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EFFICIENCY ANALYSIS OF AGRICULTURAL PRODUCTION IN THE EUROPEAN UNION

Abstract: In this paper authors examine relative technical efficiency of agricultural production in the European Union using Data Envelopment Analysis (DEA). Output oriented DEA model with variable return to scale has been applied. Four input variables were used in the model: labour, pesticides, fertilizers and used land. Production has been used as the only output variable. Results of this analysis indicate that the efficiency score values lie between 9% and 100%, with the average efficiency score of 52%. Slovenia, Estonia, Germany and Malta are characterized with the highest efficiency scores, while Cyprus, Finland and Ireland have the lowest efficiency score values. Policymakers can utilize this paper's findings to determine what elements enhance or diminish agriculture's efficiency.

Keywords: Technical efficiency, Agricultural production, Data Envelopment Analysis

1. INTRODUCTION

In the past few decades, being able to increase productivity and efficiency has become really important for making the economy better, both for individual businesses and for the country as a whole. Hence, different ways of measuring efficiency are used. The implications of measuring efficiency are reflected in the competent indicators of the position of agricultural production in one country comparing with the others in the observable sample.

The liberalization process made it easier for people to find more chances for success and bigger rewards in a market that has a lot of competition (Bojnec et al. 2012). Previous studies showed that agricultural production in Central and Eastern Europe is not as effective as in the original EU member countries (Nowak et al. 2015). Nevertheless, prior studies have shown that agriculture in EU countries has been becoming less efficient over time (Kocisova 2015). Furthermore, there is still a big difference between the new countries in the EU and the original 15 countries, especially in in terms of labour productivity (Matkovski et al.2016). This can be partly explained by the different ways these two areas specialize in different things. Central and Eastern European countries mainly focus on making products from grains and raw materials, while in the EU15, they make more products from animals and process them, which makes more money for each worker (Csaki and Jambor 2019).

During the period of accession to EU integration, there was a big increase in the trade of agricultural and food products with other countries, because their markets became more open via market liberalization process. Making productivity improvement takes time because it takes time to complete structural changes and makes agricultural policy adjustments (Erjavec et al. 2014). Therefore, in this study we investigated opportunities to increase the efficiency of agricultural production in the EU countries. In order to perform such an analysis a Data Envelopment Analysis has been applied, as one of the most commonly used tools for assessing efficiency. Applying such a powerful tool can contribute to a better understanding of the agricultural situation in the observed set of EU countries (Marcikic Horvat et al. 2020).

2. METHODOLOGY AND DATA

A well-known nonparametric method for analysing the efficiency of particular Decision Making Units (DMU) is Data Envelope Analysis (DEA). This method, in contrast to parametric statistical approaches, compares, not the mean value, but the efficiency of each DMU with the greatest efficiency score in the sample. The application of DEA methods is possible in numerous and diverse activities of the economy, if the goal is to assess the efficiency and performance of the observed DMUs. A prerequisite for starting the analysis is the careful selection of adequate inputs and outputs. The next step is the selection of the model to be used in the analysis. DEA models can be used in efficiency assessment, identification of inefficiencies, comparative analysis, benchmarking, sensitivity analysis, scenario analysis and for optimal resource allocation. Efficiency assessment refers to the analysis of different DMUs that can be related to different countries, regions, companies, etc. Similar to efficiency assessment, inefficiency identification shows the opposite results, i.e. it shows inefficient DMUs. This type of analysis is most often used within some complex systems and organizations, with the aim of identifying inefficiencies and taking corrective actions in order to completely eliminate or minimize them. Companies often use a method called benchmarking or comparative analysis. It refers to performance measurement based on a predetermined indicator. It is most often applied when comparing with a competing company or comparing with successful companies in another branch, with the aim of determining the market situation in which the company is currently located. Also, in addition to the external benchmarking analysis, the company can opt for an internal analysis, where the internal segments of the company are compared using different parameters. A sensitivity analysis can also be performed using the DEA method. Within this analysis, the impact of changes in parameter values within the observed variants is evaluated. The goal is to determine the impact of changed input or output values on efficiency. Scenario analysis is mainly used with hypothetical scenarios, where different outcomes in different situations are analyzed. This analysis is about forecasting, that is, the future. During the analysis, different scenarios are created in which adjustments and changes in input and output values are made, in order to understand the possible effects on efficiency. Based on the results of the analysis, the company can make a business decision more easily, given that it has insight into the most effective.

Resource allocation is an extremely useful type of analysis in which the DEA method can also be applied. In this way, an adequate allocation of resources can be determined while at the same time expecting maximum results, i.e. improvement of overall efficiency.

In our study, the output-oriented BCC model has been used to calculate and compare the relative technical efficiency of agricultural production in the EU countries in 2021. The DEA is carried out by solving the following model (Banker et al. 1984) of linear programming:

$$\begin{aligned} & \max \phi \\ & s.t. \sum_{j=1}^{n} x_{ij}\lambda_j \le x_{io} \quad i = 1,2,\ldots,m; \\ & \sum_{j=1}^{n} y_{rj}\lambda_j \ge \phi y_{ro} \quad r = 1,2,\ldots,s; \\ & \sum_{j=1}^{n} \lambda_j = 1 \\ & \lambda_j \ge 0 \end{aligned} \tag{1}$$

where n is the number of DMU_s and DMU_o represents the country under evaluation. Assume that we have s output variables and m input variables. Observed output and input values are y_r and x_i respectively, thus y_{ro} is the amount of output r used by DMU_o, while x_{io} is the amount of input i used by DMU_o. λ is the DMU's weight and the efficiency score is ϕ.

Data on agricultural production for 27 EU countries are presented in the Table 1. Inputs are given through the columns of pesticides, fertilizers, land used and labor. Pesticides and fertilizers provide information on their use in agricultural production in 2021, for each country separately. Used land refers to hectares of agricultural land on which agricultural production is based, while labor force refers to the number of employed workers in agriculture in 2021. The produced quantities are expressed in tons and refer to the total quantity of produced agricultural products in 2021. The data on the produced quantities represent the value of the output in the DEA model.

Table 1: Initial data of agricultural production of EU countries in 2021

Country	Pesticides (t)	Fertilizers (t)	Used land in 000 ha	Labour	Production (t)
Austria	5862	169676.76	25974594	160820	10835900
Belgium	5709.67	230006.28	1365.67	45430	14083650
Bulgaria	4484	458771.93	50465972	193570	15168812
Croatia	1463	178324	1476	113780	6214610
Cyprus	1115.4	14786.93	1231349	12320	345597
Czechia	3461.1	367895	3529797	132940	14789940
Denmark	2975.53	312589.18	2618	59020	14644410
Estonia	885.92	72446	987	17560	1677400
Finland	4032.4	220003	2268	104710	3988760
France	69602.42	2753165	28553754	675950	131994961
Germany	49071.47	1517184	16591	517350	421298606
Greece	4766.65	319715.11	5867188	446020	13269350
Hungary	8858.11	669848	50436886	203900	19582410
Ireland	3090.94	713772.36	4337	106420	3092080
Italy	50345	958218.41	124030309	913470	51819600
Latvia	1984.43	152292	1970	58870	3694400
Lithuania	2590.5	318341	2937.8	72710	7829200
Luxembourg	122.71	14180.88	132811	3330	187600
Malta	70.76	1159.54	27607	2150	56760
Netherlands	11291.6	275177	1812	205070	20929690
Poland	26534	1729000	14499.46	1390530	70189140
Portugal	9583.2	169688.26	39622955	130560	8100318
Romania	5598	922487	13079	911410	39742730
Slovakia	1620	178338.58	1856	62600	6846880
Slovenia	931	44578	610.96	39160	1019047
Spain	76173.55	1860154.94	262284464	802730	73217521
Sweden	1858.9	296933	3002.91	99610	8711890

Source: Food and Agriculture Organization of the United Nations

Based on initial data on agricultural production in EU countries, a descriptive statistical analysis was performed where the minimum and maximum values, average parameter values and standard deviation were determined. The data are shown in Table 2 and allow insight into the structure and main features of the analyzed data.

Table 2: Descriptive statistics of agricultural production of EU countries in 2021

Indicator	Pesticides (t)	Fertilizers (t)	Used land in 000 ha	Labour	Production (t)
Min	5862	1159.54	610.96	2150	56760
Max	76173.55	2753165	262284464	1390530	421298606
Average	13114.16	552545.64	21934336.92	277110.74	35678935.63
St. Dev.	21623.94	675953.94	55256616.87	358429.47	82603018.43

Source: author's calculations

3. RESULTS AND DISCUSSION

In order to evaluate the technical efficiency of agricultural production in European countries, the MaxDEA software has been used. In this case, the output orientation of the DEA model was selected and the technical efficiency was assessed using BCC model with variable return to scale. Based on the results shown in the Table 3, we can conclude that four countries (Estonia, Germany, Malta and Slovenia) achieved the highest possible efficiency of agricultural production in the year of 2021. The average efficiency score is 0,52 which shows that there is room to improve efficiency of agricultural production in the EU countires. The lowest efficiency score values are achieved by Cyprus, Finland, Ireland, Portugal and Spain.

Table 3: Technical efficiency of agricultural production of EU countries in 2021

Country	Efficiency Score	Rank
Austria	0.231137	21
Belgium	0.864883	7
Bulgaria	0.399223	14
Croatia	0.918719	5
Cyprus	0.089923	27
Czechia	0.506465	12
Denmark	0.729699	10
Estonia	1	1
Finland	0.136921	26
France	0.313305	18
Germany	1	1
Greece	0.328241	16
Hungary	0.259032	20
Ireland	0.144376	25
Italy	0.194822	22
Latvia	0.324881	17
Lithuania	0.465839	13
Luxembourg	0.372699	15
Malta	1	1
Netherlands	0.641882	11
Poland	0.310443	19
Portugal	0.172773	24
Romania	0.885823	6
Slovakia	0.835115	8
Slovenia	1	1
Spain	0.17379	23
Sweden	0.829931	9

Source: author's calculations

Countries that achieved efficiency score below 1 may improve their efficiency levels by raising the level of agricultural production (output) with the constant level of the input variables. Thus, in addition to the information on efficiency score, DEA also provides useful information for decision makers on possible ways of efficiency improvement which are presented in the Table 4. Data in the Table 4 presents the projected (ideal) values of the DEA model variables that should maximise the overall efficiency of the sample.

Table 4: Results of DEA model – Projections

Country	Projection (Pesticides)	Projection (Fertilizers)	Projection (Used land)	Projection (Labour)	Projection (Production)
Austria	5517.54773	169676.76	26382.49094	59418.25261	46880875.78
Belgium	2619.659616	110757.2741	1365.67	45430	16283873.13
Bulgaria	4484	137700.0062	26614.84596	48551.39394	37995829.95
Croatia	1463	89222.02392	1476	23467.42664	6764432.905
Cyprus	511.2224088	14786.93	27507.97829	6781.080509	3843260.199
Czechia	3461.1	106052.6807	26844.80726	37796.48692	29202318.91
Denmark	2975.53	133435.4591	2618	38986.95954	20069114.55

Estonia	885.92	72446	987	17560	1677400
Finland	4032.4	166329.6382	2268	50128.1105	29131749.65
France	49071.47	1517184	16590.99998	517350	421298606
Germany	49071.47	1517184	16591	517350	421298606
Greece	4766.65	146444.8655	26551.30256	51523.21373	40425672.45
Hungary	8858.11	273029.8361	25631.48889	94541.36984	75598513.08
Ireland	3090.94	133965.5185	4337	39748.9707	21416820.5
Italy	31004.66996	958218.41	20652.65273	327393.2549	265984689.1
Latvia	1984.43	104289.3899	1970	28791.68484	11371531.88
Lithuania	2590.5	121116.6586	2937.8	34878.36252	16806674.51
Luxembourg	122.71	2766.812031	27595.32096	2696.209228	503355.8534
Malta	70.76	1159.54	27607	2150	56760
Netherlands	4549.178058	155257.2417	1812	75100.16771	32606737.74
Poland	26534	832374.4857	14499.46	282239.9068	226093278.9
Portugal	5517.919431	169688.26	26382.40736	59422.16073	46884071.16
Romania	5598	195315.8487	13079	63701.12989	44865334.5
Slovakia	1620	93355.76158	1856	25010.7068	8198731.227
Slovenia	931	44578	610.96	39160	1019047
Spain	49071.47	1517184	16591	517350	421298606
Sweden	1858.9	98654.95497	3002.91	27211.92824	10497119.77

Source: author's calculations

4. CONCLUSION

Agricultural production is an economic branch that has many benefits from different aspects. One of the most important is, of course, ensuring food security. Food security refers to the provision of sufficient food for the entire population. Within the European Union, there are significant differences regarding the volume of agricultural production, that is, the amount of agricultural products produced. Some countries have more developed agriculture and the entire agribusiness sector, while on the other hand there are countries that do not have the opportunity to reach an enviable level of agricultural production.

Natural resources and weather conditions have the greatest influence on the success of agricultural production. Countries like France, Germany, Spain and Italy have extremely favourable conditions for carrying out agricultural production, while the same cannot be said for countries like Malta, Cyprus and Luxembourg. The mentioned countries have limited arable land and climatic conditions that do not suit many agricultural crops. The advantage of the EU is the facilitation of easier foreign trade exchange, where imports and exports take place freely between countries.

The positive impact of agricultural production is reflected in the strengthening of the national economy, where through the export of agricultural products to foreign countries, it is possible to obtain foreign currency, which creates an inflow of funds into the budget. This enables the expansion of the number of jobs and many other benefits.

Finding opportunities to increase the efficiency of agricultural production in the EU countries was the major goal of this article, which focused on research into the technical efficiency of agriculture and its sources of inefficiency. More precisely, policymakers can utilze this paper's findings to determine what elements enhance or diminish agriculture's efficiency. This research can also help farmers, as their choices on how to use inputs and outputs are critical to the efficiency of agriculture.

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