
Agricultural Productivity in Europe: Hicks-Moorsteen Productivity Index Analysis

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Abstract:

Purpose: The aim of the study was to measure and analyse the productivity level of agricultural activity in 25 European Union countries and to analyse the factors influencing this level.

Approach/Methodology/Design: The data covers the years 2009-2019 and was obtained from the EUROSTAT database. Aggregated Hicks-Moorsteen TFP total productivity indices were used for measurement and analysis. On the basis of the average productivity level, countries were grouped into groups based on the analysis of their position in the productivity index quartiles.

Findings: European agriculture is diversified in terms of productivity. The level of productivity and its changes are determined, on the one hand, by changes in the level of effectiveness and, on the other hand, by changes in technology. The decomposition of productivity indices allows you to find these determinants.

Practical Implications: The performed analysis allowed for grouping the surveyed countries in terms of the productivity of agricultural activity. The decomposition of productivity indices made it possible to find determinants of this productivity. The performed analysis can be used as one of the criteria for allocating funds to implement reforms and policies related to European agriculture. The results also make it possible to identify possible sources of increasing the level of productivity.

Originality/Value: The presented research enriches the knowledge on agricultural productivity in the European Union. In addition, Hicks-Moorsteen total productivity indices were used, which are rarely found in publications in this area.

Keywords: Agriculture, agricultural efficiency, TFP total productivity indices, Data Envelopment Analysis, EU-25.

JEL codes: O47, C38, Q13.

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1. Introduction

The European economy is constantly changing in various areas of life, both social and economic. These changes determine various types of actions and initiatives taken both at the European Union and national level. Agriculture is also one of the areas affected by these changes. The reforms implemented under the Common Agricultural Policy, such as “Agenda 2000”, “Mid Term Reform”, “Health Check” or the indirect and direct payment systems, are intended, among others, to adapt to these changes. The effect of the reforms being implemented are changes in the value of applied inputs and effects, which has a direct impact on the level of productivity and efficiency of agricultural activity, hence the need to conduct analyses. The results of these analyses can be found, among others, in the works of Kumbhakar and Lien (2010), Zhu and Oude-Lansink (2010), Swinnen and Vranken (2010), and Quiroga *et al.* (2017).

TFP (Total Factor Productivity) indices are most often used to measure the level of productivity and its changes. Most of the works use non-parametric methods for this purpose, mainly DEA models. Examples of such work at the supranational level include such studies by, Cankurt *et al.* (2013), Akande (2012), Latruffe *et al.* (2012), Rusielik (2013), Cechura *et al.* (2014), and Baráth and Fertő (2016). A much smaller part of the research uses parametric models. In this case, the stochastic SFM (Stochastic Frontier Models) models dominate. For example, research by Kumbhakar and Lien (2010), Quiroga *et al.* (2017), and Zhu *et al.* (2008).

One of the most common TFP indexes is the Malmquist index, the form of which can be found in the work of Färe *et al.* (1994). However, since the method assumes the adoption of constant effects of scale (CRS), it gives rise to a discussion of possible errors and unreliable outcomes. O’Donell (2010; 2012a; 2012b) and Hoang (2011), in the research on agricultural productivity, indicated a greater usefulness of aggregated TFP indices, including Hicks-Moorsteen indexes, for measuring agricultural productivity, which resulted, among others, from accepting the assumptions of variable effects of scale (VRS) and better adjustment of the model to technologically weaker conditions.

For this reason, the presented research attempts to measure productivity and its changes in European agriculture with the use of Hicks-Moorsteen TFP indexes. These indexes can also be decomposed into components related to the level of effectiveness and the level of technology. However, it should be emphasized that the estimated indicators are relative, i.e., they are estimated in relation to other objects.

The aim of the research was to analyse the level of productivity of agricultural activity in 25 European Union countries (EU-25) and to analyse the components influencing this level. The research covers the years 2009-2019. The data was obtained from the EUROSTAT database.

2. Research Method and Data

In the case of a single input and a single effect, the total factor productivity (TFP) is usually defined as the ratio of the effect to the input. When dealing with a multidimensional situation, TFP can be defined as the ratio of aggregate effects to aggregate inputs. If we know the price relations, such calculations do not pose any problems. Often, however, we have to deal with a situation where we do not have complete information on this subject. O'Donnell (2008) defined how this problem can be solved without knowing these relations, using productivity indexes based on relations between the examined objects. Indexes of this type measure the relationships between the analysed objects, while the estimated productivity is relative. In this case, aggregated distance functions are used, which can be calculated using linear programming methods and the assumptions of the DEA (Data Envelopment Analysis) method. The Hicks-Moorsten productivity index was used in the presented study.

Assuming that: $x_{it} = (x_{1it}, \dots, x_{Kit})'$ and $q_{it} = (q_{1it}, \dots, q_{Jit})'$ are vectors of inputs and outputs, the TFP of the object i in the period t is:

$$TFP_{it} \equiv \frac{Q_{it}}{X_{it}} \quad (1)$$

where $Q_{it} = Q(q_{it})$ is the aggregate effect, $X_{it} = X(x_{it})$ is the aggregate input, and $Q(\cdot)$ and $X(\cdot)$ are non-decreasing, non-negative, linearly homogenous functions (O'Donnell, 2011).

Knowing the maximum level of productivity in a given period t , we can calculate the efficiency of a given object, understood as the ratio of the observed TFP of the object i to the maximum TFP that can be achieved using the technology available in a given period. This can be represented by the following equation:

$$TFPE_{it} = \frac{TFP_{it}}{TFP_t^*} = \frac{Q_{it}/X_{it}}{Q_{it}^*/X_{it}^*} \quad (2)$$

Where TFP_t^* denotes the maximum TFP achievable with the technology from period t , and Q_{it}^* and X_{it}^* denote aggregate effects and aggregate inputs at the TFP maximization point.

By transforming the equation (2) into the form (3), it can be decomposed into:

$$TFP_{it} = (TFP_t^*) \times (TFPE_{it}), \quad (3)$$

where the first parenthesis is a measure of the technology level (MP) and the second parenthesis shows the level of performance (TFPE).

In turn, the productivity index that measures the TFP of an object i in the period t in relation to object h in the period s can be represented by the following equation:

$$TFP_{hs,it} = \frac{TFP_{it}}{TFP_{hs}} = \frac{Q_{it}/X_{it}}{Q_{hs}/X_{hs}} = \frac{Q_{hs,it}}{X_{hs,it}}, \tag{4}$$

where $Q_{hs,it} = Q_{it}/Q_{hs}$ is the effect index and $X_{hs,it} = X_{it}/X_{hs}$ is the input size index. O’Donnell (O’Donnell, 2008, 2010, 2010a) described indexes of this form as fully *multiplicatively-complete*. Depending on the form of the assumed distance function, indexes of this type may take various forms. Assuming that q_0, x_0 are the effect and input vectors, respectively, t_0 denotes the reference period in time, while $D_0(\cdot), D_I(\cdot)$ are, respectively, the distance functions of effects and inputs, and that $Q(q) = [D_0(x_{hs}, q, s)D_0(x_{it}, q, t)]^{1/2}$ and $X(x) = [D_I(x, q_{hs}, s)D_I(x, q_{it}, t)]^{1/2}$ is the Hicks-Moorsteen index presented by the equation (Diewert, 1992):

$$TFP_{hs,it}^{HM} = \left(\frac{D_0(x_{hs}, q_{it}, s) D_I(x_{hs}, q_{hs}, s) D_0(x_{it}, q_{it}, t) D_I(x_{hs}, q_{it}, t)}{D_0(x_{hs}, q_{hs}, s) D_I(x_{it}, q_{hs}, s) D_0(x_{it}, q_{hs}, t) D_I(x_{it}, q_{it}, t)} \right)^{1/2}.$$

The index defined in this way was proposed by Diewert as the quotient of Malmquist indices oriented on effects and inputs. As mentioned before, the distance and input functions were estimated using the DEA method by solving the appropriate linear programming tasks.

The research used data on agriculture in the European Union countries from the EUROSTAT database. The data covers the years 2009-2019. Table 1 presents the basic descriptive statistics of the variables adopted for the model. The statistics are calculated on the basis of the average for 2009 and 2019.

Table 1. Descriptive statistics of variables in 2009 and 2019

	Year	Average	Min	Max	Stand. Dev.
$y1$ – agricultural production (EUR million)	2009	13241,7	524,6	61851,	16461,3
	2019	17188,3	979,4	74676,	20554,2
$x1$ – agricultural area (thousand ha)	2009	7491,8	468,5	35177,	8628,0
	2019	7190,4	479,8	29024,	7857,5
$x2$ – labour (thousand AWU)	2009	448,2	29,3	2213,8	599,2
	2019	360,2	18,9	1675,8	449,6
$x3$ – direct costs (EUR million)	2009	4784,9	266,7	25132,	6091,8
	2019	5777,0	385,3	25012,	6738,3
$x4$ – general economic costs (EUR million)	2009	3396,2	121,3	15510,	4026,0
	2019	4273,2	237,8	19397,	4919,2
$x5$ – depreciation (EUR million)	2009	2169,5	82,5	10263,	3028,1
	2019	2522,3	146,2	10807,	3319,1

Source: Own research based on the EUROSTAT database.

The model was built on the basis of literature analysis and it covers the basic factors of production in agriculture, i.e., land, capital and labour. The data has been grouped into a set of variables whose combination reflects the technology of agricultural production. The following set of variables was adopted: ($y1$) agricultural production (EUR million), ($x1$) agricultural area (thousand ha), ($x2$) labour (thousand AWU), ($x3$) direct costs (EUR million), ($x4$) general economic costs (EUR million) and ($x5$) depreciation (EUR million). Direct costs ($x3$) include, seeds and seed potatoes, fertilizers, protections, veterinary medicine and feed. Costs that include the variable ($x4$) include: energy, materials, building maintenance, agricultural services and other indirect costs.

The result of the preliminary analysis of variables was the exclusion of three countries from the study, i.e., Cyprus, Luxembourg and Malta. Due to the fact that the model of agricultural activity is too different in these countries, the system of variables was not sufficiently consistent with the analysed group. Therefore, in accordance with the assumptions of the DEA method, they were eliminated from further research.

Comparing the statistics of variables in 2009 and 2019, it can be concluded that in the analysed countries the level of agricultural production increased, and with it the level of individual inputs. The exception is labour input (AWU), which has decreased compared to the initial period. It can be argued here that human work, along with the progress, has been replaced by more effective technologies. However, this requires separate studies, because 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.

3. Results

Based on the assumptions and variables adopted for the model, the Hicks-Moorsten total productivity index (TFP) was estimated for each of the analysed countries. The indices were estimated in 2009-2019. The results of the TFP indexes measurement are presented in Table 2.

Table 2. EU total agricultural productivity (TFP) indicators in 2009-2019

Country	Year										
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	0,780	0,824	0,770	0,898	0,822	0,770	0,773	0,805	0,885	0,875	0,871
Belgium	1,000	1,079	1,043	1,053	0,991	0,997	1,017	0,997	1,034	0,998	1,031
Bulgaria	1,000	1,053	0,949	1,063	1,034	1,029	1,013	1,025	1,029	1,001	1,008
Croatia	1,000	1,016	1,044	1,014	0,978	0,962	1,017	1,019	1,002	1,019	1,029
Czech Republic	0,665	0,679	0,629	0,805	0,818	0,814	0,732	0,714	0,667	0,638	0,673
Denmark	1,000	1,094	1,020	1,050	1,011	1,015	0,963	1,000	1,061	0,984	1,045
Estonia	1,000	1,162	1,020	1,134	1,101	1,026	1,059	0,992	1,140	0,982	1,149
Finland	0,734	0,699	0,581	0,597	0,613	0,609	0,550	0,596	0,638	0,582	0,615

France	1,000	1,133	1,006	1,044	1,013	1,034	1,011	0,987	1,046	1,038	1,000
Germany	1,000	1,074	1,004	1,061	1,050	1,009	0,958	1,006	1,053	0,947	1,031
Greece	1,000	1,005	1,000	1,011	1,011	1,029	1,032	0,980	1,039	0,982	1,016
Hungary	0,583	0,597	0,536	0,730	0,769	0,810	0,799	0,820	0,809	0,778	0,794
Ireland	0,590	0,679	0,693	0,760	0,858	0,886	0,922	0,892	0,955	0,861	0,812
Italy	1,000	1,001	1,001	1,047	1,054	0,990	1,035	0,996	1,014	1,028	0,994
Latvia	1,000	1,072	0,988	1,014	1,108	1,002	1,037	0,977	1,045	0,961	1,077
Lithuania	0,729	0,811	0,710	0,841	0,873	0,819	0,826	0,725	0,740	0,657	0,689
Netherlands	1,000	1,060	1,004	1,020	1,051	1,025	1,012	1,022	1,033	0,979	1,019
Poland	1,000	1,060	1,003	1,067	1,019	0,978	0,995	1,036	1,056	0,984	1,022
Portugal	0,964	0,932	0,893	0,874	0,897	0,923	0,998	0,961	0,978	0,958	0,995
Romania	0,772	0,699	0,630	0,923	0,784	0,734	0,725	0,732	0,810	0,907	0,855
Slovakia	1,000	0,994	0,835	1,020	0,992	0,986	1,011	1,005	1,031	1,076	0,980
Slovenia	1,000	1,032	1,000	1,084	0,976	1,029	1,052	0,997	0,999	1,095	0,985
Spain	1,000	1,038	1,013	0,999	1,041	1,011	1,032	1,044	1,021	1,009	0,997
Sweden	0,676	0,721	0,705	0,771	0,753	0,752	0,780	0,796	0,804	0,683	0,725
United Kingdom	1,000	1,022	0,950	0,988	1,072	1,015	0,979	0,961	1,019	0,987	1,006
Average	0,886	0,925	0,864	0,944	0,938	0,922	0,922	0,914	0,946	0,908	0,925
Minimum	0,583	0,597	0,536	0,597	0,613	0,609	0,550	0,596	0,638	0,582	0,615
Maximum	1,000	1,162	1,044	1,134	1,108	1,034	1,059	1,044	1,140	1,095	1,149

Source: Own study.

The average level of the TFP productivity index for the entire analysed group ranged in the analysed years from 0.864 to 0.946. It can be seen that after large fluctuations in 2009-2012, the value of this indicator has stabilized. The lowest level of TFP was recorded in 2009-2012 in Hungary, and in subsequent years in Finland. For each country, the geometric mean of the TFP level was calculated and the samples was divided into quartiles. On this basis, groups of countries were distinguished according to their position in quartiles:

- A - 1 quartile – Finland, Czech Republic, Hungary, Sweden, Lithuania, Romania, Ireland.
- B - 2 quartile – Austria, Portugal, Slovakia, United Kingdom, Croatia, Greece.
- C - 3 quartile – Italy, Germany, Bulgaria, Spain, Poland, Netherlands.
- D - 4 quartile – Belgium, Denmark, Slovenia, Latvia, France, Estonia.

Assume that Group A are countries with the lowest level of productivity, group B are countries with a low level of productivity, group C are countries with an average level of productivity, and group D are countries with the highest level of productivity, respectively. In the next step, an attempt was made to describe the differences between individual groups, based on the analysis of the shaping of a few selected economic indicators converted into agricultural area (AA). The year 2009 and 2019 were analysed.

The results are presented in Table 3. The indicators analysed are:

- agricultural production (thousand EUR/ha of AA)
- labour input (AWU/100 ha off AA)

- direct costs (thousand EUR/ha of AA)
- general economic costs (thousand EUR/ha of AA)
- depreciation costs(thousand EUR/ha of AA).

For the adopted indexes, the harmonic mean for each group was calculated. In group A, i.e., countries with the lowest TFP productivity level, the production level and direct cost indicators were the lowest, while other indicators were also at a low level. Comparing the year 2009 and 2019, it can be concluded that in this group of countries there was a relatively high increase in production, but at the same time there was a high increase in production, but at the same time there was a high increase in the level of costs, especially general economy and depreciation. At the same time, the lowest decrease in the employment level was recorded in this group. Investments reflecting an increase in the depreciation level translated into an increase in the level of production, but this increase was offset by an above-average increase in costs.

Group B, i.e., countries with a low level of TFP productivity, are the countries with the lowest increase in agricultural production, average increase in direct costs and a slight increase in general economic costs and depreciation. As in the case of other groups, there was a decline in AWU labour inputs. It can be seen that this group has a low level of investment, which suggests the lowest level of depreciation. This is reflected in the lowest increase in the level of production.

In group C, i.e., countries with a relatively high level of TFP, we can observe that the level of production increased moderately in the analysed years, less than in group A. At the same time, the highest increase in the level of investment among the analysed groups was recorded. In 2009, this level was definitely the lowest, while in 2019 it was similar to the other groups. Despite these dependencies, this group was characterized by high TFP indexes. The reason for this was the highest decrease in AWU labour inputs and the lowest increase in general economic costs.

Group D are the countries with the highest TFP productivity. In this group, the highest increase in production per ha of AA can be observed with a moderate increase in the level of investment. This group also recorded the highest increase in the level of direct and general economic costs. There has also been a significant reduction in AWU labour input. This allowed for the maintenance of the highest level of TFP indicators.

Table 3. Average level of economic indicators in ABCD groups in 2009 and 2019

Wyszczególnienie	Grupa	2009	2019
y/x1 – agricultural production (thousand EUR/ha of AA)	A	1,01	1,49
	B	1,45	1,74
	C	1,59	2,12
	D	1,07	1,73
x2/x1 labour input	A	4,06	3,48

(AWU/100 ha off AA)	B	4,42	3,72
	C	6,00	4,88
	D	3,54	2,98
$x3/x1$ – direct costs (thousand EUR/ha of AA)	A	0,43	0,54
	B	0,50	0,61
	C	0,56	0,64
	D	0,50	0,66
$x4/x1$ – general economic costs (thousand EUR/ha of AA)	A	0,30	0,44
	B	0,40	0,44
	C	0,38	0,48
	D	0,29	0,47
$x5/x1$ – depreciation (thousand EUR/ha of AA)	A	0,16	0,23
	B	0,20	0,21
	C	0,12	0,23
	D	0,15	0,21

Source: Own study.

As mentioned earlier, the level of productivity is influenced by two components, i.e. the level of efficiency (TFPE) and the level of technology (MP) related to the maximum productivity in a given period. Based on these assumptions, the TFP index was decomposed into these two elements. The results of this decomposition are presented in Tables 4 and 5.

Table 4. The level of efficiency (TFPE) of EU agriculture in 2009-2019

Kraj	Rok										
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	0,829	0,853	0,835	0,900	0,834	0,838	0,827	0,833	0,890	0,880	0,881
Belgium	0,949	0,965	0,855	0,906	0,950	0,963	0,855	0,937	0,886	0,993	0,863
Bulgaria	0,935	1,000	0,942	0,947	0,966	0,965	0,922	0,951	0,923	0,928	0,928
Croatia	0,877	0,881	0,905	0,902	0,888	0,802	0,787	0,757	0,728	0,761	0,833
Czech Republic	0,777	0,771	0,766	0,884	0,865	0,874	0,802	0,763	0,757	0,765	0,790
Denmark	0,927	0,973	0,971	0,936	0,887	0,927	0,888	0,999	0,958	0,865	0,966
Estonia	0,065	0,250	0,276	0,290	0,330	0,576	0,325	0,170	0,505	0,274	0,556
Finland	0,760	0,745	0,696	0,688	0,706	0,706	0,648	0,700	0,716	0,685	0,726
France	0,673	0,304	0,573	0,357	0,535	0,293	0,314	0,325	0,584	0,516	0,605
Germany	0,798	0,693	0,676	0,686	0,741	0,776	0,423	0,441	0,634	0,652	0,590
Greece	0,967	0,966	0,990	0,931	0,971	0,973	1,000	0,926	0,965	0,952	0,980
Hungary	0,739	0,739	0,701	0,833	0,846	0,881	0,853	0,864	0,840	0,865	0,865
Ireland	0,744	0,798	0,824	0,835	0,913	0,904	0,936	0,903	0,940	0,876	0,853
Italy	0,886	0,944	0,512	0,469	0,536	0,523	0,822	0,451	0,824	0,524	0,505
Latvia	0,463	0,678	0,718	0,599	0,779	0,786	0,793	0,746	0,714	0,630	0,693
Lithuania	0,759	0,792	0,728	0,863	0,887	0,839	0,833	0,703	0,749	0,696	0,738
Netherlands	1,000	0,993	0,933	0,872	0,869	0,879	0,760	0,948	0,997	0,838	0,833
Poland	0,998	0,814	0,979	0,911	0,898	0,910	0,928	0,863	0,901	0,819	0,868
Portugal	0,945	0,900	0,921	0,857	0,914	0,930	0,975	0,905	0,910	0,942	0,945
Romania	0,843	0,810	0,745	0,963	0,802	0,769	0,813	0,790	0,813	0,884	0,831
Slovakia	0,873	0,877	0,767	0,892	0,857	0,893	0,937	0,881	0,852	0,922	0,829
Slovenia	0,130	0,292	0,321	0,366	0,297	0,235	0,681	0,582	0,606	0,320	0,306

Spain	1,000	0,803	0,798	0,797	0,932	0,766	0,935	0,935	0,701	0,862	0,684
Sweden	0,751	0,673	0,785	0,794	0,790	0,817	0,810	0,825	0,831	0,750	0,810
United Kingdom	0,971	0,789	0,710	0,747	0,906	0,913	0,815	0,823	0,844	0,814	0,785
Average	0,700	0,731	0,728	0,735	0,767	0,754	0,758	0,716	0,792	0,730	0,750
Minimum	0,065	0,250	0,276	0,290	0,297	0,235	0,314	0,170	0,505	0,274	0,306
Maximum	1,000	1,000	0,990	0,963	0,971	0,973	1,000	0,999	0,997	0,993	0,980

Source: Own study.

Again, on the basis of the geometric mean of the level of performance indicators (TFPE), the position of individual countries in quartiles was determined. The results of this grouping are as follows:

A_E - 1 quartile – Finland, Germany, Italy, Estonia, France, Latvia, Slovenia.

B_E - 2 quartile – Czech Republic, Hungary, Lithuania, Romania, Sweden, United Kingdom.

C_E - 3 quartile – Ireland, Austria, Croatia, Slovakia, Poland, Spain.

D_E - 4 quartile – Greece, Bulgaria, Netherlands, Belgium, Denmark.

The A_E group are countries with the highest level of TFPE efficiency, the B_E group are countries with a low level of efficiency, the C_E group are countries with an average level of efficiency and, accordingly, the D_E group are countries with the highest level of efficiency.

Table 5. The level of technology (MP) in EU agriculture in 2009-2019

Kraj	Rok										
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	0,941	0,966	0,922	0,997	0,987	0,919	0,935	0,967	0,994	0,994	0,988
Belgium	1,053	1,118	1,220	1,162	1,044	1,035	1,190	1,064	1,167	1,004	1,195
Bulgaria	1,069	1,053	1,007	1,123	1,071	1,066	1,099	1,078	1,115	1,079	1,086
Croatia	1,141	1,154	1,154	1,124	1,102	1,200	1,293	1,346	1,376	1,338	1,235
Czech Republic	0,856	0,880	0,821	0,911	0,946	0,930	0,913	0,936	0,881	0,834	0,852
Denmark	1,079	1,123	1,051	1,122	1,140	1,095	1,084	1,001	1,107	1,138	1,082
Estonia	1,377	4,641	3,702	3,913	3,340	1,783	3,258	5,840	2,257	3,579	2,065
Finland	0,966	0,938	0,835	0,868	0,869	0,862	0,849	0,852	0,891	0,850	0,846
France	1,486	3,723	1,755	2,925	1,892	3,525	3,223	3,040	1,792	2,011	1,653
Germany	1,253	1,549	1,486	1,546	1,417	1,301	2,264	2,282	1,662	1,453	1,746
Greece	1,035	1,040	1,010	1,085	1,041	1,057	1,032	1,058	1,076	1,032	1,037
Hungary	0,789	0,807	0,765	0,877	0,909	0,920	0,937	0,949	0,963	0,899	0,918
Ireland	0,793	0,851	0,841	0,910	0,940	0,980	0,985	0,988	1,016	0,984	0,952
Italy	1,128	1,060	1,957	2,235	1,968	1,893	1,259	2,209	1,231	1,964	1,966
Latvia	2,159	1,582	1,376	1,691	1,422	1,274	1,309	1,310	1,462	1,525	1,555
Lithuania	0,961	1,024	0,976	0,975	0,984	0,976	0,992	1,031	0,989	0,944	0,934
Netherlands	1,000	1,067	1,076	1,170	1,209	1,166	1,332	1,078	1,036	1,168	1,223
Poland	1,002	1,302	1,024	1,171	1,134	1,075	1,072	1,199	1,172	1,202	1,176
Portugal	1,020	1,035	0,970	1,020	0,982	0,993	1,024	1,062	1,074	1,017	1,053
Romania	0,915	0,864	0,846	0,959	0,978	0,955	0,892	0,927	0,996	1,026	1,029
Slovakia	1,145	1,134	1,090	1,144	1,157	1,105	1,078	1,141	1,210	1,167	1,183
Slovenia	7,682	3,534	3,112	2,959	3,284	4,377	1,545	1,715	1,648	3,424	3,224
Spain	1,000	1,294	1,269	1,253	1,117	1,321	1,104	1,117	1,455	1,171	1,457
Sweden	0,899	1,072	0,899	0,971	0,953	0,920	0,963	0,965	0,967	0,910	0,895

United Kingdom	1,030	1,295	1,338	1,323	1,183	1,111	1,202	1,167	1,208	1,213	1,283
Average	1,149	1,265	1,187	1,286	1,224	1,223	1,217	1,277	1,195	1,245	1,233
Minimum	0,789	0,807	0,765	0,868	0,869	0,862	0,849	0,852	0,881	0,834	0,846
Maximum	7,682	4,641	3,702	3,913	3,340	4,377	3,258	5,840	2,257	3,579	3,224

Source: Own study.

In the case of the agricultural technology level (MP), as a result of grouping individual countries based on their position in quartiles, the following groups were obtained:

A_MP - 1 quartile - Finland, Czech Republic, Hungary, Romania, Sweden, Ireland, Austria.

B_MP - 2 quartile – Lithuania, Greece, Portugal, Bulgaria, Belgium, Denmark.

C_MP - 3 quartile – United Kingdom, Croatia, Slovakia, Poland, Spain, Netherlands.

D_MP - 4 quartile – Germany, Italy, Estonia, France, Latvia, Slovenia.

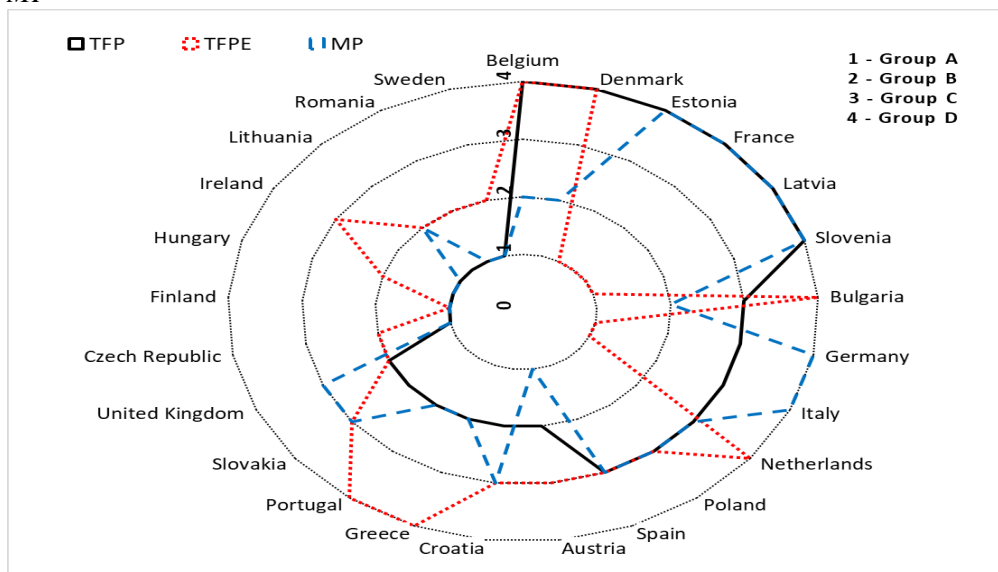
The A_MP group are countries with the lowest level of MP technology, the B_MP group are countries with a low level of technology, the C_MP group are countries with a medium level of technology and, accordingly, the D_MP group are countries with the highest level of technology.

Then, an analysis of the impact of individual productivity components on the position of individual countries in quartiles was carried out. Differences between individual countries can be seen in the impact of individual components on their positions. For example, a country’s position in the group with the highest TFP level was not always associated with the same position in the group with the highest efficiency and in the group with the highest level of technology. The comparison of the results with the position of individual countries is presented in Figure 1.

In group A, i.e., countries with the highest level of TFP productivity (4 quartile), it can be seen that in the case of Belgium and Denmark, the high level of productivity was determined by maintaining the highest level of technical efficiency (TFPE). On the other hand, in the case of other countries in this group, i.e., Estonia, France, Latvia and Slovenia, a high impact of technology (MP) was recorded with a low level of efficiency.

In the group of countries with the average level of TFP productivity (3 quartile), it can be seen that in the case of Bulgaria and the Netherlands, this level was determined by the highest level of efficiency (TFPE) and the average level of technology. In turn, Germany and Italy showed a very low level of efficiency and a very high level of technology. In the case of Poland and Spain, both a high level of efficiency and technology were recorded.

Figure 1. Average TFP productivity for 2009-2019 and its components TFPE and MP



Source: Own study.

In the group of countries with a low level of TFP productivity, most countries showed high and very high efficiency, while the technological level was medium or low. For example, Greece and Portugal are countries where efficiency is very high and the level of technology is low.

In countries with a very low level of TFP productivity, they tended to be characterized by a very low level of technology and a low level of efficiency. Finland is the worst in this respect, where both the level of efficiency and technology are very low.

4. Conclusions

In 2009-2019, the average level of agricultural productivity shows a slight increasing trend. The average value of the TFP total productivity index ranges from 0.86 to 0.95. The analysis shows that in the analysed period there are significant differences in the level of TFP indexes between individual countries. This level ranged from 0.53 to 1.16. The highest levels of productivity were recorded in Belgium, Denmark, Slovenia, Latvia, France and Estonia. The lowest levels of productivity were recorded in Finland, the Czech Republic, Hungary, Sweden, Lithuania, Romania and Ireland.

In most of the analysed countries, the level of productivity was stable in the analysed years. The position of these countries in terms of the level of productivity has not changed. There has been an upward trend in productivity levels in several countries.

These countries include Hungary, Ireland and Romania. At the same time, these were countries from the group with the lowest level of productivity. In turn, Finland and Lithuania recorded a decline in the level of productivity. Comparing selected economic indicators related to the agricultural area (AA) in 2009 and 2019, it can be concluded that the highest production was recorded in the groups of countries B and C.

However, due to the high level of inputs, especially labour, productivity in these countries was not the highest. AWU labour inputs decreased in all countries. In the countries with the highest level of productivity (group D), the highest increase in the level of production was recorded as compared to 2009. At the same time, there was the highest increase in direct and general economic costs. In turn, in the group of countries with the lowest level of productivity (group A), both the production level indicators and the cost level indicators were the lowest. At the same time, in this group, as compared to 2009, there was a significant progress in the level of production.

The decomposition of TFP indexes into efficiency change indexes (TFPE) and technology change indexes (MP) showed that the average level of agricultural efficiency in European countries shows a growing tendency, while the average maximum productivity index oscillates at the level of 1.23. It can also be concluded that the level of TFP productivity in individual countries was determined to a different extent by changes in efficiency and changes in technology. Most of the countries with the highest levels of productivity had the highest level of technology-related indicators with a very low level of efficiency. In the group of countries with the lowest level of productivity, a very low level of indicators related to technology and a low level of effectiveness were recorded. On the other hand, in the groups of countries with an average and low level of productivity, the level of the discussed indicators is varied and no clear relationships have been found.

The differences in the level of productivity as well as in the level of the analysed components of this productivity give grounds for the conclusion that individual countries use their resources and the inputs they use in a more or less effective manner. The European Union, while implementing the Common Agricultural Policy and other policies supporting agriculture through the redistribution of financial resources, should consider linking their amount with this type of indicators. This would allow for a more rational use of these funds.

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