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USING MALMQUIST TOTAL FACTOR PRODUCTIVITY METHOD FOR AGRICULTURAL SECTOR EFFICIENCY OF MIKTA COUNTRIES

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ABSTRACT

MIKTA is a diverse and cross-regional grouping of powers that brings together Mexico, Indonesia, the Republic of Korea, Turkey and Australia. MIKTA countries are significant economic powers and all are members of the Group of Twenty. Bye the way, agricultural development is one of the most powerful tools to finish extreme poverty, improve shared prosperity, and find food for a forecasted 9.7 billion people by 2050. But agricultural growth, reduction in powerty and food security are at risk. Recent shocks such as COVID-19 related disruptions to extreme weather, pests and conflicts are all affecting food systems, resulting in inflation and increasing hunger. Increasing climate change could further reduce yields, especially in the food insecure regions around the world. So, the research aims whether the agricultural sector performs well or not within the MIKTA countries which are thought of bearing significant importance for their relavant continents. In this meaning, data for MIKTA countries throughout 2018 and 2019 from World Bank has been taken. Here, agricultural land, rural population and rural population percent of total population are inputs. On the other hand, agriculture, forestry, and fishing value added is the output of the DEA model. Then, analysis have been done using Malmquist Total Factor Productivity Method (MTFPM), super efficiency measures have been found out and ineffective countries in MIKTA have been detected.

Keywords: MIKTA, MTFPM, Super Efficiency, Agriculture, DEA

JEL-Classifications: C81, C61, C67

1. INTRODUCTION

MIKTA, It is an informal consultation and coordination platform between Mexico, Indonesia, South Korea, Turkey and Australia. The first Foreign Ministers meeting of MIKTA, which was implemented on September 25, 2013, within the framework of the general meetings of the 68th UN General Assembly, was also held on the aforementioned date. Since its inception, MIKTA has routinely convened three times a year at the level of Foreign Ministers. MIKTA does not have a secretariat, and the coordination of MIKTA meetings is provided by the country, the MIKTA Term President, who is elected by rotation every year. In 2022, the Presidency of MIKTA was transferred to Turkey by Australia. Turkey's MIKTA Presidency is global health, effective migration management and food security.

All five countries included in MIKTA are members of the G20 and are open economies with a democratic and pluralistic system. The five countries, which are active actors in their regions, make significant contributions to regional and global peace and stability, and often follow similar and constructive approaches in the face of international problems.

Sustainable development plays a key role for MIKTA countries. For sustainable development, sustainable agriculture is vital. For this reason, agriculture systems around the world must become efficient and less wasteful.

Land, healthy soils, water and plant resources are important basic inputs into food producing, and their increasing scarcity makes it mandatory to manage them sustainably.

In the next part, literature survey about the productivity concept in agriculture sector has been done.

2. LITERATURE SURVEY

Hayami and Ruttan (1970) studied 38 developed and underdeveloped countries agricultural productivity using the Cobb-Douglas production function. Without using data envelopment analysis and Malmquist Efficiency Index to measure productivity, this study has been reference to many other following studies.

Luh and Stefanou (1991) used indexing and econometric methods to study efficiency of agriculture growth in the United States between 1948 and 1982. Thirtle and Bottomley (1992) studied the chained efficiency indexing methodology to examine United Kingdom agricultural efficiency during the 1967 -1990 period. Huffman and Evenson (1992) proposed econometric evidence on the improvement of public and private research to US agricultural efficiency between 1950-1982. Bureau, Färe, and Grosskopf (1995) analyzed three non-parametric measures of agricultural efficiency using data on some European countries and United States during the period from 1973 to 1989. Craig, et al (1997) using a data set 98 countries and 13 geo-political regions developed measure of land and labor efficiency over the period 1961 to 1990. Echevarria (1998) looked into the value land, labor and capital in agriculture using Canadian data between 1971-1991. Ball, et al (1999) analyzed efficiency in agriculture by assessing the contributions of each state in the United States for productivity growth. The study included the 48 states between 1960-1990. Pfeiffer (2003) studied productivity growthof agriculture in Andean Community. He found that the negative productivity growth in agriculture is because of geographical, social or political circumstances. Stewart et al (2009) studied the growth rates of agricultural output, aggregate input use and total factor productivity in crops and livestock production and found variations in total factor productivity growth between Canadian Provinces. Fuglie (2010) examined a wide global and regional view of agricultural total factor productivity growth between 1961 and 2007 using data on 171 countries. The study used econometric methods. Öztop and Uçak (2017) applied a DEA-based Malmquist index to measure technical efficiency and total factor productivity change of food and agriculture firms quoted at Borsa Istanbul (BIST) between 2010 and 2015 period.

3. DATA ENVELOPMENT ANALYSIS and MALMQUIST PRODUCTIVITY INDEX

Productivity, in the most general terms, is the relationship between the output produced by a production or service system and the input used to obtain this output (Prokopenko, 1998: 3). Total factor productivity (TFP) is defined as the ratio of the total output obtained as a result of a certain production activity to the production factors used in obtaining this output (Kuruüzüm and Kaya, 2011: 344). Change in total factor productivity (CTFP) is divided into two parts: change in technical efficiency and change in technology. High technical efficiency and technological progress increase total factor productivity. One of the most frequently used methods to measure total factor productivity is the Malmquist productivity index.

DEA (data envelopment analysis) is used to calculate the Malmquist productivity index. This method was developed by Charnes, Cooper and Rhodes in 1978. This method compares the units of production that are assumed to be homogeneous among themselves. After accepting the best observation as the efficiency limit, the other observations are evaluated according to this most effective observation. While DEA takes place for any given moment, the Malmquist Efficiency Index takes into account the time dimension. This index is a powerful method used to measure the performance of especially public sector and non-profit organizations.

Malmquist productivity index is obtained by adding distance functions to the Farrel technical efficiency criterion. The index measures the change in TFP of two observations as the ratio of the distances to a common technology. The distance function is used for this measurement. This index was first discovered by Malmquist in 1953 and developed by Caves, Christensen, Dievert, Fare, and Groskopf. Index is superior to traditional total factor productivity indices because it uses data on quantities, requires fewer assumptions, measures inefficiency, does not require econometric estimation, and is simpler to implement.

The Malmquist total factor productivity index measures the change in total factor productivity of two observations as the ratio of the distances to a common technology. The "distance function" is used for this measurement. This index, developed by Caves et al., was named Malmquist after Sten Malmquist, who first suggested the idea of indexing with the help of distance functions. (Caves, Christensen, Diewert, 1982a:73-86; Caves, Christensen, Diewert, 1982b:1394-1414; Malmquist, 1953:209-242). The distance function is used to describe multi-input multi-output production technologies without specifying goals such as cost minimization or profit maximization. Distance function to the output

$$d(x,y) = \min\{\delta : (y/\delta) \in S\} \tag{1}$$

The values of the distance function d(x,y) will be 1.0 if the vector y is on the limit S (production limit); >1.0 if vector y describes a technically inactive point in S; and <1.0 if the vector y describes an impossible point other than S.

According to the output between the base period s and the following period t, following Mouse et al., the Malmquist TFVD index, within the framework of the "distance function", is,

$$m(Y_s, X_s, Y_t, X_t) = \sqrt{\left[\frac{d^s(Y_t, X_t)}{d^s(Y_s, X_s)} \times \frac{d^t(Y_t, X_t)}{d^t(Y_s, X_s)}\right]} \tag{2}$$

Here in (2), $d^s(X_t, Y_t)$ expresses the distance of the t-period observation from the s-period technology.

If the value of the m(.) function is greater than 1.0, it indicates that there is an increase in TFP from the s period to the t period, and if it is less than 1.0, when the same periods are taken into account, there is a decrease in the TFP. The above equation can be written as :

$$m(Y_s, X_s, Y_t, X_t) = \frac{d^t(Y_t, X_t)}{d^s(Y_s, X_s)} \sqrt{\left[\frac{d^s(Y_t, X_t)}{d^t(Y_t, X_t)} \times \frac{d^s(Y_s, X_s)}{d^t(Y_s, X_s)}\right]} \tag{3}$$

The first term on the right-hand side of the equation is the measure of Farrell's change in total technical efficiency between period s and period t. The expression in parentheses represents the technical change. Hence, the change in technical efficiency is

$$\frac{D_o^t(x^t, y^t)}{D_o^s(x^s, y^s)} \tag{4}$$

Then, the change in technological efficiency is

$$\left[\left(\frac{D_o^s(x^t, y^t)}{D_o^t(x^t, y^t)}\right)\left(\frac{D_o^s(x^s, y^s)}{D_o^t(x^s, y^s)}\right)\right] \tag{5}$$

Technological change (TED) measures the change in technology between two periods. The TED index gives the degree of progress resulting from innovations between the two periods. At the same time, the production frontier curve shows technological change (innovation). The value of this index is greater than 1 in case of increase in efficiency between two periods, and less than 1 in case of decrease in efficiency. In order to be able to calculate for two consecutive periods in an empirical study, all four distance functions must be found. This calculation can be done with mathematical programming. A comprehensive review of the Malmquist TFV index was done by Fare et al.

Mathematical programming models developed by Fare et al., which is the most used approach today in the calculation of distance functions used for the TFP index, are given below with matrix notation: (Fare, Grosskopf, Norris, Zhang, 1994: 66-83).

$$\begin{array}{ll} \left[d^t(y_t, x_t)\right]^{-1} = \max_{\phi,\lambda} \ \phi & \left[d^s(y_s, x_s)\right]^{-1} = \max_{\phi,\lambda} \ \phi \\ st & st \\ -\phi y_{it} + Y_t\lambda \geq 0 & -\phi y_{is} + Y_s\lambda \geq 0 \\ x_{it} - X_t\lambda \geq 0 & x_{is} - X_s\lambda \geq 0 \\ \lambda \geq 0 & \lambda \geq 0 \end{array} \tag{6}$$

$$\begin{array}{ll} \left[d^t(y_s, x_s)\right]^{-1} = \max_{\phi,\lambda} \ \phi & \left[d^s(y_t, x_t)\right]^{-1} = \max_{\phi,\lambda} \ \phi \\ st & st \\ -\phi y_{is} + Y_t\lambda \geq 0 & -\phi y_{it} + Y_s\lambda \geq 0 \\ x_{is} - X_t\lambda \geq 0 & x_{it} - X_s\lambda \geq 0 \\ \lambda \geq 0 & \lambda \geq 0 \end{array} \tag{7}$$

Calculating the distance values defined above for all periods and observations requires the solution of n(3t-2) linear programming models.

4.APPLICATION

In the application, data for MIKTA countries throughout 2018 and 2019 from World Bank has been taken. Relavant data is given below. Here, agricultural land, rural population and rural population percent of total population are inputs. On the other hand, agriculture, forestry, and fishing value added is the output of the DEA model. Comparison is carried out for two years, namely 2018 and 2019. Figure 1 shows input and ouput relation for the DEA model assumed. By the way, agricultural land is uncontrolled input.

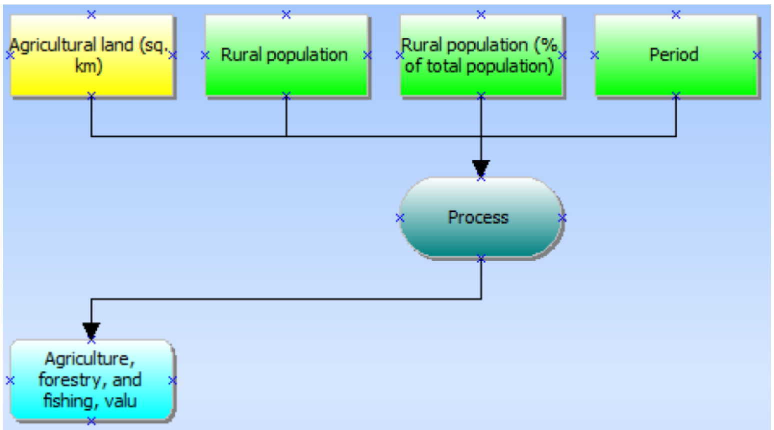


Figure 1. Input-Output Model for DEA

Table 1: Data Collected on World Bank

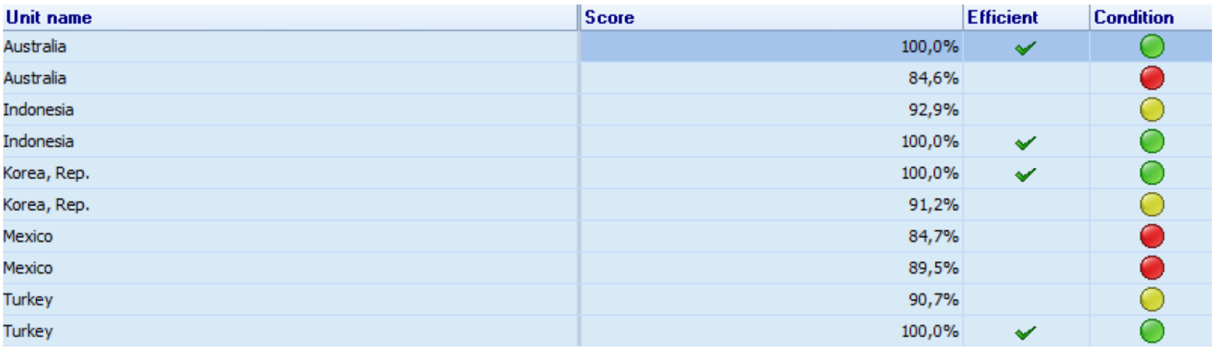
Country Name	Agricultural land (sq. km)	Rural population	Rural population (% of total population)	Agriculture, forestry, and fishing, value added (current US$)	Period
Mexico	1068910	25041299	19,844	41363853453	2018
Indonesia	623000	119581818	44,675	133499323604,59	2018
Korea, Rep.	16520	9568386	18,541	30122762381	2018
Turkey	378020	20467276	24,857	44964632176	2018
Australia	3588950	3494578	13,988	35110456554	2018
Mexico	1068910	24948670	19,556	43079169729	2019
Indonesia	623000	119115843	44,015	142266719595,99	2019
Korea, Rep.	16520	9602379	18,57	27544594684	2019
Turkey	378020	20331795	24,37	48710180479	2019
Australia	3588950	3519751	13,876	29465741668	2019

Data above at Table 1 has been uploaded on Banxia Frontier Analyst Software and analysis has been done based on CCR technique which is based on constant returns to scale and next then using BCC technique which is based on varying returns to scale. In the next section, efficiency scores for both the CCR and BCC have been computed as follows at Table 2:

Table 2: Efficiency Scores for MIKTA

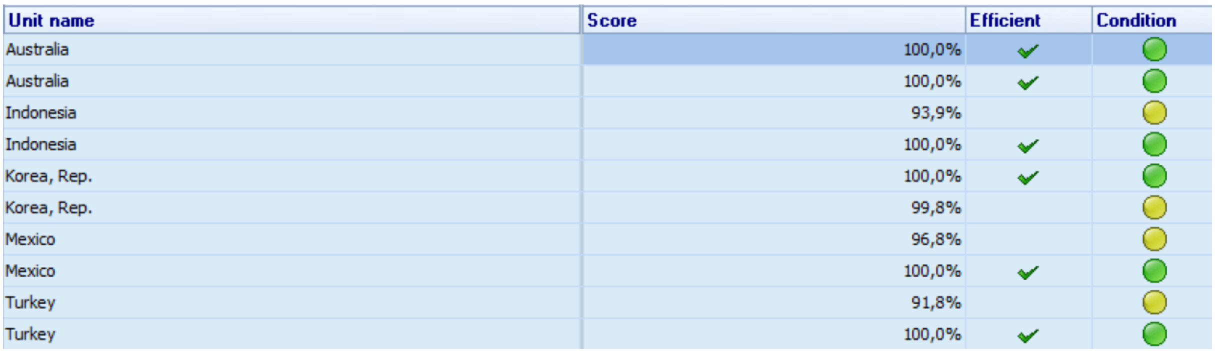
Country	Year	CCR	BCC	Scale Efficiency
Australia	2018	1	1	1
Australia	2019	0,846	1	0,846
Indonesia	2018	0,929	0,939	0,989
Indonesia	2019	1	1	1
Korea	2018	1	1	1
Korea	2019	0,912	0,998	0,914
Mexico	2018	0,847	0,968	0,875
Mexico	2019	0,895	1	0,895
Turkey	2018	0,907	0,918	0,988
Turkey	2019	1	1	1

The table above shows each country performance based on three measures. Here, scale efficiency is found dividing CCR by BCC.



Unit name	Score	Efficient	Condition
Australia	100,0%	✓	
Australia	84,6%		
Indonesia	92,9%		
Indonesia	100,0%	✓	
Korea, Rep.	100,0%	✓	
Korea, Rep.	91,2%		
Mexico	84,7%		
Mexico	89,5%		
Turkey	90,7%		
Turkey	100,0%	✓	

Figure 2. CCR scores and Conditon of Countries



Unit name	Score	Efficient	Condition
Australia	100,0%	✓	
Australia	100,0%	✓	
Indonesia	93,9%		
Indonesia	100,0%	✓	
Korea, Rep.	100,0%	✓	
Korea, Rep.	99,8%		
Mexico	96,8%		
Mexico	100,0%	✓	
Turkey	91,8%		
Turkey	100,0%	✓	

Figure 3. BCC scores and Condition of Countries

In the figures above, good results which are 1 shown by green, satisfactory results are which are close to 1 shown by yellow and poor results are shown by red. In figure 2 above, Australia's 2019 performance and Mexico's performance is bad. Korea's 2019 and Turkey's 2018 CCR efficiency is satisfactory. According to figure 3, all countries show good enough BCC technical efficiency. By the way, when we count the number of red circles, Mexico is by far has the most problems with two red circles at each year. Then, the next question is, how the countries at Figure 2 performing less than 1 (100 percent), can become productive. The answer is at table 3 below.

Table 3. Improvement Summary

Unit name	Score	Actual Agricultural land (sq. km)	Actual Rural population	Actual Rural population (% of total population)	Actual Agriculture, forestry, and fishing, valu	Target Agricultural land (sq. km)	Target Rural population	Target Rural population (% of total population)	Target Agriculture, forestry, and fishing, valu	Percent Agricultural land (sq. km)	Percent Rural population	Percent Rural population (% of total population)	Percent Agriculture, forestry, and fishing, valu
Australia	84,56	3588950	3519751	13,88	29465741668	3006167	2976386,72	11,73	29465741668	-16,2	-15,4	-15,4	0
Indonesia	92,92	623000	119581818	44,67	133499323604,59	623000	111117519,5	41,51	1,33499E+11	0	-7,1	-7,1	0
Korea, Rep.	91,22	16520	9602379	18,57	27544594684	16520	8759421,54	16,94	27544594684	0	-8,8	-8,8	0
Mexico	84,71	1068910	25041299	19,84	41363853453	1068910	21211677,62	16,81	41363853453	0	-15,3	-15,3	0
Mexico	89,53	1068910	24948670	19,56	43079169729	1068910	22336423,64	17,51	43079169729	0	-10,5	-10,5	0
Turkey	90,73	378020	20467276	24,86	44964632176	378020	18569531,52	22,55	44964632176	0	-9,3	-9,3	0

Looking at the Table above, if Turkey in 2018 reduced rular population and percent rular population of total population by 9,3 percent, then would turn out to become productive even with the same level of output. There is no suggestion for agricultural land because it is uncontrolled input.

If Australia in 2019 reduced rular population and percent rular population of total population by 15,4 percent and agricultural land by 16,2 percent, then would turn out to become productive even with the same level of output. If Mexico in 2018 reduced rular population and percent rular population of total population by 15,3 percent, then would turn out to become productive even with the same level of output. If Mexico in 2019 reduced rular population and percent rular population of total population by 10,5 percent, then would turn out to become productive even with the same level of output. The Figure 4 below shows the complete improvements to be made for MIKTA.

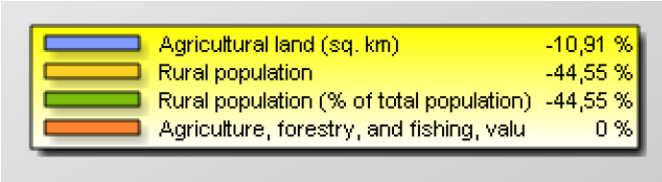


Figure 4. MIKTA Total Improvements

According to the general analysis, MIKTA as a whole should use 10, 91 percent less agricultural land input and 44,55 percent less rural population to become productive as a whole. If we want to measure productivity change based on Malmquist Total Factor Productivity, then we have to make some adjustments based on categorical data which is date on Frontier Analyst as in Figure 5. So we reach, CCR numbers in figure 6 and Malmquist Productivity Change Index for each MIKTA country in figure 7.

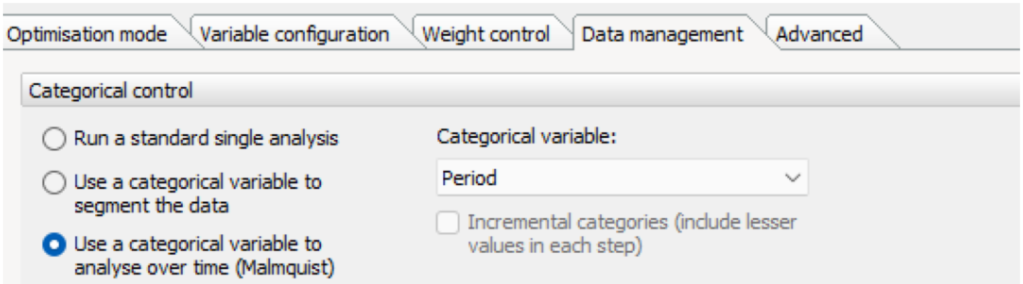


Figure 5. Setting Date as Categorical Variable To Analyze Over Time Using Malmquist

Unit name	Score	Efficient	Condition	Score	Efficient	Condition
Australia	100,0%	✔	●			
Australia				100,0%	✔	●
Indonesia	100,0%	✔	●			
Indonesia				100,0%	✔	●
Korea, Rep.	100,0%	✔	●			
Korea, Rep.				100,0%	✔	●
Mexico	90,9%		●			
Mexico				92,9%		●
Turkey	96,8%		●			
Turkey				100,0%	✔	●

Figure 6. CCR Index For Each Country Using Malmquist Method

Unit name	Malmquist index	Catchup	Frontier shift
Australia			
Australia	0,8395	1,0000	0,8395
Indonesia			
Indonesia	1,0770	1,0000	1,0770
Korea, Rep.			
Korea, Rep.	0,9128	1,0000	0,9128
Mexico			
Mexico	1,0517	1,0219	1,0292
Turkey			
Turkey	1,0980	1,0336	1,0623

Figure 7. Malmquist Productivity Change With Numbers During Years 2018 and 2019

In figure 6, Malmquist Index is a formula of “catch up” multiplied by “Frontier Shift”. Here, catch up for Mexico which is 1,0219 is found by 0,929/0,909 in Figure 6. The catch up for Turkey is 1,00/0,968 = 1,0336. For Australia, Korea and Indonesia,it equals 1. As we analyze it in detail, Turkey, Indonesia and Mexico improves productivity. By the way, Australia and Korea have decreases because of low technological change or frontier shift. However, even though Mexico increases its productivity, the country still is not good enough looking at figure 5. The super-efficiency suggested by Andersen and Petersen (1993), Banker et al. (1989) and Banker and Gifford (1988) is that the best practice frontier is calculated first without evaluating DMU_0. So, DMU_0 may get a value more than 1.

<u>Output Based CCR Super Efficiency Model</u>

$$\max \phi$$

$$s.t.$$

$$\sum_{j=1\, j\neq j_0}^{n} \lambda_j x_{ij} \le x_{i0}, \quad i = 1,\ldots,m \qquad (8)$$

$$\sum_{j=1\, j\neq j_0}^{n} \lambda_j y_{rj} \ge \phi y_{r0}, \; r = 1,\ldots,s$$

$$\lambda_j \ge 0, \quad j = 1,\ldots,n$$

Using frontier analyst, the same data has been applied using super efficiency method in figure 8.

Unit name	Score	Efficient	Condition	Score	Efficient	Condition
Australia	319,1%	✓	🟢			
Australia				291,8%	✓	🟢
Indonesia	166,7%	✓	🟢			
Indonesia				165,7%	✓	🟢
Korea, Rep.	850,9%	✓	🟢			
Korea, Rep.				730,1%	✓	🟢
Mexico	90,9%		🟡			
Mexico				92,9%		🟡
Turkey	96,8%		🟡			
Turkey				112,4%	✓	🟢

Figure 8. Super Efficiency Scores For Each Country

So the next question is what the reason is for Mexico performing poorly in terms of agricultural productivity. Mexico’s agriculture sector suffers from too many of structural inefficiencies. An existence of small farmers continues to decrease efficiency and has prevented the establishment of economies of scale. Different than Brazil or Argentina, Mexico is surrounded by small plots. As a result, agricultural efficiency differs too much from area to area. While the country involves modern fields producing food for United States, Mexico also has large undeveloped areas of land in the poor regions.

Agricultural policy has also given benefit to large-scale producers disproportionately. José Ribero, managing director at Grupo MINSA, told OBG, “Policymakers must understand the different facets of agriculture. They cannot pretend to implement one reform for the whole country, when you have stark differences in the needs of subsistence farmers and industrial agriculture.” “In most Latin American countries infrastructure is a problem in the commercialisation of agricultural products; however, this is not the case in Mexico. Here, the most pressing issue is the lack of technology, including the use of genetically modified organisms (GMOs). If Mexico were to allow the use of GMOs, it could become self-sufficient in agriculture in eight years.” By the way, fertiliser, which is very often imported, is attainable at very high costs in Mexico, making it so difficult for small scale farmers to reach and buy.

5. CONCLUSION

Agricultural policy makers in MIKTA countries by balancing the distribution of the resources may improve agricultural productivity. Thus, in these countries, with the rise of productivity, overall welfare of people may increase. For Turkey, according to the data analysis; priority in increasing efficiency in agriculture is technological progress. By the help of corrections to be made at this point, It is possible to use the most appropriate technology and technological progress can be improved.

In addition, with regular teaching seminars on technology, agricultural producers can be reached and the using of right technologies by the farmers can be achieved. Thus, a great contribution can be made to the country's economy. Besides; for technological progress in the agriculture sector, the domestic agricultural tools and domestic equipments needs to be produced by the country itself. Some agricultural tools and equipment used in the agricultural sector are still imported in Turkey and Mexico. If advanced technological agricultural equipment imported can be produced in Turkey, the agriculture sector, which is still hungry for technology can be further improved.

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