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Technical efficiency and economic performance of dairy production in the EU: the role of size

Technická efektivnost a ekonomická výkonnost mléčné produkce v EU: význam velikosti

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ABSTRACT

This paper deals with the economic performance and technical efficiency of dairy production in the European Union and its persistent and transient parts. Attention is focused on the differences in these efficiency indicators according to the economic size. The analysis covers two types of farming: specialized milk and mixed crops and livestock using FADN data in the period from 2004 to 2017. The analysis is based on the four-component model that represents the most advanced approach to technical efficiency analysis at present and the one-step estimation procedure. To the best of knowledge, this is the first application of the four-component model based on the one-step estimation procedure on these types of farming in the EU. The results show the highly efficient production in both types of farming. In both types of farming, the transient technical efficiency is higher than the persistent one. The overall and transient technical efficiency do not differ statistically among groups according to economic size. The lowest persistent technical efficiency was found in the group of highest economic size. This group has the highest share of current subsidies in gross farm income, produces the least gross farm income in total output, achieves also the lowest cost-effectiveness and the lowest value of performance indicators compared to the others.

Keywords: technical efficiency, transient efficiency, persistent efficiency, economic performance, economic size, four component model, dairy production

ABSTRAKT

Tento článek se zabývá ekonomickou výkonností a technickou efektivností mléčné produkce v EU a její přechodnou a setrvalou složkou. Pozornost je zaměřena na rozdíly v těchto ukazatelích efektivnosti s ohledem na ekonomickou velikost. Analýza pokrývá specializovanou mléčnou produkci a smíšenou produkci s využitím dat z databáze FADN za období 2004 – 2017. Analýza je postavena na čtyř-komponentním modelu, který představuje v současnosti nejpokročilejší přístup k analýze technické efektivnosti, a na jednostupňové metodě odhadu. Zároveň se jedná o první aplikaci této specifikace stochastické hraniční analýzy pro tyto specializace v EU. Výsledky ukazují vysokou efektivnost produkce v obou typech zemědělské výroby. V obou výrobních zaměřeních je rovněž přechodná technická efektivnost vyšší než setrvalá. Celková a přechodná technická efektivnost se statisticky neliší mezi skupinami dle ekonomické velikosti. Nejnižší setrvalá technická efektivnost byla zjištěna ve skupině s nejvyšší ekonomickou velikostí. Tato skupina má nejvyšší podíl běžných dotací na hrubé přidané hodnotě, produkuje nejméně hrubé přidané hodnoty v celkové produkci, dosahuje nejnižší nákladové efektivnosti a zároveň nejnižších hodnot ukazatelů výkonnosti ve srovnání s jinými skupinami.

Klíčová slova: technická efektivnost, přechodná efektivnost, setrvalá efektivnost, ekonomická výkonnost, ekonomická velikost, čtyř-komponentní model, mléčná produkce

INTRODUCTION

The EU dairy sector is the second biggest agricultural sector in the EU, representing more than 12% of total agricultural output. The abolishment of the dairy quota system in the EU, a continual price-cost squeeze, and risk factors such as milk and feed price volatility have increased competition in the EU dairy sector. The sector's problems are likely to be exacerbated by the effects of the coronavirus pandemic, which has led to further price declines and overproduction in some EU regions. Only the most efficient farms can survive in such an environment. Therefore, it is important to analyze technical efficiency and its short-term (transient) and long-term (persistent) parts, as a basic prerequisite of competitiveness and also economic performance, as a basic prerequisite of farm viability.

According to Bravo-Ureta and Pinheiro (1993), technical efficiency is defined as the firm´s ability to produce maximum output given a set of inputs and technology. Researchers consider it is important to decompose the overall technical efficiency into its transient and persistent parts because one gets more detailed information about the nature of the inefficiency. The current political trends focus the research attention on the effect of size, however, not only on the technical efficiency but also on the profitability as a financial ability of a farm to generate sufficient earnings to cover its operating expenses and to survive and further on other indicators of economic efficiency.

The question whether small farms perform better than large farms is often the subject of debate in both the theoretical and empirical literature. Latruffe (2010) according to Buckwell and Davidova (1993) mentions that small farms are not affected by labor and organization problems and that family labor is highly motivated as it stands to benefit from farm profits. On the other hand, large farms are claimed to achieve economies of scale and to benefit from preferential access to output and input markets. At the EU level, there is an intense debate on the future shape of the CAP, which should not only reduce the overall amount of money under the subsidy system but also CAP payments for large farms. A possible subsidy ceiling would hit post-communist countries such as the Czech Republic, Slovakia, and East Germany the most. Therefore, the analysis regarding size is important from a policy point of view. The results should be useful for obtaining a better understanding of the sort of policies that should be implemented to give adequate support to a sector with the above-mentioned problems.

The EU dairy production is carried out on specialized farms or mixed farms. Although specialization does offer advantages, specialized farm revenues are tied to a single output. Such dependence can become a substantial threat as it increases farmers' vulnerability to income shocks. Mixed farms, with a more varied output, are less vulnerable. De Roest et al. (2018) states that the earlier policy framework, with intervention prices and variable import levies, achieved relative stability of farm gate prices and created the ideal setting for more specialized farms to follow a strategy of seeking to continuously reduce production costs. As recent EU dairy sector crises show, price volatility is now a major challenge.

The main aim of the paper is, regarding size, to analyse the technical efficiency, its transient and persistent parts, and economic performance. Moreover, the paper tried to answer the research question if the milk production in the European Union faces unfavourable agrarian structure or the lack of knowledge and whether the competitiveness and sustainability are influenced by economic size.

Theoretical Background

The analysis of technical efficiency in the EU dairy sector based on different methods and data sources is discussed by several authors (Latruffe et al., 2011, Zhu et al., 2012, Špička and Smutka, 2014, Žáková Kroupová, 2016, Madau et al., 2017, Latruffe et al., 2017). Latruffe et al. (2011) and Zhu et al. (2012) include, among other determinants, the farm size of dairy farms (measured as economic size) as an explanatory variable in the inefficiency model. The results concerning technical efficiency and farm size are mixed, e.g. Latruffe et al. (2011) found out the negative and significant association of farm size and technical efficiency in the case of France, Ireland, the Netherlands, and Spain. The opposite is pointed out for Germany and the UK and according to Zhu et al. (2012) also for Sweden. As Latruffe et al. (2011) state, the results depend on the country, the type of farming, and the size indicator.

Many authors focus the research attention also on the relationship between technical efficiency and agricultural subsidies, whose importance varies considerably for groups of farms according to economic size. A general conclusion is that subsidies to dairy farms reduce their technical efficiency. This has been empirically shown in several studies (see for example Latruffe et al., 2011, Zhu et al. 2012, Žáková Kroupová, 2016). Zhu et al. (2012) explain this by the fact that a higher degree of coupling in farm support negatively affects farm efficiency. Zhu et al. (2012) further state that the motivation of farmers to work efficiently is lower when they depend on a higher degree on subsidies as a source of income, which is consistent with the results of Martin and Page (1983).

Bojnec and Latruffe (2013), but outside the dairy sector, investigate the influence of farm size and subsidies on farm performance, which is especially measured with profitability, technical, and allocative efficiency. They find out that small farms in Slovenia are less technically efficient but more allocative efficient and profitable. This can be associated with the provision of generous subsidies to the small Slovenian farms, which are negatively related to farms' technical efficiency but positively related to their profitability.

As was mentioned above, the main conclusion regarding the relationship between size and technical inefficiency is not clear. A more accurate view of this problem can be provided by the decomposition of overall technical inefficiency into short-term and long-term parts. According to Njuki and Bravo-Ureta (2015), the former part - transient technical inefficiency - is connected with shocks associated with new production technologies, human capital, and learning-by-doing, while the latter - persistent inefficiency - represents structural problems in the organization of the production process (Filippini and Greene, 2016), or a systematic lack of managerial skills (see Kumbhakar and Lien, 2017). However, papers dealing with transient and persistent technical inefficiency in the EU dairy sector are missing. The exception is Baležentis and Sun (2020) who focus on the Lithuanian dairy sector but without taking into account the size effect. Methodologically, these authors follow a four-component model proposed by Tsionas and Kumbhakar (2011).

The four-component model is the extension of the Greene's (2005) True Random Effects Model and presents a distinction of the random component of stochastic frontier models into four independent components: latent heterogeneity ($\alpha_i \sim N(0,\sigma^2_\alpha)$), persistent technical inefficiency ($u_{0i} \sim N^+(0,\sigma^2_{u0})$), transient technical inefficiency ($u_{it} \sim N^+ (0,\sigma^2_{u,t})$) and stochastic error ($v_{it} \sim N^+ (0,\sigma^2_v)$). According to Kumbhakar and Tsionas (2012), this model is called Generalized True Random Effects (GTRE). In the case of European agriculture, this four-component stochastic frontier model is empirically applied by Bokusheva and Čechura (2017), Pisulewski and Marzec (2019), and Addo and Salhofer (2019). All of these authors analyze the technical efficiency of European crop production. The first and the last of these authors also take into account the effect of size on technical efficiency. However, their results are again ambiguous. While Addo and Salhofer (2019) point out the positive effects of economies of size on persistent technical efficiency, Bokusheva and Čechura (2017) point out that transaction costs which may increase with farm size cause significant input use inefficiencies which cannot be eliminated easily over time.

Estimation of the GTRE model can be done in several ways. Kumbhakar et al. (2014) introduce a multi-step approach, which is simple to implement with an advantage of the technology parameters robustness to distributional assumptions on the error component (Lien et al, 2018). Colombi et al. (2014) present a single-step full maximum likelihood procedure that is more efficient and less biased than the multi-step approach but cumbersome to implement in practice. Filippini and Greene (2016) cope with the limitations of the Colombi's et al. (2014) full information maximum likelihood procedure of a single-step approach and propose a simulation-based single-step maximum likelihood estimator that is relatively easy to implement. There are also other procedures, e.g. Tsionas and Kumbhakar (2011) propose Bayesian technique.

MATERIAL AND METHODS

The analysis of technical efficiency of the EU milk production is based on an assumption that the transformation process can be well approximated by the input-distance function (IDF) with the following properties: symmetry, monotonicity, linear homogeneity, and concavity in inputs and quasi-concavity in outputs (Greene, 2005). The input-orientation is preferred over the output one due to the prevailing existence of milk quotas in the analyzed period 2004-2017 that represent a strong restriction on the maximum quantity of milk production and caused that agricultural producers focus primarily on reducing inputs to produce almost fixed output (see Kumbhakar et al., 2008). This means that the goal of profit maximization can be achieved by minimizing the cost of producing a fixed (quota) output. According to Skevas et al. (2018), the outputs can be assumed as exogenous under this optimization condition.

The IDF is specified in a translog functional form. This second-order local approximation of any twice-differentiable function satisfied Diewert's minimum flexibility requirement for flexible form (see Pisulewski and Marzec, 2019). The translog input distance function for two outputs (y), five inputs (x) and time (t) is defined as:

$$\begin{aligned}\ln D_{it}^{I} = {} & \alpha_0 + \textstyle\sum_{m=1}^{2} \beta_m \ln y_{m,it} + \\ & + \tfrac{1}{2} \textstyle\sum_{m=1}^{2} \sum_{n=1}^{2} \beta_{mn} \ln y_{m,it} \ln y_{ni,t} + \sum_{m=1}^{2} \sum_{j=1}^{5} \delta_{mj} \ln y_{m,it} \ln x_{j,it} + \sum_{j=1}^{5} \beta_j \ln x_{j,it} + \\ & + \tfrac{1}{2} \textstyle\sum_{j=1}^{5} \sum_{k=1}^{5} \beta_{jk} \ln x_{j,it} \ln x_{k,it} + \alpha_t t + \tfrac{1}{2} \alpha_{tt} t^2 + \sum_{m=1}^{2} \alpha_{mt} \ln y_{m,it} t + \sum_{j=1}^{5} \alpha_{jt} \ln x_{j,it} t,\end{aligned} \tag{1}$$

where subscripts *i*, with *i=1,2,…,N*, and *t*, with *t =1,…,T*, refer to a certain FADN region and time (year), respectively. ***α***, ***β*** and ***δ*** are vectors of the parameters to be estimated. The symmetry restrictions imply that $\beta_{jk}=\beta_{kj}$ and $\beta_{mn}=\beta_{nm}$. The time trend included in the IDF allows for capturing the joint effects of embedded knowledge, technology improvements, and learning-by-doing in input quality improvements (see Čechura et al., 2017). Here, α_t and α_{tt} capture the global effect of technical change on the IDF, while α_{mt} and α_{jt} measure the bias of technical change.

Implying the homogeneity property of the IDF (Knox Lovell et al., 1994) that is imposed by normalising all the inputs by one input (x_1 in our case), the IDF can be rewritten as:

$$\begin{aligned}\ln D_{it}^{I} - \ln x_{1,it} = {} & \alpha_0 + \textstyle\sum_{m=1}^{2} \beta_m \ln y_{m,it} + \\ & + \tfrac{1}{2} \textstyle\sum_{m=1}^{2} \sum_{n=1}^{2} \beta_{mn} \ln y_{m,it} \ln y_{ni,t} + \sum_{m=1}^{2} \sum_{j=2}^{5} \delta_{mj} \ln y_{m,it} \ln \tilde{x}_{j,it} + \sum_{j=2}^{5} \beta_j \ln \tilde{x}_{j,it} + \\ & + \tfrac{1}{2} \textstyle\sum_{j=2}^{5} \sum_{k=2}^{5} \beta_{jk} \ln \tilde{x}_{j,it} \ln \tilde{x}_{k,it} + \alpha_t t + \tfrac{1}{2} \alpha_{tt} t^2 + \sum_{m=1}^{2} \alpha_{mt} \ln y_{m,it} t + \sum_{j=2}^{5} \alpha_{jt} \ln \tilde{x}_{j,it} t,\end{aligned} \tag{2}$$

where $\ln \tilde{x}_{j,it} = \ln x_{j,it} - \ln x_{1,it}$.

After introducing statistical error term (v_{it}), latent heterogeneity (w_i), and replacing $\ln D^{I}_{it}$ with inefficiency terms: persistent technical inefficiency (u_{i0}) and transient technical inefficiency (u_{it}), that is $u_{i0}+u_{it}=\ln D^{I}_{it}$, the IDF takes the form of the Generalized True Random Effect model (see Kumbhakar and Tsionas, 2012):

$$\begin{aligned}-\ln x_{1,it} = {} & \alpha_0 + \textstyle\sum_{m=1}^{2} \beta_m \ln y_{m,it} + \\ & + \tfrac{1}{2} \textstyle\sum_{m=1}^{2} \sum_{n=1}^{2} \beta_{mn} \ln y_{m,it} \ln y_{ni,t} + \sum_{m=1}^{2} \sum_{j=2}^{5} \delta_{mj} \ln y_{m,it} \ln \tilde{x}_{j,it} + \sum_{j=2}^{5} \beta_j \ln \tilde{x}_{j,it} + \\ & + \tfrac{1}{2} \textstyle\sum_{j=2}^{5} \sum_{k=2}^{5} \beta_{jk} \ln \tilde{x}_{j,it} \ln \tilde{x}_{k,it} + \alpha_t t + \tfrac{1}{2} \alpha_{tt} t^2 + \sum_{m=1}^{2} \alpha_{mt} \ln y_{m,it} t + \\ & + \textstyle\sum_{j=2}^{5} \alpha_{jt} \ln \tilde{x}_{j,it} t - u_{i0} - u_{it} + v_{it}\end{aligned} \tag{3}$$

where $v_{it} \sim N(0, \sigma_v^2)$, $u_{it} \sim N^{+}(0, \sigma_u^2)$, $u_{i0} \sim N^{+}(0, \sigma_{u0}^2)$.

The above-mentioned normalization ensures the exogeneity of inputs (Sipiläinen et al., 2014) and consistency of estimation (Kumbhakar, 2011). Moreover, all variables in logarithm are normalized by their sample mean, which makes it possible to interpret the estimated first-order parameters as elasticities at the geometric mean of the sample.

From equation (3), it is possible to quantify the IDF elasticity with respect to m^th^ output (see Latruffe et al., 2012) as $e_{mit}=(\partial \ln D^{I}_{it})/(\partial \ln y_{(m,it)})$ and then quantified the economies of scale (Rasmussen, 2010):

$$RTS = -\left[\textstyle\sum_{m=1}^{2} e_{mit}\right]^{-1}. \tag{4}$$

The GTRE is fitted by the maximum simulated likelihood with Halton sequence in the SW NLOGIT 5.0. The simulated log-likelihood function is defined according to Filippini and Greene (2016):

$$\begin{aligned}\log L_S(\alpha, \beta, \lambda, \sigma, \sigma_w, \sigma_{1u}) = {} & \textstyle\sum_{i=1}^{N} \log \frac{1}{R} \sum_{r=1}^{R} \left\{ \prod_{t=1}^{T} \left[\frac{2}{\sigma} \phi \left(\frac{e_{it} - (\sigma_w W_{ir} - \sigma_{u0} |U_{ir}|)}{\sigma} \right) \times \right.\right. \\ & \left.\left. \Phi \left(\frac{-(e_i - (\sigma_w W_{ir} - \sigma_{u0} |U_{ir}|) \lambda)}{\sigma} \right) \right] \right\},\end{aligned} \tag{5}$$

where: $e_{it} = y_{it} - \alpha - \beta' x_i$, $\lambda = {}^{\sigma_{u,t}}/_{\sigma_v}$, $\sigma = \sqrt{(\sigma_{u,t}^2 + \sigma_v^2)}$, $e_i = y_i - \alpha - \beta' x_i$, R represents the number of simulations.

The estimation of technical efficiency is based on moments generating approach of Colombi et al. (2011):

$$E(\exp\{t\acute{}u_i\}|e_i) = \frac{\bar{\Phi}_{T+1}(Re_i+\Lambda t,\Lambda)}{\bar{\Phi}_{T+1}(Re_i+\Lambda)} \times \exp\left\{t\acute{}Re_i + \frac{1}{2}t\acute{}\Lambda t\right\}, \qquad (6)$$

where: $\Lambda = [V^{-1} + A\acute{}\Sigma^{-1}A]^{-1}$, $\Sigma = \sigma_v^2 I_T + \sigma_w^2 1_T 1\acute{}_T$, $V = \begin{bmatrix} \sigma_{u0}^2 & 0\acute{}_T \\ 0_T & \sigma_u^2 I_T \end{bmatrix}$, $R = \Lambda A\acute{}\Sigma^{-1}$, $A = -[1_T|I_T]$, $I_T = T \times T$ is a unit matrix, $(1_T, 0_T) = \begin{pmatrix} 1 & 0 \\ \vdots & \vdots \\ 1 & 0 \end{pmatrix}$.

The elements of technical efficiency are then gradually calculated from (6) using -log[E (exp{$t\acute{}u_i$}|e_i)], see Filippini and Greene (2016). According to Kumbhakar et al. (2014), total technical efficiency (OTE) is quantified from persistent and transient technical efficiency:

$$OTE_{it} = \exp(-\hat{u}_{i0}) * \exp(-\hat{u}_{it}). \quad (7)$$

Moreover, the relationship between these parts of overall technical efficiency, economic performance, and economic size is analyzed. Economic performance is measured especially by the profitability indicators and other indicators of economic situation, see Table 1. Indicators describing the production (for example importance of subsidies or degree of specialization, etc.) are also included in the analysis. According to Commission Regulation (EC) 1242/2008, the economic size of the farm is expressed in Standard Output (SO), which is the sum of all the standard outputs per hectare of crop and per head of livestock on farm and is expressed in euro. In this study, the subjects under investigation are divided into three size groups: small (0-99,999 Eur of Standard Output), medium (100,000-749,999 Eur), and large (over 749,999 Eur). The differences between size groups are analyzed and tested by Kruskal-Wallis test. This test is favored over parametric ANOVA due to the normality violation (tested by the Shapiro-Wilk test) and due to the significantly different number of observations in each group. These tests are done in STATA 15.1.

The analysis uses an unbalanced panel data set of the type of farming (TF) TF14 - 45 “specialist milk” and the TF14 – 80 “mixed crops and livestock” drawn from the FADN database. The definition of both types is mentioned in FADN methodology (European Commission, 2010), which is based on Commission Regulation (EC) 1242/2008[1]. The data covers the period from 2004 to 2017. The data set of TF specialist milk consists of 1,449 observations of FADN regions (more in European Commission, 2010) in 27 EU member states. For Cyprus and Greece, no data is available in the TF14 - 45 specialist milk. The data set of TF mixed crops and livestock consists of 1,153 observations of FADN regions in 28 EU member states.

Table 1. Selected indicators based on FADN

Indicators of production conditions	Dairy cows/total utilized agricultural area (UAA)	SE085/SE025	Other efficiency indicators	Gross farm income/total output	SE410/SE131
	Paid labor input/total labor input	SE020/SE010		Total output/total input	SE132
	Rented UAA/total UAA	SE030/SE025	Profitability indicators	Farm net income/total labor	SE420/SE010
Importance of subsidies	Total current subsidies/ total output	SE605/SE131		Farm net income /total inputs	SE420/SE270
	Total current subsidies/ gross farm income	SE605/SE410		Farm net income /total assets	SE420/SE436
Degree of specialization	Milk production /total output	SE216/SE131	Productivity indicators	Total output/total labor	SE131/SE010
				Farm net value added /total labor	SE415/SE010

Source: FADN

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[1] According to Commission Regulation (EC) 1242/2008 the “type of farming” of a holding is determined by the relative contribution of the standard output of the different branches of crop and animal production of this holding to the total standard output of this one. The type of farming 45 “specialist milk”(according to TF-14 grouping) can be described by the principal type of farming 45 “specialist dairying” (with these thresholds: “dairy cows > 3/4 of total grazing livestock; grazing livestock > 1/3 of grazing livestock and forage”). The type of farming 80 “mixed crops and livestock” can be described by the principal type of farming 83 “Field crops – grazing livestock combined” (with these thresholds: General cropping > 1/3; grazing livestock and forage > 1/3), and by the principal type of farming 84 “Various crops and livestock combined” (holdings in class 8, excluding those in class 83).

For Cyprus, only a low number of observations are available in this type of farming. That is why the observations of Cyprus are excluded from the data set. Observations with zero dairy cows are also excluded.

The data included in the model represent average farm data for each EU-region and each observed year in the model. Although regional data represent the lowest level of aggregation freely available within the FADN database, it introduces several limitations to the analysis, see Madau et al. (2017). For example, the estimated frontier based on regional data may differ from the true frontier estimated based on-farm data and it is impossible to model the meta-frontier. The regional data does not allow evaluate the intra-region variability of the outputs and inputs involved in the dairy processes. However, the use of aggregate data represents an opportunity to estimate a technical efficiency for the EU as a whole. Data from the FADN database make it possible to obtain a long time series for all Member States and cover more than 90% of the standard output of the sector.

For the estimation of the IDF in this study, the following outputs and inputs are used: milk production (y_1) in kilos (SE125N), other production (y_2) in EUR, which is determined as the sum of crop production (SE135), other animal production (SE206 minus the production of milk in EUR (SE216)) and other production (SE256), the cost of feed for grazing livestock (x_1) in EUR (SE310), labor (x_2) measured in working hours (SE011), the total utilized agriculture area (x_3) in hectares (SE025), capital (x_4) in EUR measured as the depreciation (SE360) plus contracted work (SE350) and the costs of other materials (x_5) in EUR (total intermediate consumption (SE275) minus feed for grazing livestock (SE310)). Outputs, as well as inputs (except for the milk production, labor, and land), are deflated by price indices (individual output and input indices (2010 = 100) – source the EUROSTAT database). The sample summary statistics for FADN regions are presented in Table 2.

RESULTS AND DISCUSSION

The estimated parameters of the input distance function for both analyzed types of farming are presented in Table 3. The majority of parameters are statistically significant at the 1% significance level. Since all variables are normalized in logarithm by their sample mean, the first-order parameters can be interpreted as the elasticities of the IDF with respect to outputs and as the shadow share of inputs in the total input at the geometric mean of the sample. The IDF estimate is interpreted firstly for the TF-14 45 specialist milk, then the estimate of the TF-14 80 mixed crop and livestock's IDF is interpreted.

Table 2. Descriptive statistics for the variable in the sample

	Specialist milk				Mixed crops and livestock			
	Mean	SD	Min.	Max.	Mean	SD	Min.	Max.
Milk [ths. kilos]	433.1	454.4	7.5	3009.7	142.7	310.5	0.1	2007.9
Other production [ths. Eur]	68.5	100.7	1.2	804.5	150.9	235.4	2.8	1759.2
Feed [ths. Eur]	60.8	62.2	0.8	352.1	24.9	44.4	0.1	314.3
Labour [hours]	5887.5	6817.8	1959.0	72184.3	5801.3	9016.2	1306.1	91378.9
UAA [hectares]	89.6	134.0	1.7	1041.9	124.8	202.7	1.2	1210.2
Capital [ths. Eur]	38.6	44.5	0.5	352.9	40.3	59.0	0.4	412.8
Cost of other material [ths. Eur]	82.7	112.8	0.9	734.5	113.5	190.7	1.6	1533.7
Cases	1,449				1,153			

The monetary values are in 2010 levels. SD denotes standard deviation.

Source: Own calculation

Table 3. Parameters estimate of the IDF

	Specialist milk		Mixed crops and livestock			Specialist milk		Mixed crops and livestock	
	Coeff.	SE	Coeff.	SE		Coeff.	SE	Coeff.	SE
y1	-0.5562***	0.0064	-0.0857***	0.0029	x33	-0.0475***	0.0110	0.0156	0.0175
y2	-0.1726***	0.0051	-0.5455***	0.0121	x44	0.1431***	0.0130	0.0735***	0.0219
x2	0.3812***	0.0057	0.4608***	0.0120	x55	0.1523***	0.0286	0.1428***	0.0327
x3	0.1378***	0.0061	0.0407***	0.0099	x23	0.0068	0.0119	0.0077	0.0148
x4	0.0986***	0.0068	0.0985***	0.0111	x24	0.0804***	0.0114	0.0199	0.0143
x5	0.1773***	0.0104	0.3131***	0.0138	x25	-0.0820***	0.0181	0.1365***	0.0222
t	0.0072***	0.0004	0.0027***	0.0008	x34	-0.0278***	0.0091	0.0512***	0.0130
tt	-0.0004*	0.0002	-0.0015***	0.0003	x35	0.0588***	0.0186	-0.0321*	0.0177
y1t	0.0005	0.0010	0.0023***	0.0005	x45	-0.0788***	0.0168	-0.1773***	0.0230
y2t	0.0062***	0.0006	0.0031***	0.0011	y1x2	-0.0648***	0.0191	-0.0445***	0.0064
x2t	0.0100***	0.0009	0.0114***	0.0010	y1x3	0.0293**	0.0136	-0.0040	0.0053
x3t	-0.0085***	0.0007	-0.0048***	0.0013	y1x4	0.0225**	0.0108	-0.0019	0.0071
x4t	0.0095***	0.0009	-0.0011	0.0014	y1x5	-0.0661***	0.0173	0.0666***	0.0091
x5t	-0.0057***	0.0016	-0.0022	0.0020	y2x2	-0.0288***	0.0101	-0.0884***	0.0161
y11	-0.1981***	0.0206	-.0428***	0.0016	y2x3	-0.0267**	0.0105	0.0042	0.0158
y22	-0.0988***	0.0110	-0.1428***	0.0173	y2x4	0.0307***	0.0094	0.0690***	0.0151
y12	0.0696***	0.0106	0.0032	0.0057	y2x5	0.0385***	0.0137	0.0252	0.0234
x22	-0.0429**	0.0204	-0.1112***	0.0208	Means for random parameters				
Sigma	0.0830***	0.0029	0.0875***	0.0038	Const.	0.2105***	0.0062	0.1849***	0.0102
Lambda	1.3396***	0.1694	1.1089***	0.1857	Sigma_α	0.1583***	0.0026	0.1154***	0.0031
Log-likelihood	1,671.2858		1,248.1250		Sigma_u 0	2.9495***	0.1138	0.5364***	0.0475

Milk is y_1, y_2 is other output, x_2 is labor, x_3 denotes land, x_4 is capital, x_5 is material (excluding feed), and t is time variable, SE denotes standard error; ***, **, * denotes significance at the 1%, 5%, and 10% levels respectively; Sigma_α is the standard deviation of time fixed symmetric effects; Sigma_u0 is the standard deviation of time fixed one-sided effects

Source: Own calculation

As can be seen from Table 3, the input share of capital is the lowest (0.10), the input share of labor is the highest (0.38), and the elasticity of the milk output is about 0.56 in the TF-14 45 specialist milk. That is, the share of capital in the total input is only 10%, but the share of labor is about 38%. A high share of labor and a low share of capital in total inputs of dairy farms are also found by Sipiläinen et al. (2014) based on data from Finnish and Norwegian milk production. However, over analyzed time, the share of capital in total input has been increasing (that is capital-using technology is exhibited) and the share of land and other material (except for feeds) has been reducing (i.e material- and land-saving technology). This may indicate a modernization of production towards more material-efficient and less land-bound technologies. The negative inversion of the sum of partial elasticities of outputs, which corresponds to economies of scale, is according to t-test (t-value = 68.858) different from one at the 1% significance level and averages 1.41. That is, milk production can be characterized by the existence of increasing returns to scale. In only 5% of cases (in particular the regions of Germany and Slovakia) the estimated value of economies of scale is less than one, which corresponds to decreasing returns to scale. The prevailing increasing returns to scale for European dairy farms are also identified by Čechura et al. (2017). The estimate of the parameter αt that measures the shift of the input distance function over time, ceteris paribus, reveals moderate technological regress. Applied to the duality between input-distance and cost functions, this informs about the slight increase in production costs over the analyzed period. It can be added that this increase was decelerating (α_{tt} <0) over the analyzed period at the 10% level of significance.

In the case of the TF mixed crops and livestock, the share of land in total input is the lowest (0.04), and similarly to the TF specialist milk, the share of labor is the highest (0.46). Moreover, technology is biased towards labor and against land in the analyzed period (in other words, it is labor-using and land-saving). The input share of capital is similarly to the TF specialist milk 10%, but the input share of material (except feed) is higher in the TF mixed crops and livestock. This is in line with the share of crop production in total output, which is 47% on average, requiring greater involvement of other materials. The elasticity of the milk output is only 0.09. The mixed production had undergone technological regress in the analyzed period but with a lower intensity than the TF specialist milk. This technological regress was decelerating over the analyzed period. Similarly to the TF specialist milk, the TF mixed crops and livestock also exhibits the increasing returns to scale (the average value is 1.52 and is different from one at the 1% significance level (t-value = 47.273) and in only 5% of cases (in particular the regions of Germany, in the Czech Republic and Slovakia) the estimated value of economies of scale is less than one. The magnitude of returns to scale in both types of farming reveals that the producers have a substantial potential to improve their productivity by increasing scales of operations, evaluated on samples means.

Lambda - the ratio of the standard deviation of the inefficiency term u_{it} to the standard deviation of the stochastic term v_{it} - is significant in both types of farming and reflects the relatively low contribution of stochastic noise to the error term ε_{it}. The standard deviations of the time fixed symmetric effects (σ_{α}) and the time fixed one-sided effects (σ_{u0}) are also significant at the 1% significance level. The transformation process is highly efficient in both types of farming, see Table 4. The mean values of overall technical efficiency are 84% in the TF specialist milk and 87% in the TF mixed crops and livestock. That is, the milk producers can save 16% of inputs and the mixed producers 13% on average. Only 10% of subjects have lower overall technical efficiency than 82% in the TF specialist milk and then 85% in the TF mixed crops and livestock. The mean is slightly lower than the median of overall technical efficiency in both types of farming, which points to a skew of overall technical efficiency. Only a few low values of technical efficiency can be found in the analyzed samples. The standard deviation of the overall technical efficiency of the TF mixed crops and livestock is slightly lower than in the TF specialist milk case. That is, the subjects are more similar in the overall efficiency of the production process in the case of the TF mixed crops and livestock than in the TF specialist milk.

In both types of farming, the persistent technical inefficiency poses a greater problem for agriculture production than the transient component. The transient technical efficiency is higher than the persistent one at the mean as well as at the median level and exhibits greater variability. As in Addo and Salhofer (2019) research, the transient component fluctuates a lot over the observed period. According to this result, it can be concluded that there is a higher number of subjects lagging behind best practice in the short-term compared to the representation of the subjects that are lagging behind in the long-time period. On the other hand, the loss of resources is due to structural problems and permanent managerial failures in the production process. Therefore, to eliminate this waste of resources and to promote the sustainability of

Table 4. Technical efficiency

Percentile	Specialist milk			Mixed crops and livestock		
	Transient	Persistent	Overall	Transient	Persistent	Overall
Min.	0.7768	0.8649	0.6896	0.7882	0.9028	0.7229
10th	0.9221	0.8838	0.8156	0.9294	0.9132	0.8503
25th	0.9423	0.8842	0.8337	0.9425	0.9143	0.8616
Med.	0.9541	0.8849	0.8441	0.9550	0.9151	0.8732
75th	0.9627	0.8853	0.8516	0.9631	0.9154	0.8811
90th	0.9697	0.8859	0.8580	0.9698	0.9159	0.8873
Max.	0.9888	0.8877	0.8766	0.9881	0.9334	0.9046
Mean	0.9489	0.8848	0.8396	0.9506	0.9147	0.8695
SD	0.0236	0.0012	0.0208	0.0201	0.0016	0.0185

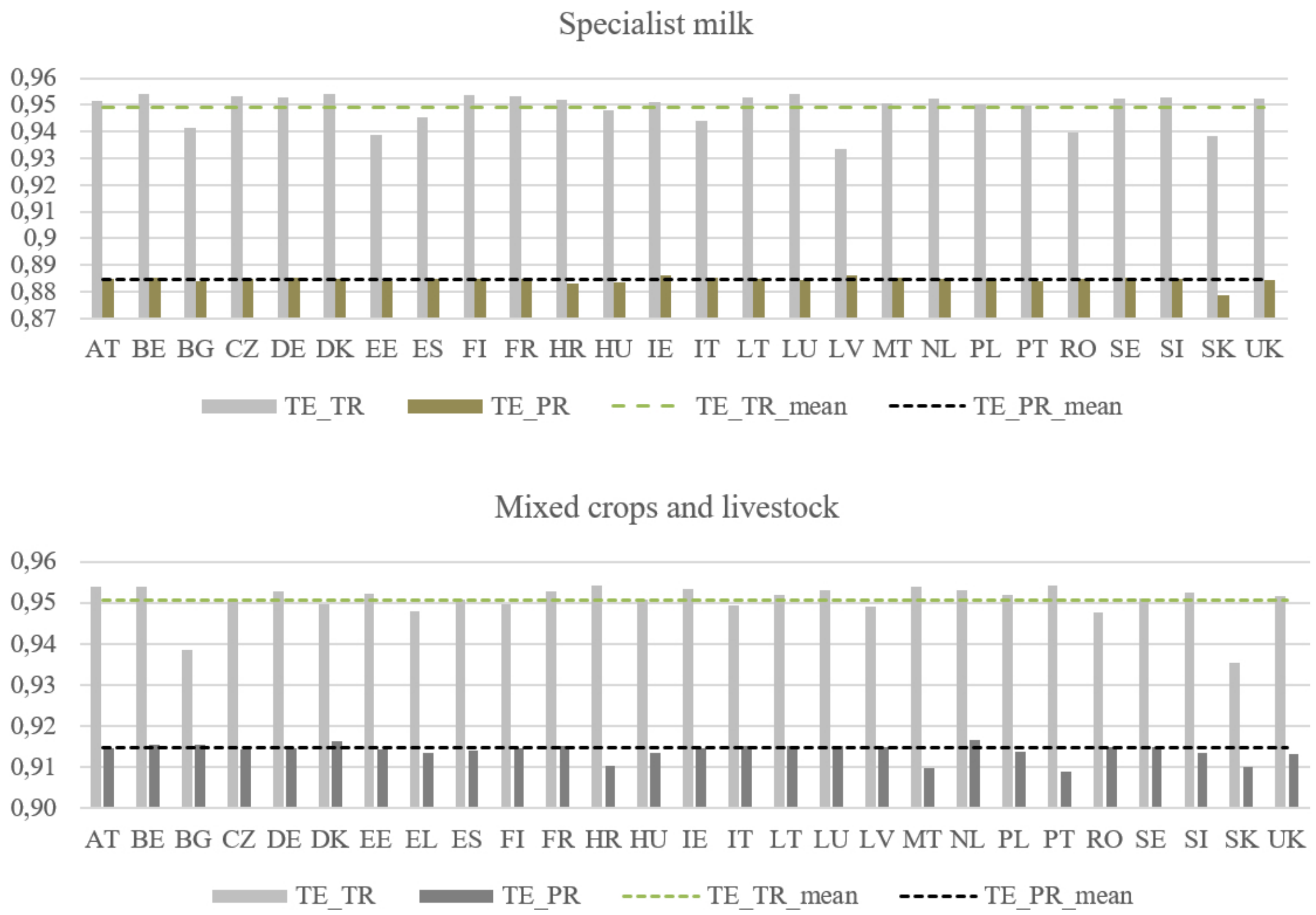
Source: Own calculation

agricultural production, agriculture policy should focus on factors affecting the persistent efficiency. Pisulewski and Marzec (2019) suggest measures that could change the agrarian structure. Management should also focus on changes in the organization of the production process, on outsourcing, and sharing options. To reduce the variability of transient technical efficiency, the measures connected with knowledge transfer and agricultural education are required, see Njuki and Bravo-Ureta (2015).

Focus on the individual countries, the TF specialist milk in Belgium, Denmark, Finland, and Luxembourg achieved the highest overall technical efficiency in the analyzed period. That is the best practice milk production is located in these countries. In the case of the mixed production, the highest overall technical efficiency was found in the Netherlands, Belgium, Austria, and Luxembourg. The Slovakian, Croatian, and Hungarian milk producers are systematically lagging behind the best-practice technologies, see Figure 1. In these countries, the systematic loss of competitive advantage is also revealed in the case of the TF mixed crop and livestock. Although the lowest persistent technical efficiency in the TF mixed crops and livestock was found in Portugal. To conclude, it is appropriate to consider structural changes to increase efficiency, productivity, and profitability in these types of farming in Slovakia, Croatia, Hungary, and Portugal.

The TF specialist milk in Latvia, Slovakia, and Estonia cope with the highest technical inefficiencies in the short-term period. In the case of the TF mixed crops and livestock, the lowest transient technical efficiency is found in Slovakia, Bulgaria, and Romania. The agriculture policy in these counties should focus on factors affecting the short-term inefficiency, which includes the adoption of new technologies, managerial skills, knowledge transfer, or agricultural education (Njuki and Bravo-Ureta, 2015). On the other hand, agriculture policy can itself caused a decrease in technical efficiency. As Pisulewski and Marzec (2019) conclude, the considerable subsidies under the Common Agricultural Policy (CAP) allow inefficient farms to survive. The results point out the importance of differentiated policies at the country level and in relation to individual sectors.

In line with current political trends, it is also appropriate to analyze the relationship between size, efficiency, and consequently economic performance. The results reveal that the impact of economic size on the overall technical efficiency and the transient technical efficiency is not statistically significant for both types of farming. Due to the normality violation and due to the significantly different number of observations in each group, the result



Note: AT is Austria, BE is Belgium, BG is Bulgaria, CZ is Czechia, DE is Germany, DK is Denmark, EE is Estonia, EL is Greece, ES is Spain, FI is Finland, FR is France, HR is Croatia, HU is Hungary, IE is Ireland, IT is Italy, LT is Lithuania, LU is Luxembourg, LV is Latvia, MT is Malta, NL is the Netherlands, PL is Poland, PT is Portugal, RO is Romania, SE is Sweden, SI is Slovenia, SK is Slovakia, UK is the United Kingdom

Figure 1. Transient (TE_TR) and persistent (TE_PR) technical efficiency in member states

of the nonparametric Kruskal-Wallis test, which tests median differences between groups, is favored. Only by the persistent technical efficiency, the difference between the size groups at the 5% level of significance is proved. The lowest values of the persistent technical efficiency show the group “large” in both production types. Addo and Salhofer (2019) have analyzed determinants of the persistent and transient parts of the overall efficiency of Austrian crop farms, they observe that the share of subsidy negatively and the crop specialization positively impacted both parts of efficiency. As can be seen from Table 5, the group “large” has the highest dependence on operating subsidies (measured by the share of current subsidies in gross farm income) and the lowest degree of specialization (in the case of TF specialist milk) among the size groups and at the same time the lowest value of persistent technical efficiency. Therefore, this result can support the states of Addo and Salhofer (2019) regarding a positive influence of specialization and the negative influence of dependence of subsidies on persistent technical efficiency.

The group “large” can be also characterized by the decreasing returns to scale, especially in the TF mixed crops and livestock. Suppose the homothetic production technology, it can be concluded that the size of these producers is too large and the restructuring to optimal size could bring a reduction of input waste or in other words cost-savings, especially in the long-term. On the other hand, the group “small” as well as “medium” exhibits the increasing returns to scale in both types of farming.

That is, a shift to optimal size is appropriate to achieve more sustainable and competitive production in the long term period.

The group "large" can be also more confronted with structural problems in the production process, can be less able to adapt to change (in regulations or subsidy system). Effective production is suppressed by subsidies as sources of income, which in this category represent the largest share of gross farm income. This implies that subsidy policy is not optimally set. This can be useful information in debates on the future shape of the CAP. It can be assumed that a change in the CAP and possibly capping will have an impact on the size structure of agricultural holdings. The influence of various subsidy instruments on technical efficiency is then discussed in a number of studies, e.g. Rizov et al. (2013), Latruffe et al. (2017), Minviel and Latruffe (2017).

Focus on economic performance, the Kruskal-Wallis test reveals the statistically significant differences between size groups in all measures of profitability and productivity at the 5% significance level. From the rest of the production characteristics presented in Table 5, only the difference in the share of current subsidies in total output in the TF mixed crops and livestock is not statistically significant based on the Kruskal-Wallis test at 5% level.

Table 5. Technical efficiency, performance, and other indicators according to the economic size

Variable name	Unit	Specialist milk			Mixed crops and livestock		
		Small	Medium	Large	Small	Medium	Large
Technical efficiency overall		0.8366	0.8408	0.8407	0.8680	0.8715	0.8662
Transient		0.9456	0.9502	0.9509	0.9490	0.9525	0.9485
Persistent		0.8847	0.8849	0.8842	0.9146	0.9150	0.9132
Economies of scale		1.64	1.34	0.99	1.66	1.48	0.91
Paid labor input/total labor input	%	14.63	21.40	86.40	16.79	21.33	93.37
Rented UAA/total UAA	%	48.86	64.50	78.32	47.45	72.06	83.22
Current subsidies/total output	%	19.20	17.49	20.53	23.24	22.28	22.61
Current subsidies/gross farm income	%	31.71	35.25	44.20	38.00	43.98	47.71
Milk production/total output	%	63.99	71.24	57.86	12.77	17.16	28.18
Total output/total labor	EUR/AWU	28,068.96	98,758.72	110,956.60	24,376.71	104,630.90	91,563.04
Farm net value added /total labor	EUR/AWU	11,753.38	34,171.01	36,934.45	11,506.25	33,712.19	33,494.62
Gross farm income/total output	%	60.58	49.42	46.59	61.95	50.27	48.82
Total output/total input	EUR	1.34	1.12	0.87	1.21	0.98	0.84
Farm net income/total labor	EUR/AWU	11,753.38	23,726.39	5,942.68	8,783.72	17,350.64	3,169.86
Farm net income /total inputs	%	59.40	30.67	4.26	47.31	17.97	2.24
Farm net income /total assets	%	12.04	7.41	2.03	8.26	5.30	1.04
L. and m. term loans/total assets	%	2.11	5.64	12.09	2.76	8.74	10.70
Short term loans/total assets	%	5.43	17.80	31.12	4.12	20.94	18.41

Source: Own calculation

The group “large” in both production types can be characterized by the highest share of hired labor and hired land and is significantly most burdened with loans compared to other groups. The share of hired labor and hired land increases with the economic size, reflecting the greater representation of small family farms in the first group.

As already mentioned, the share of current subsidies in gross farm income shows a high dependency of group “large” in particular; current subsidies account for 44.2% of gross farm income in the TF specialist milk and 47.1% in the TF mixed crops and livestock. The value of the indicator is higher for the mixed production in all size groups. It can be said that the category “large” also creates the least gross farm income in relation to total output compared to other size groups. This share decreases with economic size in both types of farming. The group “large” achieves also the lowest value of cost-effectiveness, measured by the share of total output in total input. One euro of costs will not bring a single euro of production in both types of farming (the TF specialist milk: small – 1.34, large – 0.87; the TF mixed crops and livestock: small – 1.21, large – 0.84). The higher values of this indicator are observed in the TF specialist milk. The performance indicators only reflect the above mentioned. The group “large” is the least profitable with comparison to other groups, measured by the share of farm net income in total costs or total assets, for both types of farming.

Although there is no statistically significant difference in overall technical efficiency for groups according to the economic size, persistent efficiency, economic performance, and other indicators differ considerably for each group. The group “large” in both types of farming is less productive, because it creates the least gross farm income in relation to total output, achieves the lowest value of cost-effectiveness, and thus also the lowest value of profitability in comparison to other groups. Therefore, it can be stated that a higher share of subsidies not only reduces the efficiency of production but also does not help to increase profitability.

CONCLUSION

The goal of this paper was to analyze the economic performance, technical efficiency, and its persistent and transient parts for milk production in the European Union with respect to economic size. Attention was focused on the specialized milk production and mixed crops and livestock production using FADN data in the period from 2004 to 2017. The authors are aware of the advantages and disadvantages of using aggregated data. Although, the use of farm data would provide clearer information on the impact of size on the technical efficiency and economic performance of the EU dairy production, the use of aggregate data represents an opportunity to estimate a technical efficiency for the EU as a whole.

From a methodological point of view, the analysis was based on the four-component model that represents the most advanced approach to technical efficiency analysis at present and the one-step estimation procedure, which is more efficient compared to the multi-step variant. The main contribution of this paper is the practical application of this recently developed model in the analysis of the efficiency of the European dairy production and comparison of the technical efficiency and economic performance results in different size groups. To the best of knowledge, this is the first application of four-component model based on the single-step estimation procedure on these types of farming in the whole EU.

The results show the highly technically efficient production in both types of farming. The transient component of technical inefficiency that is caused by singular, non-systematic management mistakes (for example poor response to price or demand changes) is higher than the persistent one, that captures inefficiencies due to recurring identical management mistakes, structural problems in the sector, or unsuitable factor allocations that are difficult to change over time.

Moreover, the results show that the transient technical efficiency did not differ statistically between groups according to economic size. However, economic size had an impact on persistent technical efficiency scores for both types of farming. The lowest persistent technical efficiency was found in the group of highest economic size. Although this group is nearest to the technically optimum size on the mean value, it is most inefficient in resource use. The highest score of persistent technical efficiency achieves the group "medium", evaluating on sample mean. This indicates that the group "medium", on the one hand, can use its size to more efficient use of production factors while being more flexible in adapting to sectoral changes.

The research points out that the milk production in the European Union faces unfavorable agrarian structure and that the size structure affected the competitiveness and sustainability of milk production. The main conclusion for both types of farming is that the group with the highest economic size is the most persistently inefficient. This size group has the highest share of current subsidies in gross farm income, is the least specialized (in case of the TF specialist milk), produces the least gross farm income in total output, and achieves also the lowest cost-effectiveness (measured by the share of total output to total input). A higher share of subsidies does not lead to higher efficiency compared to other size groups. Even a higher share of subsidies does not lead to higher profitability compared to other size groups. This points to existence of so-call soft-budget constraints in European milk production and calls for the revision of the agrarian policy.

Knowledge of the level of technical efficiency and performance in different size groups can support the policymakers in better targeting of the agrarian policy in general. It implies the reduction of subsidies for low-efficiency farms causing the soft-budget-constrains. This research is probably the first paper with the practical application of decomposition of technical efficiency to the transient and persistent part in the EU livestock (dairy) sector. The analysis of other factors affecting overall, transient and persistent technical efficiency will be the subject of further research. The possibility of a broader discussion of results with other authors would certainly be beneficial for further research.

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