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TECHNICAL EFFICIENCY DETERMINANTS OF OECD COUNTRIES' AGRICULTURAL PRODUCTION - A STOCHASTIC FRONTIER ANALYSIS APPROACH

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Abstract

The purpose of this study is to analyze the efficiency in OECD countries' agricultural sector and also to examine some selected factors that affecting the efficiency of production in this sector. For this aim, using Stochastic Frontier Analysis (SFA) during the period 2015-2019, the agricultural producers' technical efficiency in all 38 OECD member countries was evaluated. However, some factors affecting efficacy in these countries were also examined. According to the study's results, the average technical efficiency value in the agricultural sector of OECD countries in the 2015-2019 period was 78.6%. The countries with the lowest and highest average technical efficiency were Luxembourg and Colombia, respectively. On the other hand, as a result of the examination of the factors affecting the efficiency in these countries, it was revealed that the Global Innovation Index variable did not affect the efficiency of agricultural producers, but the reel exchange rate and agricultural pesticide use variables positively affected the efficiency.

Key words: *efficiency, Stochastic Frontier Analysis (SFA), OECD Countries, Global Innovation Index, agricultural economics*

INTRODUCTION

The agricultural sector is of special importance in terms of having significant capabilities and capacities and is noteworthy in terms of its role in providing food to the people and raw materials of some industries. Also, most of the income from non-oil exports comes from this sector and has a comparative advantage over other economic sectors due to high employment and less foreign exchange [11]. The agricultural sector, as the oldest production activity with a rural origin, has been of special importance in the process of growth and development of different countries in different periods. The researches in different countries development process shows that it is vital the development of agricultural sector as one of the most important economic sectors for sustainable development realization of each country; Therefore achieving prosperity and development in other sectors, including industry is not possible without removing the development obstacles in this sector. From the point of view of the European Union, achieving economic development requires achieving agricultural development [20]. Agricultural development is the most important priority in national development programs in most countries and it plays a very important role in the process of growth and development of these countries. Since this economic sector is important in terms of meeting the nutritional needs of the people and the raw materials of industries as well as creating employment and income, its stability and continued growth can be considered as major factors contributing to social stability and economic growth of society [10]. But without management and empowerment of production resources in agricultural sector, development in this sector is not possible. Therefore, in order to maintain production resources and the optimal use of these resources, as well as making a positive change in the agricultural sector situation, paying attention to the development of this sector is necessary. However, today, being interested to the agricultural sector has become a obligation and political independence that it is tied to food security and the basic needs of the people. Therefore, to address this need, efforts should be made to improve the use of production resources in the agricultural sector [5].

Due to the low level savings of most farmers, the most important way for farmers to raise the required capital is to use bank credits. The development of the agricultural sector and its future is a concern of many policymakers in the most country and apparently in all the plans of the country more attention is paid to other sectors. Among the variables, bank credits used in the agricultural sector can lead to increase the economic growth of country by increasing this sector's value added. Therefore, using correctly and optimally of bank credits, can remove lack of financial resources problem that it is one of the important barriers in the growth and development of the agricultural sector. Solving this, lead to improved performance of agricultural inputs and therefore increase the value added of this sector [18]. In addition, like every production sector, innovations and inventions in this sector may affect the technical performance of the producers. On the other hand, many economists believe that the existence of a strong agricultural sector is a necessity in the process of economic development, and until the development barriers of this sector are removed, other sectors will not achieve growth and development. The experience of successful countries in the field of agricultural production shows that the use of capital equipment in various agricultural activities has led to increased productivity of factors of production, including management, labor and land. This, in addition to covering the cost of production factors and creating a good return on investment, has led to a surplus of domestic supply and the development of agricultural products exports [15].

Therefore, considering the importance of the agricultural sector in the country's economy, this study seeks to examine the optimal use of production factors in the agricultural sector of OECD countries and also to examine the impact of some economic factors such as agricultural pesticides used, reel exchange rates and innovation on the efficiency of this sector using the Stochastic Frontier Analysis (SFA) method in the period between 2015-2019.

MATERIALS AND METHODS

The literature on Stochastic Frontier Analysis began in the 1950s with the [12], [6] and [19] and continued by [17]. According to [7]'s definition, technical efficiency is the firm's ability to obtain the maximum output from a certain amount of input. In addition, Farrell was the first to be able to estimate technical efficiency in practice. This evolutionary path in efficiency measurement was initially associated with non-parametric methods and then parametric approaches were used by focusing on production functions. In parametric frontier models, the production inefficiency component is expressed by a specific probability distribution function, while in nonparametric models, this component is considered without considering a statistical distribution function.

Nonparametric models include Data Envelopment Analysis (DEA) models, which is in fact a mathematical programming method. These models estimate frontier functions by determining the best performance among all observations and relate all firm deviations from the frontier to inefficiencies. On the other hand, parametric frontier models include Deterministic Frontier Approach (DFA) models and Stochastic Frontier Analysis (SFA) models. Following a theoretical framework for measuring performance presented by Farrell, [2] introduced the model of a deterministic frontier function. In this model, it is assumed that the only source of error in the frontier production function is inefficiency, and the impact of other error terms and statistical disturbances is not considered [14]. Later, practical measurements of efficiency using a stochastic frontier production function method performed by [1].

The derivative form of the original model for measuring efficiency using the production function estimation proposed in 1987 by the model of Aigner, Lovell, Schmidt, Meeusen and Den Broeck for cross-sectional data was as follows:

$$Y_i = f(X_i, \beta) TE_i e^{V_i} \quad (1)$$

where: Y is the output and X is input. In the model, the efficiency is between zero and one $(0 \leq TE(y_i, x_i) \leq 1)$ and β is the vector of the production function parameters that must be estimated. v is a random component that converts a certain frontier to a stochastic frontier and explains factors that are beyond the control of the producer; Factors such as favorable or unfavorable external events (such as luck, weather, machine malfunctions) as well as measurement errors and other unimportant variables that have been excluded from the model.

Since the production function is specified linearly with respect to the variables, the experimental function is presented as follows:

$$\ln Y_i = \ln f(X_i, \beta) + \ln TE_i + V_i = \ln f(X_i, \beta) - U_i + V_i \quad (2)$$

U_i is a measure of technical inefficiency so that $U_i = -\ln TE_i$ and it is representative of the factors that cause inefficiency in production and includes such things as differences in skills and effort or lack of effort of management and employees, unique information of an enterprise and information constraints and so on. The economic interpretation of U_i , which defines inefficiency, is consistent with Farrell's definition. Since the efficiency (TE_i) cannot be greater than one, U_i must include one-sided values. Therefore, in the models that will be used in the research, the basic model for panel data is expressed in the following general form:

$$Y_{it} = f(X_{it}; \beta) + \varepsilon_{it} \quad (3)$$

or

$$Y_{it} = \beta_\circ + X'_{it}\beta + \varepsilon_{it} \quad (4)$$

Where Y_{it} represents the amount of output or product of firm i (i = 1,2,…., N) at time t. X_{it} represents the homogeneous matrix of K and β is the unknown $K \times 1$ vector of the coefficients to be estimated. The residual term ε is also introduced as follows:

$$\varepsilon_{it} = V_{it} - U_{it} \quad (5)$$

where, U_{it} represents inefficiency and V_{it} represents the random error terms. It should be noted that the deviation from the observed points of the frontier production function depends on the two parts U_{it} and V_{it}, and the econometric logic of the separation of U_{it} and V_{it} is that these two random variables are different in terms of behavioral characteristics. As a result, the value of U_{it} can be separated from V_{it}, by specifying a model for U_{it}. It is also assumed in all models that the random term has a normal distribution with a mean of zero and an sismilar variance δ_v^2:

$$V_{it} \sim iidN(0, \delta_v^2) \quad (6)$$

To identify the factors that change technical efficiency, [13] and [17] proposed the term U_i inefficiency as a function of some of the factors affecting firm's inefficiency and the component of random error. Later, [3] introduced an equivalent model to this model, except that the use of panel data was allowed. The specifications of the Battese and Coelli model are as follows:

$$Y_{it} = X_{it}^*\beta + (v_{it} - u_{it}) \quad (7)$$

$$u_{it} = Z_{it}\delta + w_{it} \quad (8)$$

u_{it} are non-negative variables indicating technical inefficiencies and are assumed to be distributed independently of v_{it} and has a normal distribution N (M_{it} , δ_u^2) thet interrupted at zero with mean of $M_{it} = Z_{it}\delta$ and variance of δ_u^2. z is the vector $(1 \times m)$ of the variables affecting the inefficiency value during the period under study. δ is also a vector (m × 1) of unknown coefficients that must be estimated.

Explanatory variables Z_{it} can also include inputs of random frontier production function. The random variable w_{it} has a interrupted normal distribution with mean zero and variance σ_w^2 and at the point of intersection is equal to $-Z_{it}\delta$ and must always be $w_{it} \geq -Z_{it}\delta$. Under these assumptions, the term u_{it} becomes non-negative with a interrupted distribution of $N(M_{it}, \delta_u^2)$.

To estimate the Battese and Coelli inefficiency effects model, the maximum likelihood method can be used to simultaneously estimate the parameters of the random frontier function and the technical inefficiency effects model.

In this study, the data of the agricultural sector producers of 38 countries that are members of the Organization for Economic Co-operation and Development (OECD) during 2015-2019 will be used. Although data for 2020 year are available for some of the variables discussed, since this year's data are missing in some countries, and also in order to include all of the OECD group countries in the analysis, 2019 year was considered as the last updated year. While 20 countries joined to OECD until 14 December 1960, 18 countries have joined this group since then, increasing the total number of member countries to 38.

The data required in the study were obtained from the [8], [16] and [9]databases and annual reports between the period of 2015-2019. Stochastic Frontier Analysis (SFA), which is an econometric approach, was taken into account to make the estimations and estimations were made using FRONTIER 4.1c and EXCEL 2003 programs.

According to the method discussed, it is necessary to determine the input and output variables. In addition, there is a need to define the variables used in the inefficiency model. In the literature, different input and output variables are used to analyze the efficiency in the agricultural sector. however, in this sector, labor force and capital stock data are frequently used as input variables, while the value added or production value of agricultural products is used as output variable. A total of four input variables will be used, with the use of agricultural land and the amount of energy used in the agricultural sector along with labor force and capital stock variables. The agricultural sector value added of the countries is considered as the only output variable. The agricultural pesticides used in this sector, the real exchange rates of the countries and the Global Innovation Index variables were used as the variables affecting the inefficiency of the agricultural sector producers in OECD countries.

Global Innovation Index includes two sub-categories of innovation input and innovation output. Innovation input represents innovative activities and has five sub-categories: inputs, human capital and research, infrastructure, market Sophistication, and business Sophistication. The innovation output represents the results of innovative activities and it includes two sub-categories: the knowledge and technology outputs and the creative outputs [4].

RESULTS AND DISCUSSIONS

The main purpose of this study is to examine the performance analysis in the agricultural sector of OECD countries between 2015-2019 and also to examine some variables that affect this performance. Stochastic Frontier Analysis (SFA) method, which is a parametric method, was used to estimate the efficiency values of the countries. For estimating the production function of the agricultural sector by this method, the type of function on which the data fit should be specified. In most studies, the Translog or Cobb-Douglas production function is usually used. However, in this research, a hypothesis test will be made to determine the appropriate function type and it will be decided which function to use by looking at the test results. However, there is a need to determine the distribution type in the study and also to test the hypothesis that the term inefficiency affects the agricultural production of these countries.

Due to the approximate standard deviation of t-test coefficients, this test is not satisfactory and therefore to test the significance of the frontier production function, the generalized maximum likelihood ratio test (LR) is used:

$$LR = -2[\text{Log likelihood}(H_\circ) - \text{Log likelihood}(H_1)] \qquad (9)$$

where: $\text{Log likelihood}(H_\circ)$ and $\text{Log likelihood}(H_1)$ denote the Likelihood value of the constrained and unconstrained functions, respectively. The distribution of the test is the extended Chi-Square distribution with numbers of restrictions as degrees of freedom.

The hypothesis testing results of likelihood ratio for frontier production function parameters are shown in Table 1. The hypothesis test in the first row is done to determine the appropriate production function.

Table 1. Log likelihood Ratio Tests Results

Null Hypothesis	Log likelihood	LR Value	Critical Value		Decision
			%1 level	%5 level	
$\beta_{11} = \beta_{12} = \cdots = \beta_{ij} = 0$	-57.88 -57.34	1.08	22.525	17.670	$H_\circ$ accepted
$\mu = 0$	144.54 144.91	0.74	5.412	2.706	$H_\circ$ accepted
$\delta_1 = \delta_2 = \cdots = \delta_n = 0$	144.54 -57.88	404.84	10.501	7.045	$H_\circ$ rejected
$\gamma = 0$	-	448.07	12.483	17.670	$H_\circ$ rejected

Source: Research Findings.

Accordingly, the Cobb-Douglas production function was tested against the Translog production function. Since the LR value could not exceed the critical value at the 1% or 5% significance level, the test result was not significant and therefore the $H_\circ$ hypothesis was accepted. Therefore, the Cobb-Douglas production function, which is a constrained function, was determined as the appropriate function form for this study.

The hypothesis of $\mu = 0$ is related to whether the model is restricted with half normal distribution or unrestricted with truncated normal distribution for the inefficiency component. According to the LR test statistics, since the LR test statistics (0.74) could not exceed the critical value, the null hypothesis could not reject and thus the half normal model is sufficient. According to these hypothesis tests, a Cobb-Douglas production function with half-normal distribution is considered for the inefficiency term in present study. Using the LR test, it will be decided whether the inefficiency term is included in the model. Accordingly, the constrained model without factors affecting inefficiency can be tested against the unconstrained model with influencing factors. This hypothesis test is in the third row of Table 2. According to the LR test results, the $H_\circ$ hypothesis is rejected because the statistical value exceeds the critical value. Therefore, in the model, besides the random term, the inefficiency term should also be included. In other words, it is necessary to examine some factors affecting inefficiency in the OECD agriculture sector. For this reason, Maximum Likelihood Ratio method estimators will be used instead of OLS method in the estimation of the model.

Whether there is an inefficiency effect in the model can also be tested by looking at the LR test of the γ coefficient. Accordingly, it is seen that the LR test statistical value (448.07) given in Table 1 is higher than the critical value. Therefore, the $H_\circ$ hypothesis was rejected and the test was significant. Thus, in this model, it has been proven again that some factors affecting inefficiency should be examined.

Table 2. The maximum likelihood estimation (MLE) for parameters of Cobb-Douglas stochastic frontier for Agriculture Sectors of OECD Countries

Variable*	Parameters	Coefficients	Std. Error	t statistics
Constant	$\beta_\circ$	1.35	0.24	5.72
Ln(AE)	β_1	0.31	0.024	12.99
Ln(ACS)	β_2	0.42	0.032	13.02
Ln(ALU)	β_3	0.14	0.023	6.17
Ln(AEU)	β_4	0.11	0.017	6.25
Sigma-Squared	$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.64	0.14	4.54
Gamma	$\gamma = \sigma_u^2/\sigma^2$	0.99	0.0018	559.32
LR	-	-57.88	-	-

* AE, ACS, ALU and AEU represent Agricultural Employment, Agricultural Capital Stock, Agricultural Land Use and Agricultural Energy Use respectively. Ln is the natural logarithm.

Source: Research Findings.

The results of estimating the maximum likelihood of the parameters in the agricultural sector of OECD countries during the period 2015-2019 using the SFA method are shown in Table 2.

Considering the results in Table 2, the coefficients of all variables were significant at the 1% significance level. This shows that the effects of the variables discussed in the agricultural sector production of OECD countries are very important.

When the signs of the variables coefficients are taken into consideration, the signs of all the coefficients have emerged in accordance with the expectations. This means that the marginal production values of the variables used in the study are positive and therefore they affect agricultural production in OECD countries in the same direction.

Looking at the scale elasticities of the agricultural sector in OECD countries, it is understood that there is a decreasing return to scale in this sector ($\varepsilon = 0.98$). Accordingly, it is seen that the increase in the production scale in these countries does not have a positive effect on production, and instead, increasing the production factors is more effective.

The gamma variable value of the model was 0.99 and its t statistical value was significant at the 1% significance level. This means that socio-economic variables that affect inefficiency are introduced in the model, and therefore the error term should consist of not only random effects but also inefficiency effects. In addition, the closer the Gamma value is to 1, the more effective the inefficiency term in the model. Therefore, an analysis of the socio-economic aspect of the OECD agriculture sector may be more appropriate to explain the current efficiency gap. This result was also revealed by the LR test of the gamma coefficient before. Therefore, the LR test confirmed that the inefficiency effect of socio-economic background in the OECD agriculture sector strongly influences technical efficiency among OECD agricultural producers.

As a result of the Maximum Likelihood Estimation (MLE) of the inefficiency effect, a description of the socio-economic factors that affecting technical efficiency is provided in Table 3.

Table 3. The Maximum Likelihood Estimation (MLE) of Inefficiency Effect

Variable	Parameter	Coefficients	Std. Error	t istatistics
Constant	$\delta_\circ$	1.31	0.87	1.50
Agriculture Energy Use	δ_1	-0.15	0.025	-6.07
Annual Exchange Rate	δ_2	-0.27	0.038	-7.04
Global Innovation Index	δ_3	0.73	0.22	0.33

Source: Research Findings.

Considering the results, the coefficients of Agricultural Energy consumption and annual real exchange rate changes were significant at the 1% confidence level. The coefficients of these variables were negative. This means that the change of these variables positively affects the agricultural production efficiency of OECD countries. The effect of energy consumption can be explained by the agricultural machinery used in this sector. Increasing energy consumption means that agricultural machinery is used more in this sector and is therefore expected to positively affect efficiency. In other words, it can be said that producers using energy for agricultural production in OECD countries are more efficient.

It is understood that the negative annual real exchange rate coefficient affects the agricultural production efficiency of OECD countries positively. The effect of the real exchange rate can be explained by the change in exports. Accordingly, an increase in real exchange rates increases the export of goods produced in that country and thus enables producers to produce more by using resources efficiently.

The coefficient of the Global Innovation Index variable was positive and insignificant. Since the coefficient of this variable is positive, it is seen that OECD agriculture sector efficiency is negatively affected. However, this variable’s coefficient is not significant. Therefore, this variable’s effect on agricultural production efficiency is not taken into account. In other words, this variable do not affect the agricultural sector efficiency of OECD countries. One of the reasons for this may be that OECD countries are generally industrial countries and innovations are made in the industrial sector and there is not much innovation in the agricultural sector of these countries. So this sector's efficiency does not affect by innovations.

The agricultural sector efficiency values of OECD countries for the period 2015-2019 are shown in Table 4.

According to the results in this Table, the general average of agricultural producers' efficiency in OECD countries was 78.6% in the period under consideration.

This means is that producers in the countries studied do not use, on average, about 21% of their resources at an optimal level.

In the period under consideration, the lowest efficiency value belongs to Luxembourg with 0.33 in 2017 and 2018 years. By promoting the quantities and use of inputs in efficient producers, it is possible to increase production by up to 0.67 in this country. Otherwise, maximum production will not be achieved. In the country group examined, the highest efficiency value occurred in the Columbia country in 2019. In the period under consideration, no country in OECD countries has reached full efficiency in the agricultural sector. In other words, it is seen that agricultural producers of all countries produce under the frontier production function. In this sense, it is seen that the technical efficiency values in these countries are in the range of 0.33-0.97.

Looking at the annual averages in Table 4, the average technical efficiency of agricultural producers in these countries did not change much between 2015-2019. This means that in these countries, not much effort has been made to reach the optimal level of agricultural products and production has been made with the same resources and production technologies.

Figure 1 shows how the technical efficiency of agriculture producers is distributed during this period.

Table 4. Annual Technical Efficiency of Agriculture Sector of OECD Countries

Country	**Year**				
	2015	2016	2017	2018	2019
Australia	0.81	0.84	0.82	0.80	0.79
Austria	0.52	0.53	0.56	0.59	0.58
Belgium	0.80	0.78	0.79	0.77	0.77
Canada	0.88	0.89	0.89	0.90	0.90
Chile	0.95	0.95	0.95	0.95	0.95
Colombia	0.96	0.96	0.96	0.96	0.97
Costa Rica	0.94	0.94	0.94	0.94	0.94
Czech Republic	0.87	0.87	0.86	0.86	0.87
Denmark	0.78	0.75	0.77	0.74	0.80
Estonia	0.56	0.50	0.51	0.42	0.53
Finland	0.73	0.74	0.73	0.72	0.73
France	0.88	0.87	0.88	0.89	0.89
Germany	0.78	0.78	0.77	0.73	0.75
Greece	0.76	0.75	0.77	0.78	0.80
Hungary	0.94	0.94	0.94	0.94	0.94
Iceland	0.87	0.86	0.85	0.85	0.86
Ireland	0.62	0.63	0.66	0.61	0.69
Israel	0.91	0.91	0.91	0.91	0.91
Italy	0.88	0.89	0.89	0.89	0.89
Japan	0.94	0.94	0.94	0.94	0.94
Latvia	0.52	0.49	0.50	0.50	0.52
Lithuania	0.58	0.58	0.57	0.53	0.55
Luxembourg	0.37	0.36	0.33	0.33	0.35
Mexico	0.94	0.94	0.95	0.95	0.95
Netherlands	0.84	0.85	0.85	0.85	0.85
New Zealand	0.82	0.80	0.80	0.82	0.82
Norway	0.89	0.88	0.89	0.89	0.90
Poland	0.86	0.87	0.87	0.86	0.86
Portugal	0.72	0.72	0.72	0.71	0.73
Republic of Korea	0.96	0.96	0.96	0.96	0.96
Slovakia	0.62	0.65	0.62	0.66	0.66
Slovenia	0.53	0.57	0.53	0.57	0.59
Spain	0.86	0.87	0.86	0.86	0.86
Sweden	0.86	0.85	0.86	0.86	0.87
Switzerland	0.56	0.57	0.56	0.58	0.59
Turkey	0.89	0.90	0.91	0.92	0.93
United Kingdom of Great Britain	0.78	0.78	0.78	0.78	0.79
United States of America	0.87	0.87	0.87	0.87	0.87
Annual Mean	*0.769*	*0.766*	0.765	*0.761*	*0.776*
General Mean	0.786				

Source: Research Findings.

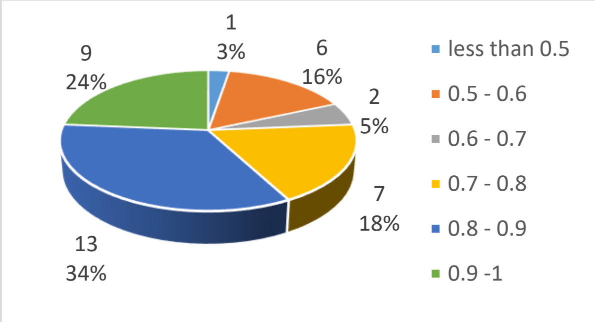

Fig. 1. Distribution of Technical Efficiency of Agriculture Sector in OECD Countries Between 2015-2019.
Source: Research Findings.

According to Figure 1, the average technical efficiency of 9 out of 38 OECD countries (24%) was above 0.9 in the period under consideration. Among countries, only one country (Luxembourg) has a technical efficiency value of less than 0.50. This corresponds to a low rate of 3% among 38 countries. It shows the potential for increasing agricultural production in this country by improving the technical efficiency of producers in the current technical conditions.

On the other hand, 13 country of OECD countries, have an average technical efficiency value between 0.80 and 0.90 in the agricultural sector. These countries have the highest rate (34%) among the total OECD countries as well. Consequently, there are is 29 countries with an average technical efficiency higher than 0.70 in the examined OECD countries, which corresponds to 76%. This shows that the agricultural producers in these countries are using the available resources close to the optimal level.

The comparative technical efficiency values of agricultural producers in OECD countries between 2015-2019 are shown in Table 5. Considering Table 5, the lowest and highest technical efficiency difference among OECD countries in the examined period belongs to Estonia with 0.142. The gap emerging in this country point to the potential of achieving the increase in agricultural production with the increase of technical efficiency in terms of production and management technology. On the other hand, the country with the lowest difference in maximum and minimum technical efficiency among these countries was the Republic of Korea with 0.001.

Table 5. Comparison of Technical Efficiency of Agricultural Sector of OECD Countries between 2015-2019

Country	Mean Efficiency	Minimum Efficiency	Maximum Efficiency	Difference
Australia	0.813	0.793	0.838	0.044
Austria	0.557	0.523	0.586	0.063
Belgium	0.783	0.766	0.804	0.038
Canada	0.892	0.883	0.900	0.017
Chile	0.952	0.951	0.953	0.002
Colombia	0.964	0.962	0.967	0.005
Costa Rica	0.940	0.939	0.941	0.003
Czech Republic	0.866	0.859	0.873	0.013
Denmark	0.768	0.744	0.797	0.053
Estonia	0.500	0.421	0.562	0.142
Finland	0.730	0.717	0.739	0.022
France	0.879	0.865	0.887	0.022
Germany	0.762	0.733	0.779	0.046
Greece	0.773	0.747	0.804	0.057
Hungary	0.938	0.937	0.940	0.003
Iceland	0.858	0.846	0.872	0.026
Ireland	0.642	0.613	0.689	0.076
Israel	0.913	0.911	0.914	0.002
Italy	0.885	0.877	0.888	0.011
Japan	0.942	0.941	0.943	0.002
Latvia	0.505	0.489	0.520	0.031
Lithuania	0.564	0.529	0.584	0.055
Luxembourg	0.346	0.328	0.367	0.039
Mexico	0.946	0.943	0.948	0.005
Netherlands	0.847	0.845	0.850	0.005
New Zealand	0.813	0.799	0.823	0.025
Norway	0.890	0.884	0.897	0.013
Poland	0.866	0.856	0.873	0.017
Portugal	0.719	0.713	0.727	0.014
Republic of Korea	0.962	0.962	0.963	0.001
Slovakia	0.641	0.619	0.664	0.045
Slovenia	0.556	0.527	0.585	0.058
Spain	0.864	0.860	0.869	0.009
Sweden	0.859	0.851	0.869	0.018
Switzerland	0.573	0.560	0.592	0.032
Turkey	0.910	0.895	0.926	0.031
United Kingdom of Great Britain	0.784	0.793	0.838	0.044
United States of America	0.869	0.523	0.586	0.063

Source: Research Findings.

However, the results of Table 5 show that, in general, OECD countries have a low difference in maximum and minimum technical efficiency of agricultural producers. Accordingly, OECD countries have the average technical efficiency values between 0.328 and 0.967. However, the lowest average technical efficiency belongs to Luxembourg (0.346) and highest belongs to Colombia (0.964) during the 2015-2019.

CONCLUSIONS

In this study, the technical efficiency of agricultural production in OECD countries during 2015-2019 was investigated. For this purpose, first, after estimating the shape of Cobb-Douglas production function and selecting it as the optimal form of the relationship between production and inputs use, the technical efficiency of these countries was measured by stochastic frontier analysis. The results showed that the average technical efficiency in the studied countries was 78.6%, which ranged from a minimum of 32.8% to a maximum of 96.7%. It was also found that Luxembourg with 34.6% had the lowest and Colombia with 96.4% had the highest average technical efficiency in this period.

The coefficients of all the inputs used in the study were positive and significant and consistent with the expectations. The input that has the most impact on agricultural production in OECD countries has been the capital stock variable. On the other hand, in the factors affecting inefficiency in these countries, the coefficient of the Global innovation index variable was positive and insignificant. However the effects of the real exchange rate and pesticides use variables on agriculture sector inefficiency were negative and significant.

In general, according to the obtained results, the following suggestions can be made:

-The results of estimating the frontier function indicated that by improving management there would be a high capacity to increase production in this sector. For this reason, considering this possibility for production increase in the agricultural sector, providing the necessary relevance measures is necessary and important.

-The results of efficiency calculation showed that there is a relatively large gap in some countries in terms of technical efficiency. The results of technical efficiency calculation showed that there is a relatively large gap in some countries in terms of technical efficiency.

-Since the GII variable does not have an effect on agricultural production inefficiency in OECD countries, instead of innovation other variables that have an effect on agricultural sector production increase should be included in these countries.

-Finally, according to the findings of this study, it can be said that instead of increasing inputs in the agricultural sector, it is necessary to emphasize the more efficient use of existing inputs and their more appropriate composition.

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