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AGRICULTURAL EFFICIENCY AND ITS COMPONENTS IN EUROPEAN UNION COUNTRIES BETWEEN 2009-2019. ANALYSIS USING AGGREGATE FÄRE-PRIMONT PRODUCTIVITY INDICES

Key words: agriculture, agricultural efficiency, TFP total productivity indices, Data Envelopment Analysis, EU-25

ABSTRACT. The aim of the research was to measure the efficiency of agricultural activities in European Union countries with the use of various measures of efficiency. The analysis covered the years 2009-2019. The calculated efficiency was relative and the starting material for its estimation were aggregated Färe-Primont productivity indices. Based on the maximum possible level of productivity in a given period, the level of relative efficiency of TFPE was estimated. The analysed countries were grouped, on the basis of this efficiency, into four groups differentiated in terms of level. Then, the TFPE index was decomposed into several separate measures of efficiency, which were further analysed. The analysis showed that there are differences in the level of efficiency between individual countries. It has been shown that agriculture in European Union countries can be considered technically efficient. The efficiency of scale is also high. The greatest variation between countries is in the case of residual efficiency.

INTRODUCTION

Agriculture in the European Union is a sector in which many analyses are performed in terms of productivity and efficiency. The nature of these studies, context and methods have changed over time, as noted in the work by Jerzy Marzec et al. [2019]. It is a result of changes in economic and social conditions in Europe and the world. Under the influence of these changes, the European Union has introduced various reforms and strategies over the years under the Common Agricultural Policy (CAP). Instruments such as “Agenda 2000”, “Mid Term Reform”, “Health Check”, the system of direct and indirect payments, as well as the linking of payments in relations to non-market (mainly environmental) objectives and the possibilities of implementing the concept of sustainable intensification of IS, as noted by Andrzej Czyżewski and Jakub Staniszewski [2018], aimed at adjusting production to new conditions. The implementation of these programmes has had an impact on the efficiency and productivity of farms as well as risk of operation and possibility of development. Considerations on this subject can be found in works by Subal Kumbhakar and Gudbrand Lien [2010], Xuequin Zhu and Alfons Oude-Lansink [2010], Johan Swinnen and Liesbet Vranken [2010] and Sonia Quiroga et al. [2017]. The currently dominant policy of sustainable development of the European Union assumes, on the one hand, the de-intensification of outlays and, on the other hand, increasing efficiency through technological progress and innovation. Despite such assumptions and greater responsibility for the environment, the CAP must be competitive, and this competitiveness is ensured by efficient and effective agricultural production [Quiroga et al. 2017]. This policy also assumes levelling out differences in the level of development of individual regions. As long as such differences exist, financial resources allocated to support for agriculture should be distributed and absorbed on the basis of an analysis of differences in the efficiency of input and resource use.

The DEA (Data Envelopment Analysis) method is often used to test the efficiency of agriculture. The studies found in various types of revisions cover approaches from various perspectives, from economic, through environmental protection, to social. They are conducted at a level of farms, countries and regions. They focus on different types of farms, crops, sizes, etc. In Science Direct databases, there are several hundred references in the last 10-year search results including the terms "agriculture, efficiency, DEA". On the other hand, research focused on European Union countries is not common [Martinho 2017]. The dominant methods here are non-parametric methods, mainly the DEA method. Examples include studies conducted by: Olalekan Akande [2012], Joanna Baran [2016], Lajos Baráth and Imre Fertő [2016], Lucyna Błażejczyk-Majka [2011, 2017], Štefan Bojnec et al. [2014], Murat Cankurt et al. [2013], Abdullahi Iliyasu et al. [2016], Marta Guth and Katarzyna Smędzik-Ambroży [2019], Beata Gavurová et al. [2019], Malgorzata Kołodziejczak [2015], Anna Nowak et al. [2015], Jakub Staniszewski [2018], Pierluigi Toma et al. [2017], which include the measurement of efficiency with the use of various models and different sets of variables.

A smaller part of the research uses parametric methods, whereby, firstly, the efficiency curve is estimated, which at a later stage forms the basis for comparisons of real objects. The methods that use SFM (Stochastic Frontier Models), stochastic models dominate and usually apply to a specific country or region and a specific type of production (for example, studies by: Lukas Cechura [2014], Subal Kumbhakar and Gudbrand Lien [2010], Tamara Rudinskaya et al. [2019] and Sonia Quiroga et al. [2017]).

There are few studies using two or more methods (for example: Viet-Ngu Hoang and Thanh Trung [2013], Kristuna Kočišová [2015], Jerzy Marzec et al. [2019] or George Vlontzos et al. [2017]).

However, there are no studies that analyse the level of efficiency estimated on the basis of the decomposition o aggregate TFP productivity indices. Indices of this type proposed in the papers by Christopher O'Donnell [2010, 2012a, 2012b] or Viet-Ngu Hoang [2011] can be decomposed into various measures of efficiency. The aim of the research presented in this study was an attempt to use the effects of this decomposition to assess the efficiency level of European agriculture. As in most studies with a regional and national cross-section, an effects-oriented model was used for the study.

MATERIAL AND METHODS

In a one-dimensional situation, the total factor productivity (TFP) of an object can be defined as the quotient of the effect and the input. When the analysed technology is more complicated, i.e. it assumes many inputs and TFP effects, we can define it as the quotient of the aggregated effects vector to the aggregated vector of inputs. The knowledge of price relations allows for trouble-free estimation of productivity indicators. When we do not know these relations, we must use an alternative approach. Such an approach is the estimation of productivity indicators based on relations between objects. Then we are dealing with relative productivity, i.e. in relation to other objects. Färe-Primont total factor productivity (TFP) indices used in the presented analysis were proposed by Christopher O'Donnell [2008] and measure the relationship of aggregated effects and inputs between analysed objects. For the measurement, aggregated distance functions are used, calculated with the use of linear programming methods (LP) and the assumptions of the Data Envelopment Analysis (DEA) method.

The total productivity of a multidimensional object *i* in period *t* can be estimated as the ration of aggregated effects to aggregated inputs [O'Donnell 2011a, p. 5]:

$$TFP_{it} \equiv \frac{Q_{it}}{X_{it}} \tag{1}$$

where: $Q_{it} = Q(q_{it})$ is the aggregate effect, $X_{it} = X(x_{it})$ is the aggregated input, *Q*(.) and *X*(.) are non-decreasing, non-negative, linearly homogenous functions, while $(x_{1it}, \ldots, x_{Kit})'$ and $q_{it} = (q_{1it}, \ldots, q_{Jit})'$ are input and effect vectors.

To measure the level of productivity as well as changes in productivity, you can use indices that show the relationship of the TFP of one object to the TFP of the reference object. For example, the productivity index measuring the relation of an i object's TFP in period t to the TFP of the h object in period s, can be represented by the equation:

$$TFP_{hs,it} \equiv \frac{TFP_{it}}{TFP_{hs}} = \frac{Q_{it}/X_{it}}{Q_{hs}/X_{hs}} = \frac{Q_{hs,it}}{X_{hs,it}} \tag{2}$$

Assuming that $D_0(.)$ and $D_I(.)$ are aggregate distance functions of effects and inputs, and assuming that $Q(q) = D_O(x_0, q, t_0)$ and $X(x) = D_I(x, q_0, t_0)$ for which q_0, x_0 are the vectors of effects and inputs and t_0 is the reference period, the Färe-Primont (*FP*) index used in this study is presented by the equation:

$$TFP_{hs,it}^{FP} = \frac{D_O(x_0, q_{it}, t_0)}{D_O(x_0, q_{hs}, t_0)} \frac{D_I(x_{hs}, q_0, t_0)}{D_I(x_{it}, q_0, t_0)} \tag{3}$$

The Färe-Primont index presented in equation (3) is based on distance functions. This type of index can be estimated and decomposed using the assumptions of the DEA method. More information and a detailed description of the estimation of unknown parameters can be found, for example in the work by Christopher O'Donnell [2011b].

TFP indices in the form of (2) can be used to compose various measures of performance. For example, if we take, as a reference point, an object with a technology ensuring the maximum level of TFP in a given t period, then the efficiency of object i in period t can be mathematically written as:

$$TFPE_{it} = \frac{TFP_{it}}{TFP_t^*} = \frac{\frac{Q_{it}}{X_{it}}}{\frac{Q_{it}^*}{X_{it}^*}} \leq 1 \tag{4}$$

where TFP_t^* denotes the maximum *TFP* obtainable in period *t*. In turn, Q_t^* and X_t^* represent a combination of aggregate effects and *TFP* maximizing inputs.

Efficiency defined in this way can be decomposed into several other measures of efficiency. For effect-oriented models, for example, the following measures of efficiency can be calculated:

$$TFPE_t = OTE_t \times OSE_t \times RME_t \tag{5}$$

where: *OTE* – denotes the technical efficiency of production assuming variable effects of scale (*VRS*). It measures the maximum *TFP* that can be achieved with the same proportion of inputs and outputs. *OSE* – means the production scale efficiency, which is calculated as the ration between *OTE* achieved assuming constant effects of scale (*CRS*) and variable effects of scale (*VRS*). It reflects the difference between the *TFP* for a technically efficient facility and the maximum *TFP* that can be obtained when operating on an optimum scale related to the production curve (*CRS*). *RME* – is the residual efficiency of the mix type, which reflects the difference between the *TFP* of the facility located on the board of *CRS* production and maximum achievable productivity ($TFP*$).

Due to editorial requirements, the study presents the synthetic results of analyses of individual measures of efficiency.

The research used data on agriculture in European Union countries from the EUROSTAT database. The data covers the years 2009-2019. Based on an analysis of literature, a model was built including the basic factors of production in agriculture, i.e. land, capital and labour. The data has been grouped into a set of variables, the combination of which reflects the technology of agricultural production. The following set of variables was adopted: (y_1) agricultural production (EUR million), (x_1) agricultural area (thousand ha), (x_2) labour (thousand AWU), (x_3) direct costs (EUR million), (x_4) general economic costs (EUR million) and (x_5) depreciation (EUR million). Direct costs (x_3) include: seeds and seed potatoes, fertilizers, protection, veterinary medicine and feed. The costs that include the variable (x_4) include: energy, materials, building maintenance, agricultural services and other indirect costs.

According to the assumptions of the DEA method, the technologies of the tested objects should be consistent. Therefore, a preliminary analysis of variables and the analysis of TFP index measurement results were performed. As a result, three countries were excluded from the study, i.e. Cyprus, Luxembourg and Malta. The system of variables in these countries was not sufficiently consistent with the analysed group. The group thus formed was designated as the EU-25. Table 1 presents the basic descriptive statistics of the variables adopted for the model. Statistics are calculated on the basis of the average for 2009-2019.

Comparing the statistics of variables in 2009 and 2019, it can be concluded that the level of agricultural production increased in the EU-25 countries and, with it, the level

Table 1. Descriptive statistics of variables in 2009 and 2019

Variable	Year	Average	Minimum	Maximum	Standard deviation
y_1 – agricultural production [EUR million]	2009	13,241.7	524.6	61,851.4	16,461.3
	2019	17,188.3	979.4	74,676.1	20,554.2
x_1 – agricultural land [thousand ha]	2009	7,491.8	468.5	35,177.8	8,628.0
	2019	7,190.4	479.8	29,024.2	7,857.5
x_2 – work [thousand AWU]	2009	448.2	29.3	2,213.8	599.2
	2019	360.2	18.9	1,675.8	449.6
x_3 – direct costs [EUR million]	2009	4,784.9	266.7	25,132.5	6,091.8
	2019	5,777.0	385.3	25,012.3	6,738.3
x_4 – general economic costs [EUR million]	2009	3,396.2	121.3	15,510.5	4,026.0
	2019	4,273.2	237.8	19,397.0	4,919.2
x_5 – depreciation [EUR million]	2009	2,169.5	82.5	10,263.4	3,028.1
	2019	2,522.3	146.2	10,807.2	3,319.1

Source: own research based on the EUROSTAT database of individual inputs. The exception is labour input (AWU), which decreased compared to the initial period. It can be hypothesised that human work, along with progress, has been replaced by more effective technologies. However, this requires separate studies, as it should be noted that the analyses were carried out at current prices and the increase in the value of inputs and effects could have been caused by their changes.

RESULTS OF STUDIES

In the first stage of the research, the Färe-Primont productivity index (TFP) in 2009-2019 was calculated for 25 European Union countries (EU-25) accepted for analysis. The synthetic results for the entire analysed group are presented in Table 2.

Table 2. Productivity (TFP) of agriculture in EU-25 countries in 2009-2019

Year	Productivity (*TFP*)		
	average	minimum	maximum
2009	0.593	0.482	0.798
2010	0.630	0.508	0.828
2011	0.573	0.468	0.769
2012	0.617	0.464	0.766
2013	0.631	0.499	0.812
2014	0.643	0.515	0.794
2015	0.644	0.494	0.832
2016	0.637	0.489	0.820
2017	0.672	0.509	0.832
2018	0.652	0.501	0.826
2019	0.667	0.527	0.814

Source: own study

The average level of TFP productivity indices in the analysed period shows an upward trend. Only in 2011, 2016 and 2018 were there periodical drops of this level.

In the next stage of the research, TFPE efficiency indicators were calculated in accordance with the equation (4). In this case, the countries with technology ensuring a maximum TFP* level in a given year were used as a reference point for calculating the efficiency level. Detailed results of the calculations for individual countries are presented in Table 3. The average level of the efficiency indicator for the entire analysed sample increased in the analysed period from 0.743 in 2009 to 0.820 in 2019. Based on the level of TFPE efficiency in individual countries, a division into groups was made based on quartile analysis. The analysis consisted of assigning the location of each country in each analysed year to one of four groups. Group I consists of countries with the lowest level of efficiency. Group II includes countries with efficiency below the median. Group III are countries above the median efficiency, while group IV are countries with the highest level of efficiency. The final allocation of a country to a given group was determined by a weighted average, where higher weights were assigned to TFPE indicators from recent years. Grouping effects are presented in Table 4.

Table 3. Indicators of agricultural efficiency (TFPE) in European Union (EU-25) countries 2009-2019

Countries EU-25	Indicators of agricultural efficiency (TFPE)										
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	0.747	0.768	0.748	0.819	0.761	0.771	0.735	0.758	0.799	0.792	0.792
Belgium	0.726	0.761	0.751	0.796	0.702	0.710	0.703	0.696	0.705	0.688	0.717
Bulgaria	0.697	0.743	0.723	0.843	0.848	0.912	0.869	0.913	0.944	0.941	0.953
Croatia	0.818	0.756	0.789	0.758	0.684	0.649	0.660	0.705	0.697	0.728	0.747
Czech Republic	0.650	0.682	0.690	0.801	0.755	0.799	0.725	0.767	0.744	0.735	0.756
Denmark	0.716	0.791	0.744	0.805	0.766	0.825	0.715	0.717	0.790	0.759	0.789
Estonia	0.604	0.705	0.648	0.763	0.762	0.773	0.708	0.597	0.730	0.675	0.763
Finland	0.668	0.664	0.623	0.648	0.654	0.672	0.594	0.622	0.623	0.607	0.647
France	0.770	0.848	0.836	0.856	0.798	0.865	0.837	0.819	0.869	0.911	0.899
Germany	0.720	0.735	0.737	0.762	0.789	0.812	0.699	0.716	0.783	0.716	0.800
Greece	1.000	0.939	1.000	1.000	0.933	1.000	0.981	0.931	0.981	0.938	0.976
Hungary	0.665	0.673	0.638	0.792	0.759	0.828	0.784	0.815	0.831	0.829	0.854
Ireland	0.613	0.658	0.678	0.708	0.689	0.754	0.756	0.759	0.812	0.722	0.780
Italy	0.944	0.908	0.915	0.978	1.000	0.991	1.000	0.979	0.985	1.000	1.000
Latvia	0.604	0.642	0.608	0.606	0.650	0.696	0.713	0.692	0.740	0.673	0.792
Lithuania	0.645	0.681	0.625	0.752	0.755	0.749	0.735	0.692	0.743	0.679	0.733
Netherlands	0.984	1.000	0.951	0.942	0.943	0.985	0.943	0.963	0.978	0.940	0.959
Poland	0.779	0.811	0.736	0.841	0.820	0.794	0.750	0.801	0.851	0.811	0.855
Portugal	0.819	0.808	0.817	0.796	0.813	0.845	0.852	0.843	0.874	0.859	0.897
Romania	0.679	0.676	0.679	0.891	0.722	0.748	0.720	0.715	0.764	0.816	0.794
Slovakia	0.751	0.787	0.729	0.879	0.822	0.851	0.788	0.802	0.793	0.788	0.775
Slovenia	0.619	0.614	0.620	0.690	0.616	0.663	0.655	0.632	0.612	0.718	0.690
Spain	0.966	0.945	0.945	0.924	0.913	0.947	0.933	1.000	1.000	0.971	0.964
Sweden	0.723	0.758	0.748	0.763	0.749	0.804	0.783	0.783	0.800	0.728	0.775
United Kingdom	0.851	0.810	0.808	0.834	0.855	0.915	0.842	0.844	0.884	0.848	0.890

Source: own study

Table 4. Grouping the EU-25 countries according to the TFPE efficiency level of agriculture

Group I	Group II
Belgium, Croatia, Estonia, Finland, Latvia, Lithuania, Slovenia	Czech Republic, Denmark, Germany, Ireland, Romania
Group III	**Group IV**
Austria, Hungary, Poland, Slovakia, Sweden	Bulgaria, France, Greece, Italy, Netherlands, Portugal, Spain, Great Britain

Source: own study

The average level of TFPE performance indicators for group I was 0.688 in the analysed period; for group II it was 0.743; for group III 0.781; while for group IV it was 0.906. Graphically, the level of the TFPE indicator for individual groups is shown in Figure 1. It can be noticed that the average level of efficiency in individual periods fluctuates, while these fluctuations in individual groups are consistent, i.e. they usually follow the same direction. On the other hand, it can also be noticed that in group I, throughout the analysed period, there is a growing trend in the level of efficiency, while in the remaining groups, from 2021, the fluctuations oscillate at the same level.

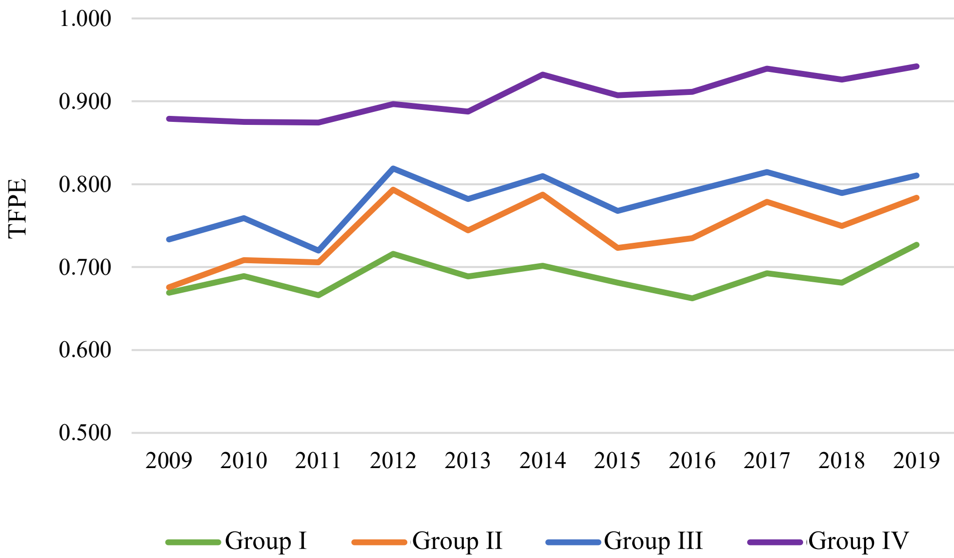

Figure 1. Agricultural efficiency (TFPE) in the analysed EU-25 groups in 2009-2019
Source: own study

Table 5. OTE, OSE and RME of agriculture in EU-25 countries in 2009-2019

Group	Indicator	Year										
		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
I	OTE	0.956	0.957	0.944	0.952	0.957	0.953	0.945	0.945	0.945	0.936	0.942
	OSE	0.895	0.913	0.906	0.928	0.926	0.918	0.929	0.862	0.875	0.884	0.916
	RME	0.787	0.793	0.784	0.816	0.783	0.810	0.786	0.829	0.849	0.836	0.851
II	OTE	0.892	0.890	0.892	0.957	0.939	0.945	0.927	0.930	0.934	0.935	0.927
	OSE	0.973	0.985	0.968	0.987	0.993	0.990	0.975	0.962	0.979	0.972	0.991
	RME	0.783	0.811	0.823	0.840	0.801	0.844	0.806	0.828	0.858	0.829	0.857
III	OTE	0.890	0.894	0.886	0.940	0.913	0.929	0.926	0.944	0.937	0.931	0.933
	OSE	0.961	0.965	0.956	0.981	0.969	0.971	0.980	0.960	0.972	0.980	0.976
	RME	0.863	0.885	0.855	0.890	0.887	0.900	0.851	0.876	0.897	0.869	0.893
IV	OTE	0.998	0.993	0.992	0.988	0.994	0.997	1.000	0.995	0.997	0.999	1.000
	OSE	0.991	0.988	0.990	0.992	0.991	0.995	0.997	0.979	0.985	0.994	0.993
	RME	0.889	0.892	0.890	0.914	0.901	0.939	0.910	0.935	0.956	0.933	0.949

Source: own study

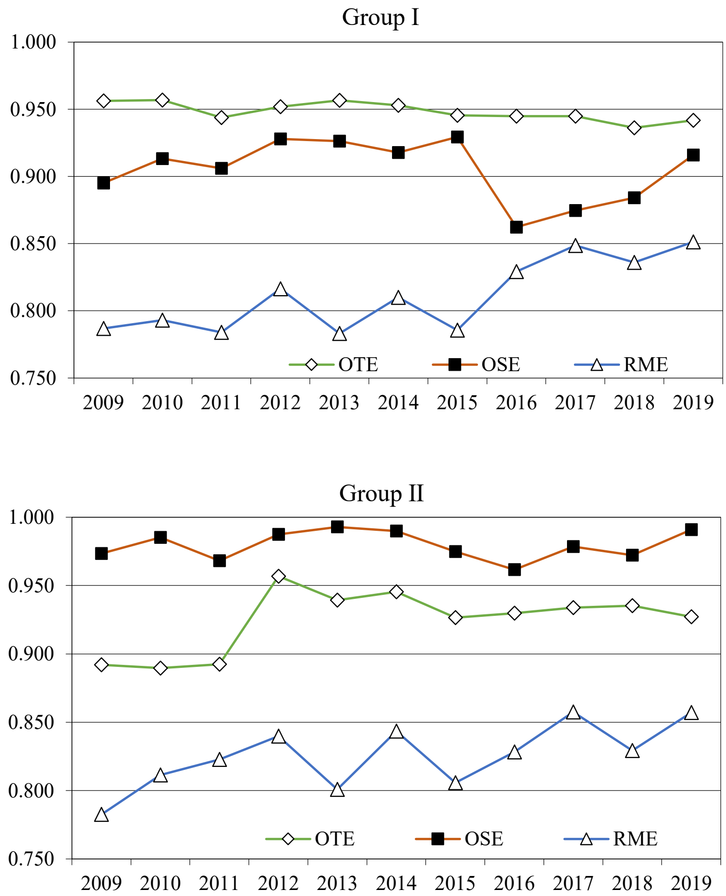

Figure 2. OTE, OSE and RME of agriculture in groups of EU-25 countries in 2009-2019
Source: own study

As previously noted, the calculated TFPE efficiency can be decomposed into several other measures of efficiency. In this study, the efficiency measures estimated in accordance with equation (5) will be analysed. The size of the technical efficiency (OTE), scale efficiency (OSE) and residual efficiency (RME) indicators are presented in Table 5 and illustrated in Figure 2.

Analysis of agricultural efficiency showed that most countries are technically efficient (OTE). Several countries showed some level of inefficiency. In group I, these were Finland and Lithuania. In group II, the Czech Republic, Ireland and Romania. In group III, Austria, Hungary and Sweden, while in group IV, Portugal. In group I, the average level of technical efficiency (OTE) was about 0.950. It can be concluded that the level of technical efficiency

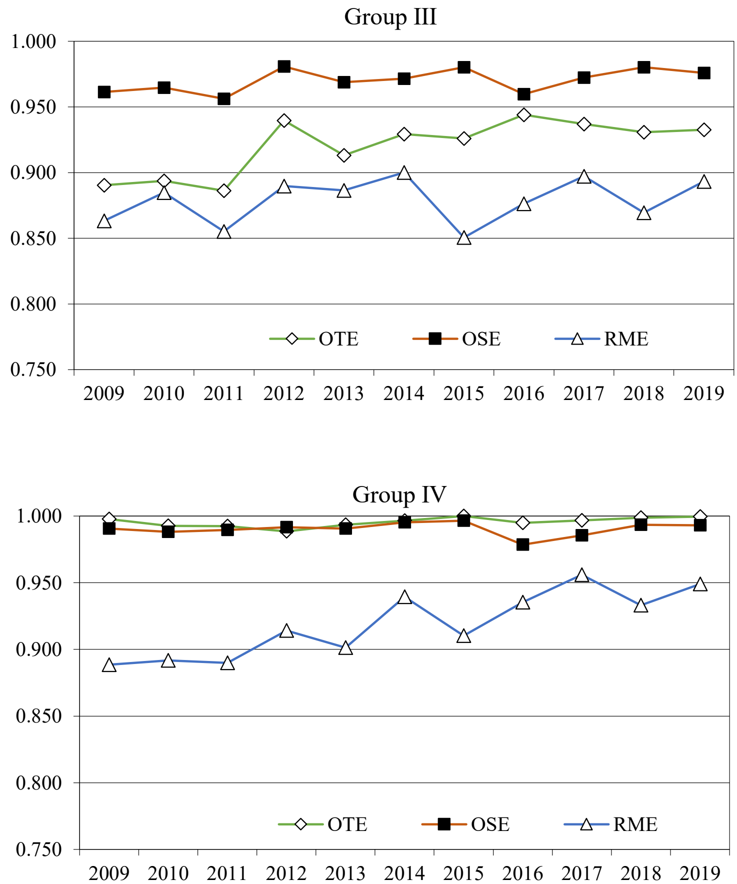

Figure 2. Countinuation

in this group slightly decreased in the analysed years. In groups II and III, the level of technical efficiency was similar. After a fairly large upward fluctuation in 2012 to around 0.950, a slight downward trend in the efficiency level can be observed. In recent years, in these groups, the average level of the OTE index was around 0.925. On the other hand, in group IV, i.e. countries with the highest level of TFPE efficiency, the OTE index was high. Apart from Portugal, all countries in this group were technically efficient and the level of this efficiency was close to or equal to 1.0. The scale efficiency analysis (OSE), which shows differences between the technical efficiency obtained with the assumption of constant scale effects (CRS) and variable effects of scale (VRS), shows that in the countries with the lowest level of efficiency (group I) these differences were the largest.

Most of the countries in this group, despite high technical efficiency, do not operate on an optimal scale. Smaller differences occurred in groups II and III. The average efficiency index of the scale oscillated around 0.975. On the other hand, in group IV, most countries operated on an optimal scale, where the OSE index was 1.0 or very close to this value.

The analysis also shows that the level of TFPE efficiency in the analysed groups was determined, to the greatest extent, by a low level of efficiency of the RME type. In the countries from group I and II, the greatest differences were between the maximum possible TFP in a given period and TFP assuming constant economies of scale. In both groups, these differences were at a similar level, they had a decreasing tendency, and the value of the index ranged from approximately 0.780 to 0.850. In the countries of group III, no clear trend of changes was observed and the indicator oscillated between 0.850 and 0.900. In group I, an upward trend was also observed, and the value of the RME index increased from 0.890 to 0.950.

SUMMARY AND CONCLUSIONS

For 25 European Union countries, total productivity (TFP) was calculated in the years 2009-2019. For this purpose, aggregated Färe-Primont productivity indices were used. It can be concluded that the average productivity level in the analysed period shows an upward trend with periodic fluctuations.

Using the maximum TFP achievable in a given period as a reference point, the TFPE performance indicators for each country were estimated. The analysis of these indicators made it possible to group the countries according to level of efficiency into four groups. Group I, i.e. countries with the lowest level of efficiency, includes Belgium, Croatia, Estonia, Finland, Latvia, Lithuania and Slovenia. Group II, i.e. countries with a higher level of efficiency, but below the median, includes the Czech Republic, Denmark, Germany, Ireland and Romania. Group III includes countries above the efficiency median, including Austria, Hungary, Poland, Slovakia and Sweden. In turn, group IV represents countries with the highest level of efficiency, i.e. Bulgaria, France, Greece, Italy, the Netherlands, Portugal, Spain and Great Britain.

In the next stage, the calculated performance indicators were decomposed into technical efficiency indicators (OTE), scale efficiency (OSE) and residual efficiency of the mix type (RME).

Most of the analysed countries are technically efficient (OTE). Some countries showed a certain level of inefficiency. In group I, these were Finland and Lithuania. In group II, the Czech Republic, Ireland and Romania. Austria, Hungary and Sweden in group III, Portugal in group IV. The lowest level of technical efficiency was recorded in Finland and the Czech Republic.

Scale Efficiency Analysis (OSE) showed that there are slight differences in the level of efficiency depending on the scale of operation. The greatest impact on the level of efficiency was recorded in group I, especially in Estonia and Latvia. In the remaining groups, the average level of this type of efficiency ranged from 0.970 to 0.990.

The residual efficiency of the mix type (RME) was the lowest among the analysed efficiency components. The lowest average level of this indicator was found in groups I and II, ranging from approximately 0.780 to 0.850. In group III, the level of this indictor ranged from 0.850 to 0.900. In turn, in group I, it was 0.890 to 0.950, respectively. The lowest level of this type of efficiency was recorded in Slovenia, Belgium, as well as Denmark and Germany.

The analysis of various types of efficiency showed that the European Union countries are diversified in terms of the use of the level of applied inputs and engaged resources in agricultural activity. There are also differences in the level of agricultural productivity across countries. The agricultural policy of the European Union, implemented through regional and specific policies, should also be based on the best use of financial resources. Therefore, the use of financial instruments should also be based on the efficiency of agricultural activity in individual countries. Hence, the principles of redistribution of financial resources should also take aspects related to the efficiency of individual countries and regions into account.

BIBLIOGRAPHY

Akande Olalekan P. 2012. *An Evaluation of technical efficiency and agricultural productivity growth in EU regions*. Wageningen: University Wageningen.

Baran Joanna. 2016. Efektywność polskiego rolnictwa na tle pozostałych krajów Unii Europejskiej (Efficiency of Polish agriculture in comparison with other European Union member states). *Wieś i Rolnictwo* 3 (172): 63-85.

Baráth Lajos, Imre Fertő. 2017. Productivity and convergence in European agriculture. *Journal of Agricultural Economics* 68: 228-248.

Błażejczyk-Majka Lucyna. 2017. Application of DEA for evaluating the efficiency of economic policy as exemplified by EU agriculture. *Studia Historiae Oeconomicae* 35: 163-176.

Blażejczyk-Majka Lucyna, Radosław Kala, Krzysztof Maciejewski. 2011. Efektywność produkcji rolniczej na obszarze Unii Europejskiej w latach 1989-2007 (Efficiency of agricultural production in the European Union, 1989-2007). *Zeszyty Naukowe Szkoły Głównej Gospodarstwa Wiejskiego w Warszawie. Problemy Rolnictwa Światowego* 11 (1): 28-38.

Bojnec Štefan, Imre Fertő, Attila Jámbor, József Tóth. 2014. Determinants of technical efficiency in agriculture in new EU member states from Central and Eastern Europe. *Acta Oeconomica* 64 (2): 197-217.

Cankurt Murat, Bulent Miran, Cihat Günden. 2013. A comparative analysis on productivity and efficiency of agricultural production of the EU and Turkey. *Journal of Food, Agriculture & Environment* 11 (2): 433-439.

Cechura Lukas, Aaron Grau, Heinrich Hockmann, Zdenka Kroupova, Levkovych Inna. 2014. *Total factor productivity in European agricultural production. International Comparison of Product Supply Chains in the Agri-food Sector: Determinants of their Competitiveness and Performance on EU and International Markets*. Compete Working Paper No. 9. Halle. IAMO.

Czyżewski Andrzej, Jakub Staniszewski. 2018. Sustainable intensification of agriculture as the composition of economic productivity and environmental pressure measures. *Scientific Journal of Warsaw University of Life Sciences. Problems of World Agriculture* 18 (3): 80-90.

Gavurová Beata, Martina Halásková, Samuel Koróny. 2019. Research and development indicators of EU28 countries from view point of super-efficiency DEA analysis. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 67: 225-242.

Guth Marta, Katarzyna Smędzik-Ambroży. 2019. Economic resources versus the efficiency of different types of agricultural production in regions of the European union. *Economic Research/Ekonomska Istraživanja* 33 (1): 1036-1051. DOI: 10.1080/1331677X.2019.1585270.

Hoang Viet-Ngu. 2011. Measuring and decomposing changes in agricultural productivity, nitrogen use efficiency and cumulative exergy efficiency: application to OECD agriculture. *Ecological Modelling* 222: 164-175.

Hoang Viet-Ngu, Thanh Trung. 2013. Analysis of environmental efficiency variation: a materials balance approach. *Ecological Economics* 86 (1): 37-46.

Iliyasu Abdullahi, Zainal Abidin Mohamed, Rika Terano. 2016. Comparative analysis of technical efficiency for different production culture systems and species of freshwater aquaculture in Peninsular Malaysia. *Aquaculture Reports* 3: 51-57.

Kočišová Kristina. 2015. Application of the DEA on the measurement of efficiency in the EU countries. *Agricultural Economics – Czech* 61: 51-62.

Kołodziejczak Małgorzata. 2015. Efektywność wykorzystania czynników produkcji w rolnictwie polskim na tle unii europejskiej (Efficiency of production factors in agriculture of Poland and European Union). *Wieś i Rolnictwo* 2 (167): 169-192.

Kumbhakar Subal C., Gudbrand Lien. 2010. Impact of subsidies on farm productivity and efficiency. [In] *The economic impact of public support to agriculture: An international perspective,* ed. V. Eldon Bal, lRoberto Fanfani, Luciano Gutierrez, 109-124. New York: Springer.

Martinho Vitor J.P.D. 2017. Efficiency, total factor productivity and returns to scale in a sustainable perspective: An analysis in the European Union at farm and regional level. *Land Use Policy* 68: 232-245.

Marzec Jerzy, Andrzej Pisulewski, Artur Prędki. 2019. Technical efficiency and productivity growth of polish crop farms. *National Economy* 298 (2): 95-125.

Nowak Anna, Tomasz Kijek, Katarzyna Domańska. 2015. Technical efficiency and its determinants in the European Union agriculture. *Agricultural Economic – Czech* 61 (6): 275-283.

O'Donnell Christopher J. 2008. *An Aggregate Quantity-Price Framework for Measuring and Decomposing Productivity and Profitability Change*. Centre for Efficiency and Productivity Analysis. Working Papers WP07/2008. University of Queensland.

O'Donnell Christopher J. 2010. Measuring and decomposing agricultural productivity and profitability change. *Australian Journal of Agricultural and Resource Economics* 54: 527-560.

O'Donnell Christopher J. 2011a. *DPIN version 3.0: a program for decomposing productivity index numbers*. Queensland: Centre for Efficiency and Productivity Analysis, University of Brisbane.

O'Donnell Christopher J. 2011b. *Econometric estimation of distance functions and associated measures of productivity and efficiency change*. Centre for Efficiency and Productivity Analysis Working Papers WP01/2011. University of Queensland.

O'Donnell Christopher J. 2012a. An aggregate quantity framework for measuring and decomposing productivity change. *Journal of Productivity Analysis* 38 (3): 255-272.

O'Donnell Christopher J. 2012b. Nonparametric estimates of the components of productivity and profitability change in U.S. agriculture. *American Journal of Agricultural Economics* 94: 873-890.

Quiroga Sonia, Cristina Suárez, Zaira Fernández-Haddad, George Philippidis. 2017. Levelling the playing field for European Union agriculture: Does the Common Agricultural Policy impact homogeneously on farm productivity and efficiency? *Land Use Policy* 68(C): 179-188.

Rudinskaya Tamara, Tomas Hlavsa, Martin Hruska. 2019. Estimation of technical efficiency of Czech farms operating in less favoured areas. *Agricultural Economics – Czech* 65: 445-453.

Staniszewski Jakub. 2018. *Wpływ struktur wytwórczych na zrównoważoną intensyfikację produkcji rolnej w krajach Unii Europejskiej po 2004 roku* (The impact of production structures on the sustainable intensification of agricultural production in the European Union countries after 2004). PhD Thesis. Poznań: Uniwersytet Ekonomiczny w Poznaniu.

Swinnen Johan F.M., Liesbet Vranken. 2010. Reforms and agricultural productivity in Central and Eastern Europe and the Former Soviet Republics: 1989-2005. *Journal of Productivity Analysis* 33: 241-258.

Toma Pierluigi, Pier Paolo Miglietta, Giovanni Zurlini, Donatella Valente, Irene Petrosillo. 2017. A non-parametric bootstrap-data envelopment analysis approach for environmental policy planning and management of agricultural efficiency in EU countries. *Ecological Indicators* 83: 132-143.

Vlontzos George, Panos M. Pardalos. 2017. Assess and prognosticate green house gas emissions from agricultural production of EU countries, by implementing, DEA Window analysis and artificial neural networks. *Renewable and Sustainable Energy Reviews* 76: 155-162.

Zhu Xuequin, Alfons Oude-Lansink. 2010. Impact of CAP subsidies on technical efficiency of crop farms in Germany, the Netherlands and Sweden. *Journal of Agricultural Economics* 61: 545-564.

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EFEKTYWNOŚĆ ROLNICTWA I JEJ KOMPONENTY W KRAJACH UNII EUROPEJSKIEJ W LATACH 2009-2019. ANALIZA Z WYKORZYSTANIEM ZAGREGOWANYCH INDEKSÓW PRODUKTYWNOŚCI FÄRE-PRIMONTA

Słowa kluczowe: rolnictwo, efektywność rolnictwa, indeksy produktywności całkowitej TFP, Data Envelopment Analysis, UE-25

ABSTRAKT

Celem przeprowadzonych badań był pomiar efektywności działalności rolniczej krajów Unii Europejskiej przy wykorzystaniu różnych miar efektywności. Analiza obejmowała lata 2009-2019. Obliczona efektywność miała charakter względny, a materiał wyjściowy do jej oszacowania stanowiły zagregowane indeksy produktywności Färe-Primonta. Bazując na maksymalnym możliwym poziomie produktywności w danym okresie, oszacowano poziom efektywności względnej TFPE. Na podstawie tej efektywności wykonano grupowanie analizowanych krajów na cztery grupy zróżnicowane pod względem jej poziomu. Następnie wykonano dekompozycję wskaźnika TFPE na kilka odrębnych miar efektywności, które poddano dalszej analizie. Analiza wykazała, że istnieją różnice w poziomie efektywności pomiędzy poszczególnymi krajami. Wykazano, że rolnictwo krajów Unii Europejskiej można uznać za efektywne technicznie. Wysoka była również efektywność skali. Największe zróżnicowanie pomiędzy krajami występowało w przypadku efektywności rezydualnej.

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