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Change in the production efficiency of European specialized milk farming

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Abstract: The aim of the article is to identify the key structural, yield and economic determinants of the change in regional efficiency of specialized milk farms over the period 2007 to 2011. The following quantitative methods were applied on the regional FADN data (panel data of 100 regions): the Malmquist productivity index, the Welsh two-sample *t*-test, and the linear regression analysis. The article put emphasis on the investment activity and investment subsidies allocated in the sample of regions. The results reveal that regions with a positive change in the production efficiency have a significantly higher average milk yield, maize yield, long-term debt ratio, income level, and investment activity than the regions with a negative change in the production efficiency. On the contrary, investment subsidies per livestock unit do not significantly differ between the progressive and other regions. Investment subsidies are slightly higher in the regions with a negative change in the production efficiency and continuously help them to mitigate the drop in technical efficiency.

Key words: agriculture, milk production, technical improvement, Malmquist index, investment

Ongoing production improvement is essential for all business enterprises in competitive markets. The competitiveness of the European agriculture is strongly supported by the European funds, especially by the European Agricultural Fund for Rural Development (EAFRD) that targets on improving competitiveness through the Rural Development Programme (RDP). The RDP has started the new seven-year programming period since 2014. In order to evaluate the previous programming period 2007–2013, it is necessary to analyse the technical improvement and the technical efficiency of various farming specializations because each specialization is supported to a different extent.

Milk production is one of the key farming types in the EU. It has been realized either within the mixed type of farming (together with crop production and other livestock production) or in the specialized milk farms. Specialized farms are technologically demanding. Farms with the specialized milk production do not have the same significance across the EU. Špička and Smutka (2014) found out that the share of milk production in the specialised dairy farms within the total milk production in the EU ranges from one quarter (Czech Republic) to just under 100% (some regions in Spain and Portugal). Based on the regional view, they also revealed that the significant economic determinants of the production efficiency in the specialised dairy farming are the farm size, herd size, crop output per hectare, the productivity of energy, and capital (at a = 0.01). Specialised dairy farms in efficient regions have a significantly higher Farm Net Value Added per AWU than the inefficient regions. Agricultural enterprises in inefficient regions have a more extensive structure and produce more non-commodity output (public goods).

Production efficiency measured in time series gives information about production/technical improvement which is very important for every farm and region in order to draw level with best practice farms or regions. The improvement of agricultural productivity is a consequence of a more efficient use of production factors (Dharmasiri 2011). The overall efficiency growth can be decomposed into technical efficiency change and scale efficiency. Existing empirical studies do not provide a clear-cut conclusion. Ohlan (2013) concludes that the decomposition of total factor productivity (TFP) growth indicates that growth is driven more by technical efficiency changes than by scale efficiency. Alternatively, Ahmad and Bravo-Ureta (1995) find out that most of output growth is attributed to the size effect and to a lower extent to the productivity growth. The sources of technical growth vary in time,

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space and specialization (Tauer 1998; Latruffe et al. 2004; Newman and Matthews 2007)."

Growth of the production efficiency and production efficiency itself could be affected by the economic, structural and other (e. g. environmental) factors. Krause and Tondlová (2014) put emphasis on the proactive approach in environmental strategy as an important factor for sustainable development.

The most important factors which determine both the technical efficiency and the total factor productivity are those connected with the institutional and economic changes (Čechura 2012). Machek and Špička (2013) discovered that productivity of agriculture does not necessarily follow the domestic economic cycle, since the output of the agricultural sector is largely dependent on the foreign demand as well as the weather conditions and other factors. The important fact is that the Common Agricultural Policy is a strong economic determinant of the technical efficiency in the EU. The current subsidies and regulations affect the efficiency of farms (Bakucs et al. 2010). The question about investment subsidies has not been answered enough.

The farm structure, especially the farming intensity is a key determinant of the technical efficiency. More extensive farms and regions have a lower technical efficiency than the more intensive ones (Špička 2014). The improvement in the technical efficiency in milk production requires adequate and quality veterinary services, the augmentation of feed and fodder resources at the farm, the integration with a formal marketing system, and scaling-up of the dairy enterprise (Bardhan and Sharma 2013, Sajjad et al. 2013). Binici et al. (2013) revealed that if a farmer with an average efficiency improved the efficiency to that of the most efficient farmer in the sample, then the average dairy farmer could achieve significant cost savings. Furthermore, the technical progress in agriculture is significantly determined by the labour qualification (Mahjoor 2013), the farm size (Munroe 2001) and the soil quality (Adhikari and Bjørndal 2011). However, the results based on the analysis of larger farms in the Czech Republic show that the size of the company does not have a statistically significant effect on the overall technical efficiency, because the effect of the scale efficiency is compensated by the effect of the net technical efficiency (Boudný et al. 2011).

Last but not least, Ferjani (2011) evaluates the effects of the environmental policy on the milk farming performance. The analysis of the farm level productivity for Swiss dairy farms does not provide any strong evidence that the farm productivity increased due to the environmental agreements.

The determinants of growth in the production efficiency of the specialized milk farms at the EU regional level in the context of investment and investment subsidies have not been empirically confirmed. The aim of the article is to set the key structural, yield and economic determinants of the change in the regional efficiency over the period 2007–2011 that represents a part of the previous RDP's programming period. The authors focus particularly on the effect of investments and investment subsidies on the improvement of specialized milk farms. The results attempt to answer the following questions and theses:

(1) Which regions experienced the positive and negative changes in the technical efficiency over the period 2007–2011? How do these two groups of regions differ from the structural and income point of view?
(2) The regions with growing technical efficiency have a higher average milk yield than the regions with decreasing technical efficiency.
(3) The regions with growing technical efficiency have a higher average maize yield than the regions with decreasing technical efficiency (maize is the essential part of cows' feed).
(4) The growth of the overall technical efficiency is significantly determined by the investment activity in the region.
(5) The growth of the overall technical efficiency is significantly determined by investment subsidies allocated in the region.

METHODOLOGY

Productivity measurement is often carried out from two perspectives: the factor productivity (TFP) which takes into account all possible inputs and outputs of an industry (firm, process), the multifactor productivity (MFP) which deals with the relationship between the output and multiple input factors, and the partial factor productivity (PFP) which deals with the productivities of the individual inputs. The article deals with the use of the Malmquist index to quantify the change in a region's efficiency over a period of time.

A producer can be defined as an economic agent transforming a set of inputs $\mathbf{x} = (x_1, x_2,..., x_n)$ into a set of outputs $\mathbf{y} = (y_1, y_2,..., y_m)$. Generally, we consider the components of these vectors to be strictly positive. In order to define the Malmquist index of productivity (Caves et al. 1982), let us consider a period during

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which the production has changed from ($\mathbf{x}_t$, $\mathbf{y}_t$) to ($\mathbf{x}_{t+1}$, $\mathbf{y}_{t+1}$). Let us suppose the output-maximizing approach which means the lesser the distance from a production frontier, the better the efficiency score. The Malmquist index of productivity for the period t, respectively for the period $t + 1$, would be the ratios

$$M_t(\mathbf{x}_t,\mathbf{y}_t,\mathbf{x}_{t+1},\mathbf{y}_{t+1}) = \frac{D_t(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_t(\mathbf{x}_t,\mathbf{y}_t)}$$
$$M_{t+1}(\mathbf{x}_t,\mathbf{y}_t,\mathbf{x}_{t+1},\mathbf{y}_{t+1}) = \frac{D_{t+1}(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_{t+1}(\mathbf{x}_t,\mathbf{y}_t)}; \quad (1)$$

where D_t denotes the value of the distance function in period t. If the technology has changed during the period, these two indexes would result in different values. Therefore, it is common to employ the geometric mean of the two indexes and specify the Malmquist index of productivity as

$$M(\mathbf{x}_t,\mathbf{y}_t,\mathbf{x}_{t+1},\mathbf{y}_{t+1}) = \sqrt{\frac{D_t(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_t(\mathbf{x}_t,\mathbf{y}_t)} \times \frac{D_{t+1}(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_{t+1}(\mathbf{x}_t,\mathbf{y}_t)}} \quad (2)$$

The index can be further decomposed in the product of two terms (Färe et al. 1992) – Equation 3.

The first term ΔTE reflects the impact of changes in the efficiency, which means that $\Delta TE > 1$ as the technical efficiency improves and $\Delta TE < 1$ as technical efficiency deteriorates. The second term ΔT captures the changes in technology (technical change) which can be expressed by the ability of a firm to produce more (or less) with the given level of inputs in t related to the levels feasible in $t + 1$. ΔT is the geometric mean of two terms, when the first term compares the two periods in terms of the period t data, and the second term the two periods in terms of the period $t + 1$data. $\Delta T > 1$ as the technical progress occurred between the periods, while $\Delta T < 0$ as the technical regress occurred between the two periods.

The Malmquist index evaluates the productivity change of a decision-making unit between two time periods and it is an example in the "comparative statics" analysis. In the non-parametric framework, it is defined as the product of "catch-up effect" and "frontier-shift effect" terms. The catch-up (recovery) term relates to the degree to which a decision-making unit improves or worsens its efficiency, while the frontier-shift (innovation) term reflects the change in the efficient frontiers between the two time periods (Cooper et al. 2006).

The possibility of the decomposition into the technical efficiency and technology changes is one of the advantages of the Malmquist-type indexes. Among other advantages, we can mention that no assumptions have to be made on the behaviour of firms (optimizing behaviour) or returns to scale. However, the Malmquist index has also some disadvantages. In particular, it is necessary to estimate the real but unknown efficiency frontier using the econometric or mathematical programming methods, which involves the necessity of a large sample of data. For a more detailed discussion of the TFP measurement data issues, see e.g. Machek (2012).

The input-oriented Data Envelopment Analysis model assumes variable returns to scale (DEAVRS method[1]). The issue of the returns to scale concerns what happens to the units' outputs when they change the amount of inputs that they are using to produce their outputs. Under the assumption of the variable returns to scale, a unit found to be inefficient has its efficiency measured relative to other units in the data-set of a similar scale size only.

The Welch two-sample t-test[2] compares the distribution between two groups – progressive regions with the positive mean Malmquist index (μ_1, group A) and degressive regions with the negative mean Malmquist index (μ_2, group B). The null and alternative hypoth-

$$M(\mathbf{x}_t,\mathbf{y}_t\mathbf{x}_{,t+1},\mathbf{y}_{t+1}) = \sqrt{\frac{D_t(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_t(\mathbf{x}_t,\mathbf{y}_t)} \times \frac{D_{t+1}(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_{t+1}(\mathbf{x}_t,\mathbf{y}_t)}} = \sqrt{\frac{D_{t+1}(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_t(\mathbf{x}_t,\mathbf{y}_t)} \times \frac{D_{t+1}(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_t(\mathbf{x}_t,\mathbf{y}_t)} \times \frac{D_t(\mathbf{x}_t,\mathbf{y}_t)}{D_{t+1}(\mathbf{x}_{t+1},\mathbf{y}_{t+1})} \times \frac{D_t(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_{t+1}(\mathbf{x}_t,\mathbf{y}_t)}} =$$
$$= \frac{D_{t+1}(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_t(\mathbf{x}_t,\mathbf{y}_t)} \times \sqrt{\frac{D_t(\mathbf{x}_t,\mathbf{y}_t)}{D_{t+1}(\mathbf{x}_t,\mathbf{y}_t)} \times \frac{D_t(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}{D_{t+1}(\mathbf{x}_{t+1},\mathbf{y}_{t+1})}} = \Delta TE(\mathbf{x}_t,\mathbf{y}_t\mathbf{x}_{,t+1},\mathbf{y}_{t+1}) \times \Delta T(\mathbf{x}_t,\mathbf{y}_t\mathbf{x}_{,t+1},\mathbf{y}_{t+1}) \quad (3)$$

[1]BCC (Banker-Charnes-Cooper) model. The BCC model used in this paper is described in more detail by Cooper et al. (2007).

[2]Welch t-test tests if the difference in the mean between two groups is equal to a hypothesized value. It assumes that the populations are normally distributed. Due to the central limit theorem the test may still be useful when the assumption is violated if the sample sizes are equal, moderate size, and the distributions have similar shape. Test does not assume that the population variances are equal.

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eses are: H_0: mean μ_1 = mean μ_2, H_A: mean μ_1 > mean μ_2 (Diff > 0) or mean μ_1 < mean μ_2 (Diff < 0). So, the one-sided test of the hypotheses is applied depending on the subjective assumptions about the efficiency determinants. The statistical analysis is processed automatically by the software NCSS 9.

DATA

The FADN database (Farm Accountancy Data Network), which annually collects the farm economic and structural results in the EU member states, provides structural and economic data in standard results. The complete data for the period 2007–2011 are available for 100 EU regions.

The farms involved were selected according to their economic size and the type of farming. The types of farming are defined in terms of the relative importance of different enterprises on the farm. The relative importance itself is measured quantitatively as a proportion of each enterprise's standard output to the farms' total standard output.

The second sampling criterion was the economic size of farms which is one of the criteria utilised to classify agricultural holdings according to the Community typology of the agricultural holdings. With the Regulation (EC) No. 1242/2008, the economic size of an agricultural holding is measured as the total Standard Output (SO) of the holding expressed in Euro. The exchange rates are published by the FADN. The sum of all the SOs per hectare of

Table 1. Regions (100) and number of farms represented (population of specialised dairy farming in 2011)

Undifferentiated member states (FADN regions)	Austria (27 020), the Czech Republic (980), Denmark (3870), Estonia (1470), Ireland (15 590), Lithuania (18 100), Luxembourg (590), Latvia (8200), Malta (100), the Netherlands (17 410), Slovakia (390), Slovenia (6330)
FADN regions within member states	
Belgium	Vlaanderen (3310), Wallonie (2060)
Bulgaria	Severozapaden (2700), Severen tsentralen (2170), Severoiztochen (1290), Yugozapaden (2480), Yuzhen tsentralen (6200), Yugoiztochen (2160)
Finland	Etela-Suomi (2400), Sisa-Suomi (3330), Pohjanmaa (2010), Pohjois-Suomi (2240)
France	Champagne-Ardenne (700), Picardie (1050), Haute-Normandie (1200), Centre (590), Basse-Normandie (5440), Bourgogne (380), Nord-Pas-de-Calais (1940), Lorraine (1740), Alsace (520), Franche-Comté (3570), Pays de la Loire (5890), Bretagne (10140), Poitou-Charentes (900), Aquitaine (1500), Midi-Pyrénées (2290), Rhônes-Alpes (4990), Auvergne (4090)
Germany	Schleswig-Holstein (3600), Niedersachsen (8420), Nordrhein-Westfalen (4910), Hessen (2520), Rheinland-Pfalz (1810), Baden-Württemberg (6890), Bayern (32270), Saarland (200), Brandenburg (360), Mecklenburg-Vorpommern (410), Sachsen (730), Sachsen-Anhalt (300), Thueringen (230)
Hungary	Nyugat-Dunántúl (330), Észak-Alföld (1150), Dél-Alföld (980)
Italy	Aosta (660), Piemonte (1880), Lombardia (5280), Trentino (680), Alto-Adige (5430), Veneto (3010), Friuli-Venezia (840), Emilia-Romagna (3420), Umbria (190), Lazio (1700), Abruzzo (610), Molise (810), Campania (2760), Puglia (1900), Basilicata (380), Sicilia (1330), Sardegna (720)
Poland	Pomorze and Mazury (10 870), Wielkopolska and Slask (14 390), Mazowsze and Podlasie (66 880), Malopolska and Pogórze (11 680)
Portugal	Açores (2790)
Romania	Nord-Est (29 540), Nord-Vest (27 250), Centru (15 150)
Spain	Galicia (11 670), Asturias (2330), Cantabria (1650), Pais Vasco (430), Navarra (220), Cataluna (720), Baleares (190), Castilla-León (1700), Andalucia (680)
Sweden	Slattbygdslan (3290), Skogs-och mellanbygdslan (1820), Lan i norra (940)
United Kingdom	England-North (2430), England-East (1080), England-West (4000), Wales (2010), Scotland (1130), Northern Ireland (3350)

Source: authors based on the FADN database

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crop and per head of livestock of each holding is the measure of its overall economic size. According to the official definition in accordance with the Regulation 1242/2008, "the Standard Output (SO) is the average monetary value of the agricultural output at the farm-gate price of each agricultural product (crop or livestock) in a given region. The SO is calculated by the member states per hectare or per head of livestock, by using the basic data for the reference period of five successive years. The SO of the holding is calculated as the sum of the SO of each agricultural product present in the holding multiplied by the relevant number of hectares or heads of livestock of the holding."

The analysis focuses on the specialised milk type of farming (code 45 in the FADN grouping). This type of farming contains only farms with the share of dairy cows more than 75% out of the ruminants on the farm. The FADN regions with the available data on the specialised dairy farming represent 25 EU member states. This paper analyses the time period 2007–2011 because 2007 represents the first year of the RDP programming period 2007–2013 and 2011 represents the last available final data and the situation after four years.

The FADN database converts the sample into the universe (field of survey) using a special weighting system. According to the FADN methodology, the weighting system is based on the principle of "free expansion": a weight calculated for the sample applies to each holding of the sample (extrapolating factor). In order to calculate this individual weight, the holdings in the sample and in the field of the survey are stratified according to the same three criteria: the FADN region, the type of farming and the economic size class. The individual weight is equal to the ratio between the numbers of holdings, of the same classification cell (FADN region x type of farming x economic size class), in the population and in the sample." Consider, for example, very large specialist dairy farms in Brittany. If there are 20 farms belonging to this group in the FADN sample and if there are 1000 in the total population, then each individual farm in the sample for that group will have the weight of 1000/20 = 50. To calculate the weighting factors, it is necessary to have an accurate and up-to-date field of survey. The FADN field of survey is a subset of the Eurostat Farm Structure Survey (FSS).

To ensure that the sample of farms adequately reflects the heterogeneity of the farm size, the field of observation was stratified before the sample of farms is selected. If this were not done, there would be a risk that the particular categories of farm (say, large dairy farms in one region, or small dairy farms in another region) would not be represented adequately (or at all) by the sample.

Table 1 gives information about the state affiliation of the analysed regions. The table contains number of farms in the universe, i.e. the population of specialised dairy farms available in the period 2007–2011. It is important to emphasize that authors use data representing the whole population, not the sample.

Seven inputs and two outputs per weighted average farm are used for the efficiency calculation. The indicators are linked with the FADN standard results codes.

- outputs in EUR: crop output (SE135), livestock output (SE206)
- land input (SE025 – utilized agricultural area in ha)
- livestock input (SE080 total livestock units)
- labour input (SE011 – actual working time in hours per year)
- capital input = total fixed assets (SE441) – land, permanent crops & quotas (SE446) – breeding livestock (SE460)
- material costs (SE281 – seeds and plants, fertilisers, crop protection, other crop specific costs. feed for grazing livestock, feed for pigs & poultry)
- veterinary costs (SE330) in EUR
- energy costs (SE345 – motor fuels and lubricants, electricity, heating fuels in EUR).

In order to remove the influence of the price development, the outputs and four inputs (expressed in monetary units) are deflated using the output and input price indices. The indices were taken from the Eurostat database of price indices. The variables are deflated in each country as follows:

- Crop output, livestock output – deflation using the price indices of crop output and animal output in each country (2005 = 100).
- Capital input – deflation using the price index of goods and services contributing to agricultural investment[3] (2005 = 100).
- Material costs – deflation using the price index of animal feedstuffs (2005 = 100).

[3]Materials, machinery and other equipment, transport equipment, buildings, other works except land improvements (other buildings, structures etc.).

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Table 2. Basic descriptive statistics of the average farms in 2007–2011 (N = 100)

Variable (per farm)	Mean	Standard deviation	Min	Max
Crop output (EUR)	35 849.06	54 259.36	1 417.4	263 537.6
Livestock output (EUR)	157 626.92	148 295.47	4 530.8	718 091.0
Utilised agricultural area (ha)	90.57	136.58	5.25	971.01
Milk yield (kg/cow/year)	6 397.99	1 544.31	2 619.44	9 242.27
Labour input (AWU)	2.83	3.47	1.22	29.78
Livestock units (LU*)	98.35	89.43	5.91	434.03
Dairy cows units	58.51	50.92	4.01	243.72
Stocking intensity (LU)/ha of forage crops	2.01	1.93	0.48	19.10

*LU (Livestock Unit) – converting average number of animals to livestock units is done applying to this number a coefficient related to the category of animal. E.g. one dairy cow is one LU.

Source: authors

– Veterinary costs – deflation using the price index of veterinary expenses (2005 = 100).
– Energy costs – deflation using the price index of energy and lubricants (2005 = 100).

Table 2 contains the basic descriptive statistics of the average farms.

The sample is heterogeneous. There is both a very small average farm size and a very large average farm size. Large farms are typical for the countries in the Central Europe (Czech Republic, Slovakia) and regions in the former Eastern Germany (Brandenburg, Sachsen, Sachsen-Anhalt , Thueringen, Mecklenburg-Vorpommern). The average milk yield varies from 2619.44 kg/cow/year (Campania, Italy) to 9242.27 kg per cow/year (Cataluna, Spain). Dairy cows are bred extensively (0.48 LU per hectare of forage crops in Slovakia) and highly intensively (19.10 LU per hectare of forage crops in Malta). However, Malta is an extreme region. The second highest livestock density is 6.27 LU per hectare of forage crops in the Italian region Campania. The highest livestock density is in most-populous regions with the lack of pasturelands.

RESULTS

The analysis reveals 57 regions with the positive efficiency change (mean 1.031) and 43 regions with the negative efficiency change (mean 0.974) in the period 2007–2011. The highest mean Malmquist index was in the Italian regions Umbria (1.167) and Emilia-Romagna (1.083), the Spanish regions Cataluna (1.139), Castilla-León (1.081) and Navarra (1.077) and the German region Sachsen (1.077). On the opposite end, there are regions in Germany (Thueringen, 0.899), Bulgaria (Yugozapaden, 0.922; Severoiztochen, 0.932; Severozapaden, 0.935), and Northern Ireland (0.931). The example from Germany shows a high heterogeneity among the regions in one country. The Appendix contains the list of regions with the positive and negative change in the technical efficiency.

The Czech Republic experienced a positive technology change (1.037) and ranked 17th place in the sample of 100 European regions in the period 2007–2011. The milk production in the Czech Republic is in the spotlight of policy makers who consider the recovery and boost of cattle production as one of the political priorities in the upcoming period.

Table 3 informs about the structural characteristics of progressive and other regions.

The average size of farms in regions with the positive change in the technical efficiency (group A) is not significantly higher than in the regions with the negative change in the technical efficiency (group B). Even if the average size of the group A is slightly higher than the group B, the difference is not statistically significant. It means that the size of farms does not significantly affect the efficiency improvement. Alternatively, the size of farm is a significant determinant of the static technical efficiency – the fully efficient regions are significantly higher than the inefficient ones (Špička and Smutka 2014).

Milk production is highly labour intensive (Řezbová and Tomšík 2012. Neither the total labour input (AWU) nor the labour input per dairy cow (AWU per LU) is a significant characteristic of the progressive regions. A statistically significant indicator at $\alpha = 0.1$ is the labour input per hectare. Progressive regions

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Table 3. Structural and yield differences between the regions with the positive (group A) and negative (group B) efficiency change

Indicator	Unit	Group A (μ_1), N = 57	Group B (μ_2), N = 43	H_0 ($\mu_1 - \mu_2$)	T-statistic	P-value	Sig.
Utilised agricultural area	ha/farm	100.134	77.931	$\mu_1 - \mu_2 > 0$	0.8624	0.19534	–
	SD*	161.942	93.357				
Total livestock units	LU**/farm	100.423	95.597	$\mu_1 - \mu_2 > 0$	0.2653	0.39570	–
	SD	89.211	90.703				
Number of dairy cows	LU/farm	59.010	57.855	$\mu_1 - \mu_2 > 0$	0.1108	0.45600	–
	SD	49.824	52.926				
Number of other cattle	LU/farm	39.357	35.385	$\mu_1 - \mu_2 > 0$	0.5382	0.29586	–
	SD	37.035	36.155				
Total labour input	AWU/farm	3.047	2.536	$\mu_1 - \mu_2 > 0$	0.7975	0.21375	–
	SD	4.302	1.875				
Labour input per dairy cow	hours/LU	151.956	154.944	$\mu_1 - \mu_2 < 0$	–0.0950	0.46224	–
	SD	190.566	122.977				
Labour input per hectare	hours/ha	121.186	181.429	$\mu_1 - \mu_2 < 0$	–1.3678	0.08807	+
	SD	153.826	256.057				
Share of hired labour	%	20.324	24.144	$\mu_1 - \mu_2 < 0$	–0.8125	0.20928	–
	SD	24.869	22.001				
Stocking density	LU/ha f.c. ***	1.846	2.229	$\mu_1 - \mu_2 < 0$	–0.8704	0.19423	–
	SD	0.810	2.800				
Milk yield per year	kg/cow	6 862.154	5 782.699	$\mu_1 - \mu_2 > 0$	3.5825	0.00029	+++
	SD	1 338.690	1 597.531				
Cereals in utilized agricultural area	%	21.079	19.134	$\mu_1 - \mu_2 > 0$	0.8151	0.20857	–
	SD	11.839	11.794				
Forage crops in utilized agricultural area	%	73.914	76.051	$\mu_1 - \mu_2 < 0$	–0.7398	0.23065	–
	SD	14.407	14.214				
Share of rented utilized agricultural area	%	61.602	61.335	$\mu_1 - \mu_2 > 0$	0.0552	0.47805	–
	SD	24.194	23.672				
Yield of maize	100 kg/ha	89.565	76.777	$\mu_1 - \mu_2 > 0$	1.8055	0.03738	++
	SD	37.727	26.401				
Debt ratio (total liabilities / total assets)	%	21.420	16.530	$\mu_1 - \mu_2 > 0$	1.4885	0.07000	+
	SD	16.715	15.912				
Long-term debt ratio	%	16.803	11.556	$\mu_1 - \mu_2 > 0$	2.0766	0.02025	++
	SD	13.712	11.516				
Short-term debt ratio	%	4.617	4.974	$\mu_1 - \mu_2 < 0$	–0.3530	0.36245	–
	SD	5.131	4.899				

*SD = Standard Deviation, **LU (Livestock Unit) – converting average number of animals to livestock units is done applying to this number a coefficient related to the category of animal. E.g. 1 dairy cow is one LU, ***f.c. forage crops. Description of statistical significance: + (α = 0.1), ++ (α = 0.05), +++ (α = 0.01)

Source: authors

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have a significantly lower labour input per hectare but not per dairy cow. It is caused by a lower livestock intensity in the progressive regions as seen from the number of livestock units per hectare of the forage crops. Nevertheless, the difference in the stocking density is not significant between the two groups. It means that the farming intensity is not a statistically significant factor for the separation of regions with the positive and negative efficiency change.

On the contrary, the yield indicators are significantly different between the two groups. The average milk yield is higher in regions with the positive efficiency change. An important factor of the increasing milk yield is a change in the structure of herds with dairy and versatile breed. An example from the Czech Republic shows that the development of dairy cows in the recent years points to the tendency of increasing the share of the dairy cow type (Holstein). In 2014, the share of the black-spotted Holstein breed in the total population of dairy breeds was 56.58%. The second most widely distributed breed is the Czech spotted breed with 38.26% share in the total population of the dairy breeds. The Holstein breed has a significantly higher annual milk yield (9275 l per cow in 2013) than the Czech spotted breed (6960 l per cow in 2013) according to the performance testing (Kvapilík et al. 2014).

The milk yield results not only from the cows' breed purpose but also from the animal welfare and the nutritive factors. The increasing milk yield has been improved by a higher feed nutrition quality, the shift from the tethering housing to free housing, technology investments, upgrading buildings and equipment either with or without public support. So, increasing the welfare makes the milk yield higher and of a higher quality and safety. For example, Michaličková et al. (2013) confirm that the low technical efficiency is a result of the inefficient utilization of feeds (balance of feed mixture, losses of storage, the substitution of individual feeds) or the inefficient utilization of its production potential in relation to the given output level (milk yield).

Besides the milk yield, the regions with the positive change in efficiency have a significantly higher yield

Table 4. Differences between regions with the positive (group A) and negative (group B) efficiency change from the investment and income points of view

Indicator	Unit	Group A (μ_1), N = 57	Group B (μ_2), N = 43	H_0 ($\boldsymbol{\mu}_1 - \mu_2$)	T-statistic	P-value	Sig.
Gross investment per livestock unit	EUR/LU*	391.916	261.964	$\mu_1 - \mu_2 > 0$	3.0552	0.00146	+++
	SD**	261.123	162.353				
Depreciation per livestock unit	EUR/LU	322.763	207.220	$\mu_1 - \mu_2 > 0$	4.0489	0.00005	+++
	SD	173.142	111.370				
Net investment per livestock unit	EUR/LU	69.151	54.744	$\mu_1 - \mu_2 > 0$	0.4991	0.30940	–
	SD	164.000	124.646				
Investment subsidies per livestock unit	EUR/LU	25.753	26.303	$\mu_1 - \mu_2 > 0$	–0.0750	0.52980	–
	SD	32.380	39.023				
Farm Net Value Added[1]	EUR/AWU	31 461.26	24 126.00	$\mu_1 - \mu_2 > 0$	2.3952	0.00927	+++
	SD	16 533.92	14 037.45				

*LU (Livestock Unit) – converting average number of animals to livestock units is done applying to this number a coefficient related to the category of animal. E.g. 1 dairy cow is one LU, **SD = Standard Deviation. Description of statistical significance: + (α = 0.1), ++ (α = 0.05), +++ (α = 0.01)

[1]The Farm Net Value Added (FNVA) per AWU (Annual Work Unit) represents the main income indicator in agriculture. AWU is the unit of measurement of the quantity of human work supplied on each farm. This unit is equivalent to the normative work of one person, full time, for one year. According to the FADN definition, the FNVA is the remuneration to the fixed factors of production (work, land and capital), whether they be external or family factors. As a result, holdings can be compared irrespective of their family/non-family nature of the factors of production employed. Since it includes costs on external factors, it is a convenient technique to compare the different farm structures within the EU-27.

Source: authors

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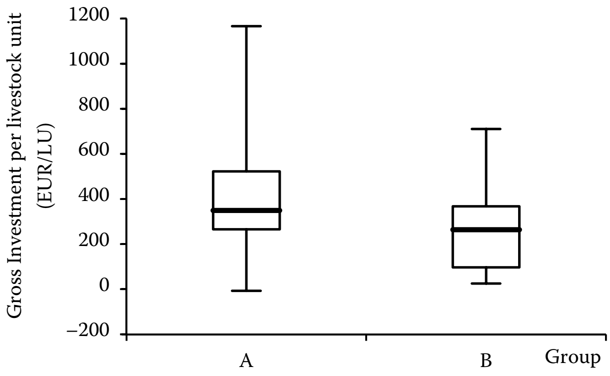

Figure 1. Gross investment per livestock unit

Source: authors

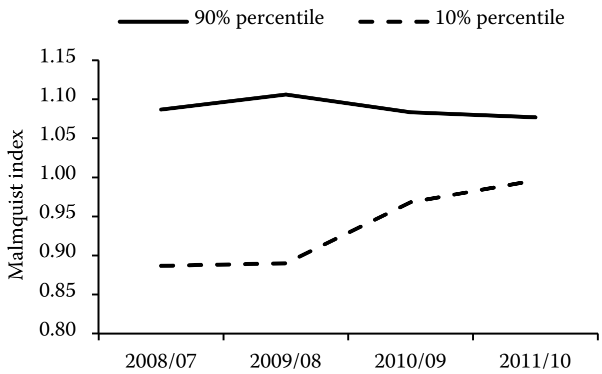

Figure 2. Development of the Malmquist index in the top and bottom group of regions

Source: authors

of maize that forms an important part of the cows' feed ration. However, the yield of maize in the progressive group A suffers from a higher variability. So, the conditions for ensuring feed are riskier. A higher yield but riskier growing conditions are typical in the more fertile regions.

Concerning the structure of the utilized agricultural area, there is no significant difference between the two groups. The share of the rented agricultural land is almost the same in the group A as in the group B.

The analysis reveals important findings about the capital structure. Progressive regions (group A) have a significantly higher debt ratio. They use more long-term debts than the regions with the negative change in the technical efficiency. It indicates that the regions in the group A invest more in upgrading technical equipment and technologies using the long-term bank loans than the group B. This finding establishes hypotheses that the growth of the overall technical efficiency is significantly determined by the investment activity in the region and the investment subsidies allocated in the region. The investment activity is measured by the gross investment[4] and net investment[5] per livestock unit and the investment subsidies per livestock unit. Table 4 shows the results of testing the hypotheses. Figure 1 depicts the differences between the gross investments per livestock unit in the groups A and B.

Gross investments per livestock unit are significantly higher in the group A compared to the group B. It indicates that gross investments play an important role in improving the technical efficiency and the competitiveness of the specialized milk farms. As a consequence of the higher investment activity, the farms in progressive regions have a significantly higher depreciation. So, the net investments per livestock unit do not significantly differ between the two groups. Moreover, the two-sample test reveals that regions in the group A have a higher income indicator FNVA/AWU.

The variability of the gross investment per livestock unit is higher in the group A. The highest mean of the gross investment in the group A in the period 2007–2011 was in the Finnish regions (more than 1000 EUR/LU), Austria (882.7 EUR/LU), Denmark (840.6 EUR/LU) and the Netherlands (666.3 EUR per LU). All these regions experienced a positive mean change in the efficiency. On the contrary, the highest gross investment per livestock unit in the group B in the period 2007–2011 was in the Swedish region

Table 5. Regression between the Malmquist index and the gross investments per livestock unit (2007–20 11)

Regression	R^2	*P*-value	Standard error
$y = 1.003096 + 0.0000105x$	0.0035	0.5563	0.0412

Notes: Variable y denotes average Malmquist index in 2007–2011, x denotes Gross investments per livestock unit

Source: authors

[4]Gross investment = purchases – sales of fixed assets + breeding livestock change of valuation.

[5]Net investment = gross investment – depreciation.

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Slattbygdslan (710.2 EUR/LU) which Malmquist index was just under 1.

However, putting the Malmquist index as a dependent variable and the gross investment per livestock unit as an independent variable in the simple linear regression model, it can be seen that there is no significant relationship between the two variables. Table 5 contains results of the regression analysis.

An interesting finding is that regions with the positive efficiency change have a similar average investment subsidy level per livestock unit as the farms in the regions with the negative efficiency change. It would seem that investment subsidies are not important. The opposite is true. Investment subsidies should help the less competitiveness farms to come closer to the best ones. That is why the group B has slightly higher average investment subsidies per hectare than the group A.

Figure 2 provides information about the development of the average Malmquist index in 90% (top) and 10% (bottom) percentile. Percentiles are set by the mean Malmquist index in the period 2007–2011.

It is obvious that the group of ten most progressive regions keeps the annual efficiency change between 1.05 and 1.10. Ten worst regions with the lowest average Malmquist index sharply increased the value of the Malmquist index towards 1. It is important to emphasize that the average amount of investment subsidy in the bottom group of regions (10% percentile) was 41.96 EUR per livestock unit. Alternatively, the average amount of investment subsidy in the top group of regions (90% percentile) was only 22.96 EUR per livestock unit in 2007–2011. Nevertheless, the average gross investments per livestock unit did not significantly differ in the period 2007–2011: 268.61 EUR/LU in 10% percentile, 240.28 EUR/LU in 90% percentile. It indicates that investment subsidies help the regions with the negative efficiency change to invest in the modernization of the technical equipment in order to be closer to the most progressive regions which are able to finance investments either through their own resources or in combination with bank loans. Without investment subsidies, the regions at the bottom of the rank would invest to a less extent or not at all.

CONCLUSIONS

The article focuses on the structural, yield and investment differences between the selected European regions with the positive and negative change of the technical efficiency in the period 2007–2011. Based on the Malmquist index, the statistical description and hypotheses testing, the results reveal some important findings related to the FADN regions.

- Some regions in Spain and Italy experienced the highest positive shift of the technology change in the EU. The regions have an above-average income level measured by the Farm Net Value Added per AWU. On the contrary, three regions in Bulgaria ranked at the bottom. The Bulgarian regions have a below-average income level. Generally, the analysis proves that the regions with the positive change in the production efficiency have a significantly higher income level (FNVA/AWU) the than regions with the negative change in the production efficiency.
- The regions with the positive change in the production efficiency have a significantly higher average milk yield and maize yield than the regions with the negative change in the production efficiency. It indicates that the herd breeding structure, the nutritional and the welfare factors are essential for improving the production efficiency. So, these areas should be supported from the new Rural Development Plan, especially in the low-income regions in order to shift towards the best practices.
- Alternatively, there is no statistically significant impact of the farm size, labour and stocking intensity and the structure of the utilized agricultural area on the efficiency change. It is in the contradiction with the static technical efficiency measured in one year which is significantly higher in larger farms with a higher production intensity.
- The regions with the positive change in the production efficiency have a higher average debt ratio and long-term debt ratio than the regions with the negative change in the production efficiency. Moreover, there is a higher gross investment activity and depreciations in the progressive regions. Nevertheless, the regression analysis does not prove the direct relationship between the Malmquist index and the gross investment per livestock unit.
- The investment subsidies per livestock unit do not significantly differ between the regions with the positive and negative change in the production efficiency. Investment subsidies are just slightly higher in regions with the negative change in the production efficiency. Investment subsidies help them to reduce the decline in the technical efficiency and shift closer towards the best regions. The Common Agricultural Policy should prefer the

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less development agricultural regions in the EU with farms that do not have a sufficient access to own financial resources and credits. Not only the investment support but also the support of complementary advisory services should be supplied.

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Appendix

List of 57 regions (and countries) with the positive change in the technical efficiency (mean 2007–2011)

(Code) FADN Region	Country	Malmquist index
(0282) Umbria	(ITA) Italy	1.1671
(0535) Cataluna	(ESP) Spain	1.1388
(0260) Emilia-Romagna	(ITA) Italy	1.0831
(0545) Castilla-León	(ESP) Spain	1.0814
(0114) Sachsen	(DEU) Germany	1.0771
(0520) Navarra	(ESP) Spain	1.0766
(0846) Centru	(ROU) Romania	1.0736
(0762) Nyugat-Dunántúl	(HUN) Hungary	1.0683
(0115) Sachsen-Anhalt	(DEU) Germany	1.0620
(0845) Nord-Vest	(ROU) Romania	1.0558
(0730) Lan i norra	(SVE) Sweden	1.0513
(0840) Nord-Est	(ROU) Romania	1.0490
(0370) Denmark	(DAN) Denmark	1.0479
(0810) Slovakia	(SVK) Slovakia	1.0458
(0766) Dél-Alföld	(HUN) Hungary	1.0399
(0100) Saarland	(DEU) Germany	1.0387
(0745) Czech Republic	(CZE) Czech Republic	1.0366
(0575) Andalucia	(ESP) Spain	1.0349
(0343) Wallonie	(BEL) Belgium	1.0349
(0341) Vlaanderen	(BEL) Belgium	1.0328
(0301) Molise	(ITA) Italy	1.0288
(0010) Schleswig-Holstein	(DEU) Germany	1.0286
(0292) Abruzzo	(ITA) Italy	1.0280
(0360) The Netherlands	(NED) Netherlands	1.0256
(0720) Skogs-och mellanbygdslan	(SVE) Sweden	1.0238
(0090) Bayern	(DEU) Germany	1.0220
(0060) Hessen	(DEU) Germany	1.0205
(0070) Rheinland-Pfalz	(DEU) Germany	1.0198
(0660) Austria	(OST) Austria	1.0190
(0132) Picardie	(FRA) France	1.0179
(0030) Niedersachsen	(DEU) Germany	1.0175
(0244) Friuli-Venezia	(ITA) Italy	1.0168
(0112) Brandenburg	(DEU) Germany	1.0166
(0330) Sardegna	(ITA) Italy	1.0152
(0153) Franche-Comté	(FRA) France	1.0148
(0690) Pohjanmaa	(SUO) Finland	1.0138
(0141) Nord-Pas-de-Calais	(FRA) France	1.0133
(0515) Pais Vasco	(ESP) Spain	1.0128
(0183) Midi-Pyrénées	(FRA) France	1.0122
(0080) Baden-Württemberg	(DEU) Germany	1.0111
(0670) Etela-Suomi	(SUO) Finland	1.0111
(0050) Nordrhein-Westfalen	(DEU) Germany	1.0109
(0152) Alsace	(FRA) France	1.0104
(0350) Luxembourg	(LUX) Luxembourg	1.0101
(0135) Basse-Normandie	(FRA) France	1.0100
(0680) Sisa-Suomi	(SUO) Finland	1.0095
(0133) Haute-Normandie	(FRA) France	1.0071
(0700) Pohjois-Suomi	(SUO) Finland	1.0069
(0241) Trentino	(ITA) Italy	1.0067
(0770) Latvia	(LVA) Latvia	1.0058
(0230) Lombardia	(ITA) Italy	1.0046
(0162) Pays de la Loire	(FRA) France	1.0043
(0820) Slovenia	(SVN) Slovenia	1.0031
(0193) Auvergne	(FRA) France	1.0027
(0500) Galicia	(ESP) Spain	1.0019
(0242) Alto-Adige	(ITA) Italy	1.0009
(0163) Bretagne	(FRA) France	1.0004

Source: authors

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List of 43 regions (and countries) with the negative change in the technical efficiency (mean 2007–2011)

(Code) FADN Region	Country	Malmquist index
(0650) Açores	(POR) Portugal	0.9996
(0832) Severen tsentralen	(BGR) Bulgaria	0.9989
(0710) Slattbygdslan	(SVE) Sweden	0.9989
(0411) England-North	(UKI) United Kingdom	0.9987
(0790) Wielkopolska and Slask	(POL) Poland	0.9985
(0131) Champagne-Ardenne	(FRA) France	0.9978
(0243) Veneto	(ITA) Italy	0.9971
(0192) Rhônes-Alpes	(FRA) France	0.9969
(0775) Lithuania	(LTU) Lithuania	0.9968
(0182) Aquitaine	(FRA) France	0.9963
(0421) Wales	(UKI) United Kingdom	0.9963
(0795) Mazowsze and Podlasie	(POL) Poland	0.9941
(0311) Puglia	(ITA) Italy	0.9923
(0164) Poitou-Charentes	(FRA) France	0.9916
(0136) Bourgogne	(FRA) France	0.9906
(0785) Pomorze and Mazury	(POL) Poland	0.9905
(0836) Yugoiztochen	(BGR) Bulgaria	0.9882
(0380) Ireland	(IRE) Ireland	0.9879
(0151) Lorraine	(FRA) France	0.9869
(0113) Mecklenburg-Vorpommern	(DEU) Germany	0.9852
(0505) Asturias	(ESP) Spain	0.9848
(0510) Cantabria	(ESP) Spain	0.9841
(0413) England-West	(UKI) United Kingdom	0.9837
(0134) Centre	(FRA) France	0.9786
(0312) Basilicata	(ITA) Italy	0.9767
(0412) England-East	(UKI) United Kingdom	0.9747
(0765) Észak-Alföld	(HUN) Hungary	0.9728
(0302) Campania	(ITA) Italy	0.9698
(0755) Estonia	(EST) Estonia	0.9697
(0320) Sicilia	(ITA) Italy	0.9673
(0835) Yuzhen tsentralen	(BGR) Bulgaria	0.9653
(0800) Malopolska and Pogórze	(POL) Poland	0.9620
(0291) Lazio	(ITA) Italy	0.9592
(0222) Piemonte	(ITA) Italy	0.9560
(0431) Scotland	(UKI) United Kingdom	0.9530
(0540) Baleares	(ESP) Spain	0.9458
(0221) Aosta	(ITA) Italy	0.9391
(0780) Malta	(MLT) Malta	0.9391
(0831) Severozapaden	(BGR) Bulgaria	0.9351
(0833) Severoiztochen	(BGR) Bulgaria	0.9319
(0441) Northern Ireland	(UKI) United Kingdom	0.9311
(0834) Yugozapaden	(BGR) Bulgaria	0.9225
(0116) Thueringen	(DEU) Germany	0.8988

Source: authors

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