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THE IMPACT OF NATIONAL INCOME ON THE TECHNICAL EFFICIENCY OF AGRICULTURE SECTOR IN DEVELOPING COUNTRIES (A METAFRONTIER APPROACH)

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Abstract

The agricultural sector, especially in developing countries, is defined as one of the most important sectors in terms of wealth and market creation, foreign exchange return and economic growth, In this study, technical efficiency and technology gap ratios in the agricultural sectors of developing countries are discussed in four different income groups for 2017 in order to see the effect of country income on sector performance. In the study, input-oriented model is estimated with the assumption of variable return to scale using data envelopment analysis (DEA) with one output and three input variables. According to the results, while the production gap was 4% in high-income countries, this gap was 86.1% in low-income countries, and therefore, it was revealed that the per capita income of countries affected the technological gap ratios and technology that they use in the agricultural sector.

Key words**:** *agriculture, metafrontier, efficiency, technology gap, developing countries*

INTRODUCTION

One of the most important issues in the development process in any country, especially developing countries, is the optimal use of factors of production in the production process. The increase in population and the relative improvement in the economic situation of individuals has led to an increase in per capita consumption in society, and this has led to an increase in demand for agricultural products. Therefore, economic policies should be done to increase agricultural production. In any production system, increasing the efficiency of inputs is one of the basic principles and increasing the efficiency of production is one of the main goals. In fact, all the countries of the world are trying to increase their production by consuming the same amount of available resources, in order to achieve progress in the field of agriculture, especially in cases where longitudinal expansion is faced with barriers to access using more resources [1]. Increasing technical efficiency can create more products from a fixed set of production factors. Among the methods of increasing production, developing production factors and making major changes in the technology of developing countries, it faces many problems and limitations. Therefore, increasing technical efficiency has been mentioned as a more appropriate solution in this regard.

Efficiency is considered an important factor in productivity and growth of developing countries. Improving efficiency in agricultural units is of particular importance. Because in developing countries, one of the most active and productive sectors in the economy is the agricultural sector. In these countries, the agricultural sector is considered as a producer of essential goods of the society, which due to the growing population, the demand for these goods increases significantly. On the other hand, in such countries, agricultural products are one of the important items of exports and foreign exchange inflows and therefore it is very important in increasing GDP. Since production in the agricultural sector is a function of factors of production such as land, labor, capital, technology and management, due to the limitations of these inputs, increasing technical efficiency, ie increasing production per consumption of the same amount of input is important [15]. Therefore, agricultural development is a precondition and an essential need for the economic development of the country, and until the barriers to development in this sector are removed, other sectors will not achieve prosperity, growth and development in a meaningful way.

In this study, technical efficiency values were obtained by using the data of 2017 for the agricultural sector of developing countries and also taking into account the national income per capita of the countries.

MATERIALS AND METHODS

The most common method used in performance measurements is efficiency estimation. The concept of efficiency, which is an evaluation criterion that shows how effectively or adequately inputs are used in line with the objectives determined by the company, and the measurement of efficiency have become very important [18]. In this context, after first looking at the issues related to the meaning of efficiency and performance measurement, the metafrontier issue will also be discussed in order to analyze the national income effect.

According to economic theories, efficiency is the result of optimizing production and resource allocation. In other words, efficiency in economics term means producing the maximum possible output using a certain amount of input. In another definition, efficiency is the ratio of the actual return obtained to the standard and determined returns, or in fact the ratio of the amount of work done to the amount of work to be done [10].

A method for measuring performance was first developed by [11]. He suggested that it would be appropriate to compare the performance of a firm with the performance of the best firms in the industry. He introduced the use of firm's data for estimation in order to carry out his proposal of efficiency measurement. Farrell performance was introduced in the following three categories:

(a)Technical Efficiency: The maximum possible production that is obtained from a certain amount of production factors.

(b)Allocative Efficiency: Determines the combination of factors of production that have the least cost per unit. If price information is available and the firm's goal is to minimize costs or maximize revenue, then it is possible to measure allocative efficiency in addition to measuring technical efficiency. In other words, the purpose of this type of efficiency is to keep the price of the inputs used in a way that minimizes the cost of production. Allocative efficiency is also called price efficiency.

(c)Economic Efficiency: Shows the firm's ability to obtain the maximum possible profit with respect to price and data levels and is obtained by multiplying technical efficiency by allocative efficiency.

Technical efficiency is defined as the part of effective efficiency that is obtained from the production function. Effective efficiency introduces input efficiency sources for each output by minimizing production costs at each level of output or, equivalently, maximizing production levels with a combination of inputs taking into account their costs. Technical efficiency shows the ability of each production unit to maximize the product with the same production resources.

[2] estimated the parametric frontier production function in the form of Cobb Douglas production function. Since they did not consider the possibility of error term and other components interfering with random frontier estimation, and considered all frontier deviations to be technical inefficiencies, their model became known as the Definitive Frontier Production function model (DFP). Subsequently, the Stochastic Frontier Production function (SFP) by econometric method firstly were introduced by [3, 5, 16].

Efficiency Measurement

In general, both parametric and non-parametric methods are used to measure efficiency. In parametric methods, the community parameter is examined. The parametric method requires a mathematical function based on which the dependent variable is estimated using independent

variables and the observed data is used experimentally to estimate the parameters of a function. In fact, in this method, first a special form for the production function (such as Cobb-Douglas, CES, Translog and etc) is considered and then with the help of one of the methods of estimating the functions which is common in statistics and econometrics, the unknown coefficients (parameters) are estimated. Because in these methods, parameters of the assumed function are estimated, they are called parametric methods.
Nonparametric methods generally examine the performance of a firm or decision-making unit with the best actual performance of firms within that industry. Non-parametric methods can be considered as the simplest methods of observing and estimating efficiency, because these methods do not consider a specific form for the production function and work directly with the observed data, and since this is not a statistical method, statistical tests cannot be used in it.
The most important non-parametric method used in estimating technical efficiency is Data Envelopment Analysis (DEA) method that proposed by [6]. This method has been proposed to develop Farrell's single-input and single-output model. The usual formula for measuring the relative efficiency of decision-making units is the efficiency of an organizational unit with multiple inputs and outputs as follows:

Efficiency = Weighted total of input/ Weighted total of outputs

The programming style of the model is shown below:

$$\max \theta = \frac{u_1 y_{1j} + u_2 y_{2j} + \cdots + u_s y_{sj}}{v_1 x_{1j} + v_2 x_{2j} + \cdots + v_m x_{mj}}$$
$$s.t: \quad \frac{u_1 y_{1j} + u_2 y_{2j} + \cdots + u_s y_{sj}}{v_1 x_{1j} + v_2 x_{2j} + \cdots + v_m x_{mj}} \leq 1$$
$$v_1, v_2, \ldots, v_m \geq 0$$
$$u_1, u_2, \ldots, u_s \geq 0$$
$$j = (1,2,3, \ldots, N) \qquad (1)$$

One of the features of the DEA model is its return to scale structure. Returns to scale can be constant or variable. Constant return to scale means that an increase in the input value leads to an increase in output by the same ratio. In variable return to scale, the increase in output is more or less than the increase in input. The [6] model (model (1)) was one of the models of constant return to scale. In this model, u is the weights of the products, v is the weights of the factors of production, y is the quantity of products, and x is the quantity of inputs. N indicates the number of firms, s, the number of outputs, m, the number of inputs and θ the efficiency coefficient of the unit under study. This equation is a nonlinear model and can be solved by numerous optimal analyses. This model can be converted to a linear model by linear transformation. The models obtained by this analysis are defined as input-oriented models [14]. In input-oriented models, while the output is kept constant at the maximum amount, it is tried to decrease the amount of inputs in order to approach the efficiency limit. Another method of solving equation (1) is to fix the numerator of the objective function ratio to a fixed number. Such models are also defined as output-oriented models. Which model to consider depends entirely on focusing on inputs or outputs [19].
Since dual problems require fewer constraints, the duality solution of problem (1) is preferred as follows:

$$\min \theta$$
s.t:
$$-y_i + Y\lambda \geq 0$$
$$\theta x_i - x\lambda \geq 0$$
$$\lambda \geq 0 \qquad (2)$$

λ is a vector consisting of constant numbers and weights of the reference set. θ shows the efficiency scores obtained for the firm between zero and 1. Y is an s × n matrix of outputs and x is the m × n matrix of inputs, where n is the number of firms. The data envelopment analysis model with the assumption of variable returns to scale obtains technical efficiency consisting of pure technical efficiency (managerial efficiency) and scale efficiencies. Accordingly, in order to create the variable return to scale (VRS) model, it will be sufficient to add NIλ = 1 constraint to the problem (2). According to this,

$\min\theta$

s.t:

$-y_i + Y\lambda \geq 0$

$\theta x_i - x\lambda \geq 0$

$NI\lambda = 1$

$\lambda \geq 0$ (3)

These models are also described as BCC models [8]. Although the BCC model is a model with a variable constraint to scale, it does not show that the firm operates in a zone of increasing or decreasing return to scale. To solve this, instead of the variable return to scale constraint, non-increasing return to scale constraint (NIλ≤1) can be added to the BCC model (problem (3)). According to this;

$\min\theta$

s.t:

$-y_i + Y\lambda \geq 0$

$\theta x_i - x\lambda \geq 0$

$NI\lambda \leq 1$

$\lambda \geq 0$ (4)

In this model, the type of return to scale (increasing or decreasing) in the scale inefficiency of a particular firm is realized by comparing the technical efficiency of non-increasing return to scale with the technical efficiency of variable return to scale. Accordingly, if they are equal to each other, the firm will be faced with decreasing returns to scale. On the contrary, the condition of increasing return to the scale in the firm will remain valid [9].

Metafrontier

The concept of metafrontier production was first introduced by [12, 13]. They assumed that there is a metafrontier of production technology in the whole industry that surrounds all the separate groups with different technologies. According to the mathematical definition of [13], the metafrontier production function can be defined as a cover for certain neoclassical production functions. The concept of cross-border production is based on the simple assumption that all firms have potential access to the best technology in the industry, although these firms actually use different technologies in different groups. Suppose that X and Y are input and output column vectors with dimensions N and M (non-negative real numbers), respectively. Consider the case where K (>1) groups exist and firms in each group operate under a specific group technology T^k (per k = 1, 2,…,K).

$T^* = \text{Convex Hull}\{T^1 \cup \ldots \cup T^k\}$

K is the number of available technologies and technology set T consists of all output vectors that can be generated using a non-negative input vector. This technology set is defined as follows:

$T = \{(x, y): x, y \geq 0\ ;\ x\ can\ produce\ y\}$

The convex frontier of group k is constructed using the DEA method using all observations of firm input and output in group k. If there are L firms in K groups and T periods, the DEA problem with the input-oriented approach assuming VRS is as follows:

$Min\ \rho_{it}$

$\lambda_{it}\ ,\rho_{it}$

s.t:

$Y_{it} + Y'\lambda_{it}\ \geq 0$

$\rho_{it}X_{it} - X''^{\lambda_{it}} \leq 0$

$J\lambda_{it} = 0$

$\lambda_{it} \geq 0$ (5)

Here Y_{it} is the output value for the firm i in the t period, X_{it} is the $N \times 1$ vector of input value of firm i in the t period, Y is $L_kT \times 1$ vector of L_k firm output value in the period t, X is the matrix with $L_kT \times N$ dimension of the input value for the firm L_k in the t period, J is $L_kT \times 1$ vectors of units and ρ_{it} is an scalar. It can be shown that the value of ρ_{it} obtained from solving the linear programming problem (5) is not less than 1 and provides information about the technical efficiency of firm i in period t. In particular, $\frac{1}{\rho_{it}}$ is the maximum relative reduction possible in inputs if firm i's output value is kept constant in period t. Therefore, ρ_{it} is the measure of input-oriented technical efficiency by solving the linear programming problem (5). The value of λ_{it}, which solves the linear programming problem (5), provides information about the references of firm i in period t. These references are the efficiency points that determine the frontier procedure on which the best inputs and outputs of firm i in period t are identified.

Solving the linear programming problem (5) separately for each firm in its own group and in each time period, identifies all the frontier procedures of the k group. To obtain metafrontier efficiency, linear problem (5) is applied to all firms in all t periods regardless of the specific group [17].

Finally, by estimating the technical efficiencies of firms with respect to metafrontier and group frontiers, it is easy to estimate the technology gap ratio at certain levels of input and output. The input-oriented technical efficiency of an observed pair (x,y) is defined according to the k-group technology as follows:

$$TE_i^k = \frac{1}{D_i^k(x,y)}$$

If the technical efficiency of a (x,y) given is measured to be 0.6, it means that y can be produced using 60% of the input vector x. The input-axis technology gap ratio can be defined using the input distance functions of T* and T^k technology as follows:

$$TGR_i^k(x,y) = \frac{D_i^k(x,y)}{D_i^*(x,y)} = \frac{TE_i^*(x,y)}{TE_i^k(x,y)}$$

Accordingly, the technology gap ratio of each group is obtained by dividing the metafrontier technical efficiency by the group technical efficiency. Since the metafrontier technical efficiency scores are not higher than the group technical efficiency scores, the technology gap rate can take numbers between zero and 1. This ratio is always between zero and 1, and is equal to 1 when the frontier of group technology over the input and output vectors x and y, coincides with the metafrontier. When data are available, the frontier may be estimated using a non-parametric technique such as Data Envelopment Analysis (DEA) or a parametric random approach such as Stochastic Frontier Analysis (SFA) [4].

RESULTS AND DISCUSSIONS

Considering the latest and available up-to-date data common to all considered variables according to the World Bank and and Food and Agriculture Organization databases, 2017 data, in this study, the technology gap ratio and technical efficiency differences in the agriculture sector of developing countries were tried to be stated. In the study, the agricultural sector value added of the countries was used as the only output variable. For the input variables, a total of three variables as the number of countries agricultural sector labor force, the agricultural sector capital stock and also the agricultural land used by the countries are used.

In order to reveal the technology gap and technical efficiency differences in countries, they were categorized into different groups according to their per capita income. Considering that there are four groups as lower middle, low, upper middle and high income countries according to the World Bank distinction, this distinction has been adhered to in the study and these four groups were discussed. According to the World Bank report, there are 145 developing countries in total. Of these, 131 countries were In order to reveal the technology gap and technical efficiency differences in countries, they were categorized into different groups according to their per capita income. Considering that there are four groups as lower middle, low, upper middle and high income countries according to the World Bank distinction, this distinction has been adhered to in the study and these four groups were discussed. According to the World Bank report, there are 145 developing countries in total. Of these, 131 countries were included in the analysis and 14 countries were excluded due to missing data. Of these 131 countries, 31 countries are in the low-income group, 43 in the lower middle income group, 40 in the upper middle income group, and 17 in the high income group.

The data required for the variables used in the study were obtained from the Food and Agriculture Organization (FAO) and World Bank databases. Using [7] DEAP 2.1 and Excel 2013 programs, an input-oriented model is estimated with the assumption of variable return to scale (VRS).

The highest, lowest and average technical efficiency and technology gap ratios of the group countries are given in Table 1. Looking at the results in the table, the group technical efficiency average is 0.646 in upper middle income countries and 0.539 in low income countries. This means that upper middle income countries produce 64.6% of maximum output under group technology, while low income countries produce only 53.9% of maximum output under group technology. When it is considered, it is seen that the group technical efficiency averages are almost close to each other in terms of group countries and the difference between them is not much.

Table 1. Group and Metafrontier Average Efficiency Values

Country Groups	Efficiency	Mean	Minimum	Maximum
High Income	TE^k	0.563	0.024	1.000
	TE^*	0.547	0.023	1.000
	TGR	0.960	0.622	1.000
Upper Middle Income	TE^k	0.646	0.068	1.000
	TE^*	0.343	0.008	1.000
	TGR	0.474	0.019	1.000
Lower Middle Income	TE^k	0.552	0.067	1.000
	TE^*	0.372	0.011	1.000
	TGR	0.563	0.090	1.000
Low Income	TE^k	0.539	0.083	1.000
	TE^*	0.102	0.001	1.000
	TGR	0.139	0.012	1.000

TE^k = group technical efficiency, TE* = metafrontier technical efficiency, TGR = Technology Gap Ratio.
Source: Research Findings.

Looking at the average values of metafrontier technical efficiency, the highest average belongs to high-income countries with 0.547 and the lowest average belongs to low income countries with 0.102 again. If interpreted similarly, while high income countries produce an average of 54.7% of potential output under Metatechnology, low income countries only produce an average of 10.2% of potential output using Metatechnology. Contrary to group technical efficiency averages, metafrontier technical efficiency averages show that the difference between group countries is large and this shows that countries with different income have technology differences.

Considering the results in Table 1, the highest value of group and metafrontier technical efficiency was 1 among all group countries.

This means that at least one country's group frontier in each group is tangent to the metafrontier function in the period under consideration. In other words, the group technology used by at least one country in that group is the same as metatechnology.

The average technology gap ratio was 0.960 in high-income countries, higher than the average in other country groups. This indicates that the technology gap in the agricultural sector was much lower (4%) in high income countries that year. This gap averaged 52.6% in upper middle income countries, 43.7% in lower middle countries, and 86.1% in low income countries. On the other hand, the technology gap ratio (TGR) maximum value is 1 for all country groups. This means that at least one country in each group has group technical efficiency and metafrontier technical efficiency values equal to 1. In other words, it means that at least one country in each group has no technology gap.

Technology gap ratio averages of group countries are shown in Figure 1.

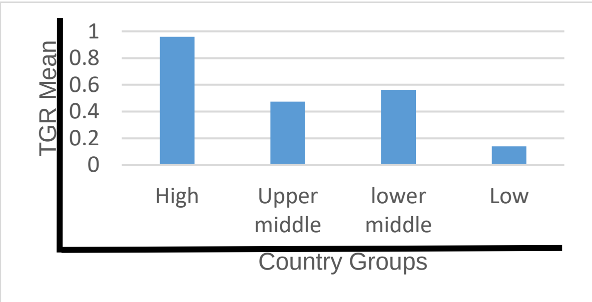

Fig. 1. TGR Average of Group Countries
Source: Research Findings.

Table 2. Technical Efficiency and Technology Gap Ratios of High Income Countries Group

Country	TE^k	TE^*	TGR
Argentina	1.000	1.000	1.000
Bahamas	1.000	1.000	1.000
Bahrain	1.000	1.000	1.000
Barbados	1.000	1.000	1.000
Brunei Darussalam	0.915	0.891	0.974
Chile	0.281	0.261	0.929
Israel	0.375	0.375	1.000
Kuwait	0.767	0.756	0.986
Latvia	0.050	0.050	1.000
Lithuania	1.000	0.915	0.915
Oman	0.070	0.070	1.000
Panama	0.039	0.039	1.000
Republic of Korea	1.000	1.000	1.000
Saudi Arabia	0.275	0.171	0.622
Trinidad and Tobago	0.328	0.305	0.930
United Arab Emirates	0.441	0.441	1.000
Uruguay	0.024	0.023	0.958
Mean	***0.563***	***0.547***	***0.960***

Source: Research Findings.

Technical efficiency, metafrontier technical efficiency and technology gap ratios of the countries within the groups are shown in Table 2, Table 3, Table 4 and Table 5.

Table 3. Technical Efficiency and Technology Gap Ratios of Upper Middle Income Countries Group

Country	TE^k	TE^*	TGR
Albania	0.611	0.121	0.198
Algeria	0.417	0.303	0.727
Azerbaijan	0.782	0.516	0.660
Belarus	0.270	0.028	0.104
Belize	0.530	0.121	0.228
Bosnia and Herzegovina	0.356	0.028	0.079
Botswana	0.303	0.269	0.888
Brazil	1.000	1.000	1.000
Bulgaria	0.708	0.061	0.086
China. mainland	1.000	1.000	1.000
Colombia	0.314	0.246	0.783
Costa Rica	0.853	0.575	0.674
Cuba	1.000	0.576	0.576
Dominican Republic	0.547	0.103	0.188
Ecuador	1.000	0.897	0.897
Equatorial Guinea	0.784	0.075	0.096
Fiji	0.421	0.083	0.197
Gabon	1.000	0.097	0.097
Guatemala	0.603	0.110	0.182
Guyana	0.641	0.063	0.098
Iran (Islamic Republic of)	0.770	0.666	0.865
Iraq	0.191	0.034	0.178
Jamaica	1.000	0.136	0.136
Jordan	0.893	0.129	0.144
Kazakhstan	0.753	0.329	0.437
Lebanon	0.679	0.137	0.202
Libya	0.429	0.008	0.019
Malaysia	1.000	1.000	1.000
Maldives	1.000	1.000	1.000
Mauritius	0.827	0.282	0.341
Montenegro	1.000	0.987	0.987
Mexico	0.438	0.399	0.911
Paraguay	0.173	0.011	0.064
Peru	0.268	0.185	0.690
Russian Federation	0.458	0.430	0.939
South Africa	0.068	0.013	0.191
Suriname	0.766	0.281	0.367
Thailand	0.713	0.463	0.649
Turkey	1.000	0.909	0.909
Turkmenistan	0.257	0.049	0.191
Mean	***0.646***	***0.343***	***0.474***

Source: Research Findings.

Looking at the results in the Tables 2, 3, 4 and 5, we may notice 6 countries in high income countries, 10 countries in upper middle income countries, 14 countries in lower middle income countries and 7 countries in low-income countries are seen as the countries that define the group frontier.

Table 4. Technical Efficiency and Technology Gap Ratios of Lower Middle Income Countries Group

Country	TE^k	TE^*	TGR
Angola	0.279	0.235	0.842
Bangladesh	1.000	0.932	0.932
Bhutan	1.000	0.590	0.590
Bolivia (Plurinational State of)	0.299	0.209	0.699
Cabo Verde	0.504	0.147	0.292
Cambodia	0.158	0.053	0.335
Cameroon	0.089	0.029	0.326
Congo	0.092	0.011	0.120
Cöte d'Ivoire	0.067	0.022	0.328
Djibouti	0.095	0.024	0.253
Egypt	1.000	0.398	0.398
El Salvador	0.145	0.048	0.331
Eswatini	0.212	0.083	0.392
Georgia	0.595	0.358	0.602
Ghana	0.265	0.169	0.638
Honduras	0.153	0.049	0.320
India	1.000	1.000	1.000
Indonesia	1.000	1.000	1.000
Kenya	0.510	0.420	0.824
Kyrgyzstan	1.000	1.000	1.000
Lao People's Democratic Republic	0.214	0.066	0.308
Lesotho	0.133	0.046	0.346
Mauritania	0.096	0.013	0.135
Mongolia	0.296	0.220	0.743
Morocco	0.309	0.223	0.722
Myanmar	1.000	0.629	0.629
Nigeria	1.000	0.864	0.864
Pakistan	0,842	0,809	0,961
Palestine	1,000	1,000	1,000
Papua New Guinea	0,945	0,547	0,579
Philippines	0,758	0,443	0,584
Sao Tome and Principe	0,816	0,273	0,335
Solomon Islands	0.675	0.176	0.261
Sri Lanka	0.421	0.140	0.333
Sudan	1.000	1.000	1.000
Timor-Leste	0.166	0.052	0.313
Tonga	1.000	0.334	0.334
Tunisia	0.070	0.023	0.329
Ukraine	0.412	0.351	0.852
Uzbekistan	1.000	0.851	0.851
Vanuatu	1.000	0.090	0.090
Viet Nam	1.000	1.000	1.000
Zambia	0.132	0.057	0.432
Mean	***0.552***	***0.372***	***0.563***

Source: Research Findings.

Table 5. Technical Efficiency and Technology Gap Ratios of Low Income Countries Group

Country	TE^k	TE^*	TGR
Afghanistan	0.193	0.032	0.166
Benin	0.330	0.031	0.094
Burkina Faso	0.354	0.028	0.079
Burundi	0.470	0.036	0.077
Central African Republic	0.564	0.013	0.023
Chad	0.096	0.007	0.073
Comoros	1.000	0.176	0.176
Democratic Republic of the Congo	0.291	0.035	0.120
Ethiopia	1.000	1.000	1.000
Gambia	1.000	0.040	0.040
Guinea	0.974	0.038	0.039
Guinea-Bissau	0.771	0.027	0.035
Haiti	0.504	0.050	0.099
Liberia	1.000	0.079	0.079
Madagascar	0.311	0.027	0.087
Malawi	0.231	0.019	0.082
Mali	0.155	0.010	0.065
Mozambique	0.087	0.007	0.080
Nepal	1.000	0.095	0.095
Niger	0.171	0.006	0.035
Rwanda	1.000	0.424	0.424
Senegal	0.354	0.020	0.056
Sierra Leone	0.408	0.033	0.081
Somalia	0.083	0.001	0.012
Syrian Arab Republic	0.234	0.011	0.047
Tajikistan	0.937	0.384	0.410
Togo	1.000	0.048	0.048
Uganda	0.376	0.031	0.082
United Republic of Tanzania	0.927	0.146	0.157
Yemen	0.744	0.301	0.405
Zimbabwe	0.137	0.007	0.051
Mean	***0.539***	***0.102***	***0.139***

Source: Research Findings.

In these countries, the technical efficiency is 1, which shows that these countries are technically fully efficient. Group technical efficiency of Turkey is equal to 1, therefore, it is among the frontier determiner countries. This means that Turkey, under group technology is used the production factors fully and efficiently.

Looking at the metafrontier efficiency results, 5 countries in high income countries, 4 countries in upper middle income countries, 6 countries in lower middle income countries and 1 country in low income countries are among the countries that define this frontier. The metafrontier technical efficiencies of these countries are equal to 1, which indicates that they are technically efficient among all countries considered, regardless of which group of countries they are in. Turkey's metafrontier technical efficiency was 0.909 and this means that among all countries Turkey used 90.9% of the production factors efficiently. In other words, under the technology set (metatechnology), can produce only 90.9% of the agricultural sector production.

Under group technology, it seems that Turkey is working full efficient and under the metatechnology its efficiency has been decreased. However, it notable that there is little difference between group efficiency and metafrontier efficiency in the real sense. On the other hand, some countries that are fully efficient within their groups have also come to the conclusion that they do not have the same efficiency among all countries and work inefficiently.

Looking at the technology gap ratios (TGR) in the groups, it is seen that there are countries where this ratio is equal to maximum 1. This indicates that the group frontier function in these countries is tangent to the metafrontier function and therefore there is no technology gap in those countries. Accordingly, it is observed that there is no technology gap in 10 countries in the high income group, 4 countries in the upper middle income group, 6 countries in the lower middle income group and 1 country in the low income group. In other words, these countries have the potential to access metatechnology. This means that they can reach the same amount of potential products using either group technology or metatechnology. This is inevitable in technically fully efficient countries. However, in high income group countries, although the countries of Israel, Latvia, Oman, Panama and United Arab Emirates have low efficiency, the technology gap ratio was equal to 1 in these countries. This shows that although these countries do not produce fully efficient but it is not important what technology (group technology or metatechnology) these countries use to achieve potential output. Because whatever technology they use they produce the same level of output. Countries similar to this situation did not appear in other country groups.

Turkey's technology gap ratio (TGR) was 0.909. This means that, using given input set and group technology, Turkey's output will achieve 90.9% of the output it will achieve using the same input set and metatechnology. In other words, while Turkey can pro-duce all output using its own group technology, with same inputs it can produce only 90.9% of the output using metatechnology. For Turkey, there is difference between group technology and metatechnology but it is obviously that this difference is not a lot.

When the TGR results of the group countries are examined, it has been revealed that the income levels of the countries have an effect on the technology they use. As a result, the dominant technology for these four groups is that of high income countries technology. Because more countries in this group of countries have a technology gap ratio (TGR) equal to 1, which shows that there is no technology gap in these countries. In other words, the potential output obtained by group technology in these countries can also be obtained by using metatechnology. Since the countries with high technology in today's world generally consist of countries with high income and countries with more research and development expenditures, the results obtained (except for a few countries) can also be considered valid.

CONCLUSIONS

The agricultural sector is defined as one of the most important sectors, especially in developing countries. Due to its extensive links with other economic sectors, the growth of this sector can lead to wealth creation, market creation and foreign exchange return, as well as industrial growth. In this study, technical efficiency and technology gap ratios in agriculture sectors according to the income levels of developing countries are discussed in four different income groups for 2017. In the study, the technical efficiency of the countries within the group was examined by estimating the group production frontier of the countries. With the findings obtained here, when the gap between the technical efficiency of each country in the group and the efficiency of the best country (technically the most efficient country) in that group is closed, it has been tried to show how much they can produce with the same technology without increasing the input. Accordingly, it was possible to increase production by 43.7% on average in the high income group, 35.4% in the upper middle income countries, 44.8% in the lower middle income countries and 46.1% in the low income group countries.

As it is thought that different technologies are used in the agricultural sector in terms of income levels of the countries in the groups, the metafrontier approach is also considered to compare the efficiency and technological gap between the groups. The results obtained here show how much production can be increased for that group without increasing inputs when the gap between technology and metatechnology of each group is eliminated. According to the results, if technology in group countries rises to metatechnology, it can be expected to increase production by an average of 4% in high income countries, 52.6% in upper middle income countries, 43.7% in lower middle income countries and 86.1% in low-income countries. These results show that the technology gap ratio (TGR) is only 96% in high income countries and therefore the technology used by these countries is closer to metatechnology and therefore the gap in production is less (4%). In other words, countries in this group can produce 96% of the output that can be produced with metatechnology, using the existing technology. Looking at the results, it is also understood that the production gap in low income countries is higher than other groups (86.1%) and therefore the technology gap ratio (TGR) is lower (13.9%) and therefore the technology used by these countries is farther from metatechnology. Thus, it has been concluded that the technological gap ratio in the agricultural sector of developing countries is higher in high-income countries and lower in low income countries. The results here can guide the politicians in the agricultural sector and increase the production level in this sector by improving production techniques both with the optimal use of existing resources and with incentive policies.

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