium input; HI: high input

Table 3. Efficiency scores of LI, MI and HI farms for the whole of Europe

Variable	LI	MI	HI
TE	0.689^{ab}	0.677^{a}	0.700^{b}
CAE	0.450^{a}	0.509^{b}	0.536^{c}
CE	0.309^{a}	0.351^{b}	0.382^{c}
SE	0.899^{a}	0.901^{a}	0.907^{a}
CAE 2009	0.450^{a}	0.510^{b}	0.537^{c}
CAE 2010	0.450^{a}	0.509^{b}	0.536^{c}
CAE 2012	0.451^{a}	0.510^{b}	0.537^{c}
% CRS	3.62	1.44	2.40
% DRS	3.80	2.56	6.04
% IRS	92.59	96.01	91.56

^{a,b,c} Values within a row with different superscripts differ significantly at $P \leq 0.05$

TE: technical efficiency; CAE: cost allocative efficiency; CE: cost efficiency; SE: scale efficiency; CRS: constant returns to scale; DRS: decreasing returns to scale; IRS: increasing returns to scale; LI: low input; MI: medium input; HI: high input

Table 4 Comparison of efficiency scores and explaining key performance indicators of LI, MI, HI farms, respectively, between the regions BNL and OSC

Characteristic	LI		MI		HI	
	BNL	BPR	BNL	BPR	BNL	BPR
TE	0.761	0.646***	0.769	0.582***	0.801	0.588***
CAE	0.482	0.282***	0.569	0.305***	0.579	0.349***
CE	0.373	0.178***	0.446	0.176***	0.471	0.208***
SE	0.948	0.904***	0.941	0.889***	0.944	0.916***
EIC per output milk (€/€1000)	294	323***	338	410***	384	491***
UAA per output milk (ha/€1000)	0.39	0.72***	0.29	0.60***	0.22	0.47***
Hours per output milk (h/€1000)	32	91***	23	87***	20	62***
Dairy cows per output milk (#/€1000)	0.45	0.66***	0.37	0.56***	0.32	0.44***
EIC per UAA (€/ha)	963	507***	1390	774***	1960	1286***
EIC per hour (€/h)	12	4***	18	6***	23	10***
EIC per dairy cow (€/cow)	682	497***	934	748***	1216	1144*
Hours per UAA (h/ha)	89	138***	85	158***	96	139***
Hours per dairy cow(h/cow)	69	139***	60	155***	62	138***
Dairy cow per UAA (cow/ha)	1.40	1.02***	1.50	1.05***	1.64	1.12***
Wages (€/h)	15	2.2	15	2.2	15	2.2
Rent price (€/ha)	357	86	357	86	357	86
Cow price (€/cow)	1399	412	1399	412	1399	412
Milk production per cow (kg/cow)	6542	5245***	7848	6179***	8706	7646***
Milk price (€/kg)	0.363	0.304***	0.361	0.303***	0.371	0.312***
Forage (ha)	52	33***	57	33***	52	49**
Concentrates cost per cow (€/cow)	352	222***	503	377***	645	664
Total cost per kg milk (€/kg)	0.549	0.258***	0.462	0.265***	0.444	0.263***

* $P \leq 0.05$
** $P \leq 0.01$
*** $P \leq 0.001$
TE: technical efficiency; CAE: cost allocative efficiency; CE: cost efficiency; SE: scale efficiency; LI: low input; MI: medium input; HI: high input

Table 5 Efficiency scores and explaining key performance indicators in the BNL region

Characteristic	LI	MI	HI
TE	0.761[a]	0.769[ac]	0.801[c]
CAE	0.482[a]	0.569[b]	0.579[b]
CE	0.373[a]	0.446[b]	0.471[b]
SE	0.948[a]	0.941[a]	0.944[a]
EIC per output milk (€/€1000)	294[a]	338[b]	384[c]
UAA per output milk (ha/€1000)	0.39[a]	0.29[b]	0.22[c]
Hours per output milk (h/€1000)	32[a]	23[b]	20[b]
Dairy cows per output milk (#/€1000)	0.45[a]	0.37[b]	0.32[c]
EIC per UAA (€/ha)	963[a]	1390[b]	1960[c]
EIC per hour (€/h)	12[a]	18[b]	23[c]
EIC per dairy cow (€/cow)	682[a]	934[b]	1216[c]
Hours per UAA (h/ha)	89[ab]	85[a]	96[b]
Hours per dairy cow(h/cow)	69[a]	60[b]	62[ab]
Dairy cow per UAA (cow/ha)	1.40[a]	1.50[a]	1.64[b]
Wages (€/h)	15	15	15
Rent price (€/ha)	357	357	357
Cow price (€/cow)	1399	1399	1399
Milk production per cow (kg/cow)	6542[a]	7848[b]	8706[c]
Milk price (€/kg)	0.363[a]	0.361[a]	0.371[a]
Forage (ha)	52[a]	57[b]	52[ab]
Concentrates cost per cow (€/cow)	352[a]	503[b]	645[c]
Total cost per kg milk (€/kg)	0.549[a]	0.462[b]	0.444[b]

[a,b,c] Values within a row with different superscripts differ significantly at $P \leq 0.05$

TE: technical efficiency; CAE: cost allocative efficiency; CE: cost efficiency; SE: scale efficiency; LI: low input; MI: medium input; HI: high input

Table 6 Efficiency scores and explaining key performance indicators in the BPR region

Characteristic	LI	MI	HI
TE	0.646[a]	0.582[b]	0.588[b]
CAE	0.282[a]	0.305[a]	0.349[b]
CE	0.178[ab]	0.176[a]	0.208[b]
SE	0.904[ab]	0.889[a]	0.916[b]
EIC per output milk (€/€1000)	323[a]	410[b]	491[c]
UAA per output milk (ha/€1000)	0.72[a]	0.60[b]	0.47[c]
Hours per output milk (h/€1000)	91[a]	87[a]	62[c]
Dairy cows per output milk (#/€1000)	0.66[a]	0.56[b]	0.44[c]
EIC per UAA (€/ha)	507[a]	774[b]	1286[c]
EIC per hour (€/h)	4[a]	6[b]	10[c]
EIC per dairy cow (€/cow)	497[a]	748[b]	1144[c]
Hours per UAA (h/ha)	138[a]	158[b]	139[ab]
Hours per dairy cow(h/cow)	139[a]	155[b]	138[a]
Dairy cow per UAA (cow/ha)	1.02[a]	1.05[a]	1.12[a]
Wages (€/h)	2.2	2.2	2.2
Rent price (€/ha)	86	86	86
Cow price (€/cow)	412	412	412
Milk production per cow (kg/cow)	5245[a]	6179[b]	7646[c]
Milk price (€/kg)	0.304[ab]	0.303[b]	0.312[a]
Forage (ha)	33[a]	33[a]	49[b]
Concentrates cost per cow (€/cow)	222[a]	377[b]	664[c]
Total cost per kg milk (€/kg)	0.258[a]	0.265[a]	0.263[a]

[a,b,c] Values within a row with different superscripts differ significantly at $P \leq 0.05$

TE: technical efficiency; CAE: cost allocative efficiency; CE: cost efficiency; SE: scale efficiency; LI: low input; MI: medium input; HI: high input