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MEASUREMENT OF EFFICIENCY WITH DATA ENVELOPMENT ANALYSIS AND MALMQUIST TOTAL FACTOR PRODUCTIVITY METHODS: AN APPLICATION ON MAJOR AIRPORTS IN TURKEY

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Abstract:
In this study, the efficiency of major airports in Turkey was measured with Data Envelopment Analysis and Malmquist Total Factor Productivity Index. In this context, the efficiency of 19 Turkish airports which have the most passenger traffic in 2017 was analysed for the 2012-2016 period. Efficiency measurements for each year were applied to the Data Envelopment Analysis and Malmquist Total Factor Productivity Index methods were used to reveal the changes in the yearly activity values of airports. When the results of the analysis are examined, it is seen that 5 airports between the years 2012-2014 and 4 airports between 2015-2016 were effective in the efficiency measurement according to the output-oriented CCR model. According to the output-oriented BCC model, 10 airports in 2012, 2015 and 2016, 11 airports in 2013 and 9 airports in 2014 were found to be effective. According to the Malmquist results, in the period of 2012-2016, an increase in the Total Factor Productivity value of most of the airports was observed. It is thought that this study will guide the relevant airport managers in terms of both operational and financial efficiency.

Key words:
Data Envelopment Analysis, Airports, Total Factor Productivity, Efficiency

INTRODUCTION

The airports can be defined as the transfer points where the passengers switch between different transportation modes, in terms of airlines, airports can be described as areas where airlines perform their operations. On a national or international scale, it can be defined as nodes connecting different transportation points or airports in different countries or cities. Regardless of its definition or description, airports for air transport are indispensable for the system. From a managerial point of view, it is important that airports be sustainable, perform their activities without disrupting the system and use their existing capacity well. When airports in Turkey are observed, it is seen that passengers and freight traffic increase year by year [1]. It is worth researching whether this increase is realized by using airports effectively.

In this study, the largest, according to 2017 passenger traffic, 19 Turkish airports' efficiency measurement for the years between 2012 and 2016 was conducted with Data Envelopment Analysis (DEA). In addition, the Malmquist Total Factor Productivity Index method was applied in order to determine the change in efficiency values from year to year. In the following sections, some of the studies in the literature will be given. Afterwards, the methods used in the research will be explained in detail and then analysis and findings will be included. After the analysis and findings, the results and recommendations section will be given.

1 LITERATURE

There are many studies related to Data Envelopment Analysis and Malmquist Total Factor Productivity methods in the literature. Most fundamentally, while DEA gives the value of activity within a certain period, Malmquist Total Factor Productivity gives the change in the value of the activity within a certain period of time. Although there are studies in which only DEA has been used in the literature, it is possible to find many studies employing DEA and Malmquist Total Factor Productivity together.

When we examine the studies done with DEA, Barros and Dieke conducted the performance evaluation of the airports in Italy and concluded that a large part of the airports subject to the analysis were efficient [2]. Lam et al. examined the operational efficiency levels at the Asia-Pacific airports and stated that the majority of the airports in the region have high efficiency [3]. Yazgan and Karkacıer evaluated the efficiency of 37 Turkish airports between the years 2008 and 2011 [4]. They used inputs such as number of employees, operating costs, terminal area, runway and apron numbers. As outputs, they used operating income, passenger, aircraft and freight traffic. As a result of the research, it has been found that Tekirdağ, Antalya, Milas-Bodrum, Adana and Tekirdağ Çorlu airports are highly efficient for each year observed. Avcı and Aktaş evaluated 2013-2014 summer and winter airport performances with DEA [5]. Research findings show that Ataturk Airport has the highest efficiency in summer and winter periods. When the lowest efficiency values are examined, it is seen that Kars and Sivas airports have the lowest efficiency in summer period and Mugla Dalaman and Milas-Bodrum airports have the lowest efficiency in winter period. Ülkü compared the efficiency levels of Spanish and Turkish airports and concluded that Spanish airports' average efficiency values are higher than Turkish airports' [6]. Bolat et al. have made measurements of efficiency with the DEA and made efficiency estimation by Artificial Neural Networks. In this context, they have viewed 41 airports in Turkey. The results of the study indicate that 19 of the examined airports are efficient [7]. Peker and Baki examined efficiency of Turkish airports with DEA for 2017 [8]. The results of the study indicated that Ankara, Antalya, Adana, Kayseri, Trabzon, Malatya and Denizli airports were efficient. Asker examined the operational efficiency of 10 major airports in Turkey [9]. He concluded that Istanbul Ataturk and Sabiha Gokcen airports were efficient. Zarraga et al. examined the effects of the 2008 crisis on the efficiency of Spanish airports and revealed that there were significant changes in the efficiency of the airports between 2009 and 2010 [10]. Tracey investigated 9 airports in Africa whether the operational efficiency is related to airport size [11]. He concluded that the size is related to the efficiency.

When we look at the studies conducted together with the DEA and Malmquist Total Factor Productivity, it is possible to find different researches in various contexts. Melchor examined the changes in the efficiency of Spanish airports with the DEA and Malmquist [12].

Gillen and Lall employing DEA and Malmquist Index tested efficiency and efficiency changes of the 22 airports in the USA [13]. Fung et al. examined efficiency and efficiency changes of airports in China employing the DEA and Malmquist Index [14]. Research findings show that an average increase in efficiency is 3% year by year. Ar examined the changes in efficiency of airports operated by Turkish General Directorate of the State Airports Authority between the years 2007 and 2011 and found that an average increase of 11.8% was achieved in Total Factor Productivity [15]. Fragoudaki et al. examined the changes in the efficiency of Greece airports in the crisis period with the Malmquist Index and concluded that despite the average increase in the efficiency scores of the airports, there were areas to be developed for efficiency increase at many airports [16]. Keskin and Ulaş investigated whether privatization affects airport performance with AHP-TOPSIS and DEA and concluded that the airports with private ownership have a higher performance [17].

When we look at the studies on DEA at airports seems that operational activity indicators such as the number of employees, number of runways, runway length, terminal area size and number of doors are used. However, in this study, input and output variables that reflect the financial situation such as total income and total expenses are used. This aspect of the study is thought to be distinguished from similar studies.

2 METHODOLOGY

2.1 Data Envelopment Analysis

Data envelopment analysis is a nonparametric efficiency method developed to measure the relative effectiveness of decision making units with similar characteristics [18]. Data envelopment analysis is one of the most commonly used methods in efficiency measurement. DEA uses linear programming to determine the points on the curve obtained using the inputs and outputs of the most efficient enterprise without using a specific production function [19].

The basic principle of data envelopment analysis is to identify the best decision-making units that can be compared and to form the active border. However, it determines the level of effectiveness of decision-making units below the efficiency limit and allows the identification of reference sets to compare inactive units [20].

The data envelopment analysis consists of three stages. These stages; determining the decision-making units to be included in the analysis, selecting input and output variables to be able to measure the efficiency of decision-making units in detail, applying the appropriate DEA models and evaluating the results obtained. The first stage is very important. In this respect, the decision-making units included in the analysis should be units that can convert input variables into output variables and should show homogeneous characteristics [21].

It is very important to determine the number of decision-making units to be included in the analysis in DEA. Although there are different opinions about this issue, the most accepted opinion; the decision-making unit is that the number must be at least twice the total number of inputs and outputs [22]. According to another view, the number of decision-making units should be at least three times the sum of inputs and outputs [23].

CCR and BCC models are used to measure the effectiveness of decision making units in data envelopment analysis. While total efficiency can be measured with the CCR model, technical efficiency and scale efficiency can be calculated with the BCC model [24].

CCR Model

The CCR model, which was first introduced by Charnes, Cooper and Rhodes in 1978, is based on a constant return scale. The CCR model can be used to calculate the total effectiveness of the relevant decision-making units, including technical efficiency and scale efficiency. The mathematical representation of the CCR model is given below [25].

$$Q_k = \max(\theta + \varepsilon \textstyle\sum_{i=1}^{m} S_i^- + \varepsilon \sum_{r=1}^{s} S_r^+) \tag{1}$$

$$\textstyle\sum_{j=1}^{n} X_{ij}\ \beta_j + S_i^- - X_{ik} = 0 \qquad i = 1, \ldots \ldots m \tag{2}$$

$$\textstyle\sum_{j=1}^{n} Y_{rj}\ \beta_j - S_i^- - \beta\, Y_k = 0 \quad r = 1, \ldots .p \quad j = 1, \ldots n \quad i = 1, \ldots .m \tag{3}$$

$$\beta_j \geq 0 \qquad S_i^- \geq 0 \qquad S_r^+ \geq 0$$

where: n - Decision Make Unıt,
s - Number of Output,
m - Number of Input.

BCC Model

The BCC model was first used by Banker Charnes and Cooper in 1984. The BCC model created by adding convexity constraint to the CCR model is based on the scale's variable return assumption. The mathematical representation of the BCC model is given below [26].

$$E_o = Max\big(\theta + \varepsilon \textstyle\sum_{i=i}^{m} S_i^- + \varepsilon \sum_{r=1}^{p} S_r^+ \big) \tag{4}$$

Restrictions,

$$\textstyle\sum_{j=1}^{n} X_{ij}\ \beta_j + S_i^- - X_{ik} = 0 \qquad i = 1,2, \ldots m \tag{5}$$

$$\textstyle\sum_{j=1}^{n} y_{rj}\ \beta_j - \theta Y_{rk} - S_r^+ = 0 \qquad r = 1,2, \ldots p \tag{6}$$

$$\sum_{j=1}^{n} \beta_j = 1 \quad \beta_j \geq 0 \quad S_i^- \geq 0 \quad S_i^+ \geq 0 \quad j = 1,2, \ldots n \quad i = 1,2 \ldots .m \quad r = 1,2, \ldots .p \tag{7}$$

where: n - Decision Make Unıt,
s - Number of Output,
m - Number of Input.

3.2. The Malmquist Total Factor Productivity Index

The Malmquist total factor productivity index is a method used to measure the development of productivity over time and to examine the causes of change. The value of the total factor productivity index is expressed as the change in the total factor efficiency, the value obtained is greater than 1, the total factor efficiency increases, and the total factor efficiency decreases if it is less than 1. The Malmquist total factor productivity index measures the change in efficiency by means of two separate components, the change in technology and the change in technical efficiency. The multiplication of these two components yields a total factor productivity index. The direction of change in the amount of output to be obtained by using the input variable with the same characteristics as the change in technology is investigated. Technical efficiency consists of the efficiency of the scale and pure technical efficiency and it is obtained by multiplication of these indices. While scale efficiency examines whether companies are working at the appropriate scale, pure efficiency measures administrative effectiveness [27].

The Malmquist index is calculated based on the distance function [28]:

$$m(Y_s, X_s, Y_t, X_t) = \sqrt{\left[\frac{d^s(Y_t, X_t)}{d^s(Y_s, X_s)} \times \frac{d^t(Y_t, X_t)}{d^t(Y_s, X_s)} \right]} \tag{8}$$

In the mathematical representation mentioned above $d^s(X_t, Y_t)$ denotes the distance of the observation of period "t" to the technological change of "s" period. If the function value of "m" is greater than 1, it means that there is an increase in total factor productivity, and if it is less than 1, there is a decrease in total factor productivity.

3 FINDINGS

It is very important to determine the inputs and outputs that will be used in the efficiency measurement of airports. In this respect, input and output variables that directly affect the financial and operational activities of airports were selected in this study. At the same time, the most widely used input and output variables in the literature have been selected by a large literature review. Input and output variables used in the study are given in Table 1.

***Tab. 1** Input and Output Variables*

Input	Output
Number of Runway	Total Number of Passenger
Terminal Size Area	Total Freight
Number of Employment	Total Number of Commercial Flights
Number of Gate	Total Revenue
Total Expense	

Considering the studies related to the measurement of efficiency in airports, it is possible to talk about two different opinions. According to the first opinion, it was argued that the relevant authorities had no effect on the output variables but had an effect on the input variables [29]. According to the second opinion, relevant authority cannot change the input variables easily, but argues that it has more potential to change the output variables [30, 2]. In this respect, in this study, the second opinion was more accurate and the efficiency measurement was carried out with data envelopment analysis based on CCR and BCC models. Efficiency measurement of the related airports was carried out through DEAP 2.1 software program. The efficiency values of the 19 airports, decision making units in this study, included in the analysis according to the output oriented CCR model are given in Table 2.

***Tab. 2** Efficiency Results of Airports According to CCR Model*

Airports	2012	2013	2014	2015	2016
İstanbul Atatürk	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
İstanbul Sabiha Gökçen	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Antalya	**1.000**	**1.000**	**1.000**	0.870	0.717
Ankara Esenboğa	0.335	0.402	0.441	0.392	0.415
İzmir Adnan Menderes	0.526	0.575	0.764	0.441	0.559
Adana	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Trabzon	0.582	0.611	0.705	0.644	0.718
Muğla Dalaman	0.361	0.458	0.717	0.302	0.301
Muğla Milas Bodrum	0.318	0.367	0.536	0.220	**1.000**
Gaziantep	0.392	0.481	0.557	0.502	0.509
Kayseri	0.443	0.520	0.709	0.512	0.528

Diyarbakır	0.723	0.966	0.944	0.898	0.568
Van Ferit Melen	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Erzurum	0.311	0.329	0.332	0.326	0.387
Hatay	0.230	0.291	0.408	0.309	0.367
Konya	0.446	0.519	0.406	0.277	0.327
Samsun- Çarşamba	0.519	0.523	0.624	0.558	0.279
Elazığ	0.421	0.454	0.557	0.454	0.341
Malatya	0.310	0.327	0.318	0.312	0.314

Source: Produced by Authors via DEAP 2.1 Program

As observed in Table 2, it is seen that during the whole period, Istanbul Atatürk, Sabiha Gökçen, Adana and Van Ferit Melen airports are effective according to the data envelopment analysis performed according to CCR model. It is observed that Antalya Airport is below the efficiency limit in 2015 and 2016. The reason for this is thought to be caused by the plane crisis with Russia in 2015. Muğla Milas Bodrum airport was only efficient in 2016. It is seen that the efficiency conditions of other airports vary over time.

The efficiency values of the airports included in the analysis according to the output-oriented BCC model are given in Table 3.

Tab. 3 *Efficiency Results of Airports According to BCC Model*

Airports	**2012**	**2013**	**2014**	**2015**	**2016**
İstanbul Atatürk	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
İstanbul Sabiha Gökçen	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Antalya	**1.000**	**1.000**	**1.000**	0.872	0.732
Ankara Esenboğa	0.369	0.404	0.442	0.400	0.441
İzmir Adnan Menderes	0.533	0.575	0.794	0.454	0.565
Adana	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Trabzon	0.960	**1.000**	0.999	0.904	0.912
Muğla Dalaman	0.862	0.968	**1.000**	**1.000**	**1.000**
Muğla Milas Bodrum	0.984	0.842	0.845	0.909	**1.000**
Gaziantep	0.773	0.712	0.775	0.751	0.733
Kayseri	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Diyarbakır	**1.000**	**1.000**	**1.000**	**1.000**	0.889
Van Ferit Melen	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Erzurum	0.324	0.345	0.351	0.344	0.496
Hatay	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**
Konya	**1.000**	**1.000**	0.459	0.403	0.390
Samsun- Çarşamba	0.694	0.720	0.666	0.960	**1.000**
Elazığ	**1.000**	0.613	0.671	**1.000**	0.683
Malatya	0.503	**1.000**	0.397	**1.000**	**1.000**

Source: Produced by Authors via DEAP 2.1 Program

As shown in Table 3, it was determined that Istanbul Ataturk, Sabiha Gokcen, Adana, Kayseri, Van Ferit Melen and Hatay airports are efficient according to the data envelopment analysis performed by the BCC model during the relevant period. Antalya Airport was efficient between 2012 and 2014, Trabzon Airport was efficient in 2013 and Mugla Dalaman airport was efficient between 2014 and 2016. It was determined that Diyarbakır Airport was not efficient only in 2016. It is thought that the reason of this may be the terror attacks between the years 2015 and 2016. Mugla Milas Bodrum and Samsun Çarşamba airports are efficient only in 2016. Konya airport is efficient only in 2012 and 2013.

In this part of the study, Malmquist total factor productivity index of the airports included in the analysis has been tried to be determined whether there is any change in efficiency and direction of change of efficiency. If the total factor productivity value is above 1, it can be said that there is a positive change. If the value is below 1, it can be said that there is a negative change. In cases where the total factor efficiency value is 1, it is not possible to talk about any changes. The total factor productivity value is the result of multiplying the efficiency value by the value of the technological activity.

Tab. 4 *Malmquist Total Factor Productivity Index Results (2012-2013)*

Airports	Technical Efficiency Change	Technological Efficiency Change	Pure Efficiency Change	Scale Efficiency Change	Total Factor Productivity Change
İstanbul Atatürk	1.000	0.964	1.000	1.000	0.964
İstanbul Sabiha Gökçen	1.000	**1.195**	1.000	1.000	1.195
Antalya	1.000	1.012	1.000	1.000	1.012
Ankara Esenboğa	**1.201**	0.924	0.990	1.213	1.110
İzmir Adnan Menderes	**1.093**	0.907	0.954	1.146	0.992
Adana	1.000	1.148	1.000	1.000	1.148
Trabzon	**1.050**	1.037	1.000	1.050	1.090
Muğla Dalaman	**1.270**	0.907	1.000	1.270	1.152
Muğla Milas Bodrum	**1.155**	0.898	1.000	1.155	1.037
Gaziantep	**1.226**	1.015	1.000	1.226	1.245
Kayseri	**1.174**	1.089	1.000	1.174	1.278
Diyarbakır	**1.336**	1.029	1.000	**1.336**	**1.375**
Van Ferit Melen	1.000	1.039	1.000	1.000	1.039
Erzurum	**1.057**	1.043	**1.085**	0.974	1.102
Hatay	**1.268**	1.124	1.000	1.268	1.425
Konya	**1.165**	1.082	1.000	1.165	1.261
Samsun- Çarşamba	**1.008**	1.066	1.000	1.008	1.074
Elazığ	**1.077**	1.113	1.000	1.077	1.199
Malatya	**1.053**	1.021	1.006	1.046	1.075

Source: Produced by Authors via DEAP 2.1 Program

According to the Malmquist Total Factor Productivity index, the effectiveness of Istanbul Atatürk, Sabiha Gökçen, Adana and Van Ferit Melen airports did not change in 2012-2013 period. The efficiency values at the other airports increased. It has been determined that the total factor productivity value of Istanbul Ataturk Airport and Izmir Adnan Menderes Airport decreased within the relevant airports. In terms of technological efficiency, it was observed that Sabiha Gökcen Airport had the highest value. In terms of pure efficiency, Erzurum Airport had the highest value. In terms of scale efficiency and total factor productivity, Diyarbakır Airport had the highest value.

Tab. 5 *Malmquist Total Factor Productivity Index Results (2013-2014)*

Airports	Technical Efficiency Change	Technological Efficiency Change	Pure Efficiency Change	Scale Efficiency Change	Total Factor Productivity Change
İstanbul Atatürk	1.000	0.792	1.000	1.000	0.792
İstanbul Sabiha Gökçen	1.000	1.067	1.000	1.000	1.067
Antalya	1.000	1.109	1.000	1.000	1.109

Ankara Esenboğa	**1.097**	0.866	0.999	1.098	0.950
İzmir Adnan Menderes	**1.329**	0.826	**1.349**	0.985	1.098
Adana	1.000	**1.162**	1.000	1.000	1.162
Trabzon	**1.154**	0.896	1.000	1.154	1.034
Muğla Dalaman	**1.566**	0.671	1.000	1.566	1.051
Muğla Milas Bodrum	**1.461**	0.673	1.000	**1.461**	0.983
Gaziantep	**1.159**	0.933	1.000	1.159	1.082
Kayseri	**1.364**	0.734	1.000	1.364	1.001
Diyarbakır	0.978	1.011	1.000	0.978	0.989
Van Ferit Melen	1.000	1.073	1.000	1.000	1.073
Erzurum	**1.011**	1.071	1.012	0.999	1.083
Hatay	**1.400**	0.857	1.000	1.400	**1.200**
Konya	0.781	0.863	0.731	1.069	0.674
Samsun- Çarşamba	**1.192**	0.946	1.000	1.192	1.127
Elazığ	**1.228**	0.835	1.000	1.228	1.025
Malatya	0.975	1.022	0.997	0.977	0.996

Source: Produced by Authors via DEAP 2.1 Program

In 2013-2014 period, with the Malmquist Total Factor Productivity index, the effectiveness of the Diyarbakir, Konya and Malatya airports decreased. Similarly, the total factor productivity value of these airports has also decreased. In terms of technological efficiency value, it was determined that İzmir Adnan Menderes Airport has the highest value. In terms of scale efficiency, Mugla Milas Bodrum Airport has the highest value. In terms of total factor efficiency, Hatay Airport has the highest value.

Tab. 6 *Malmquist Total Factor Productivity Index Results (2014-2015)*

Airports	**Technical Efficiency Change**	**Technological Efficiency Change**	**Pure Efficiency Change**	**Scale Efficiency Change**	**Total Factor Productivity Change**
İstanbul Atatürk	**1.000**	1.467	1.000	1.000	**1.467**
İstanbul Sabiha Gökçen	**1.000**	1.067	1.000	1.000	1.067
Antalya	0.870	1.135	0.874	0.995	0.987
Ankara Esenboğa	0.890	1.226	0.947	0.940	1.091
İzmir Adnan Menderes	0.577	1.297	0.698	0.827	0.748
Adana	**1.000**	1.090	1.000	1.000	1.090
Trabzon	0.913	1.270	1.000	0.913	1.159
Muğla Dalaman	0.421	**1.501**	1.000	0.421	0.632
Muğla Milas Bodrum	0.411	1.234	1.000	0.411	0.507
Gaziantep	0.902	1.242	1.000	0.902	1.120
Kayseri	0.723	1.461	1.000	0.723	1.056
Diyarbakır	0.952	1.119	1.000	0.952	1.065
Van Ferit Melen	**1.000**	1.102	1.000	1.000	1.102
Erzurum	0.982	1.113	**1.022**	0.961	1.093
Hatay	0.757	1.265	1.000	0.757	0.957
Konya	0.684	1.409	1.012	0.676	0.964
Samsun- Çarşamba	0.895	1.220	1.000	0.895	1.091
Elazığ	0.814	1.258	1.000	0.814	1.024
Malatya	0.981	1.144	1.003	0.978	1.121

Source: Produced by Authors via DEAP 2.1 Program

According to the Malmquist Total Factor Productivity index results for the period of 2014-2015, it is determined that the efficiency value of Istanbul Atatürk, Sabiha Gökçen, Adana and Van Ferit Melen remained constant. All other airports' efficiency values decreased. Muğla Dalaman Airport has the highest technological efficiency value. It is determined that Erzurum airport has the highest value in terms of pure efficiency. There was no increase in scale efficiency in all airports. The biggest increase in total factor productivity value was observed at Istanbul Atatürk Airport.

Tab. 7 *Malmquist Total Factor Productivity Index Results (2015-2016)*

Airports	**Technical Efficiency Change**	**Technological Efficiency Change**	**Pure Efficiency Change**	**Scale Efficiency Change**	**Total Factor Productivity Change**
İstanbul Atatürk	1.000	0.924	1.000	1.000	0.924
İstanbul Sabiha Gökçen	1.000	1.032	1.000	1.000	1.032
Antalya	0.825	0.949	0.873	0.944	0.783
Ankara Esenboğa	**1.058**	0.988	0.987	1.071	1.045
İzmir Adnan Menderes	**1.269**	0.931	**1.021**	1.242	1.181
Adana	1.000	0.997	1.000	1.000	0.997
Trabzon	**1.115**	0.901	1.000	1.115	1.004
Muğla Dalaman	0.997	1.010	1.000	0.997	1.007
Muğla Milas Bodrum	**4.540**	**1.250**	1.000	**4.540**	**5.674**
Gaziantep	**1.014**	0.879	1.000	1.014	0.891
Kayseri	**1.030**	0.845	1.000	1.030	0.871
Diyarbakır	0.632	0.922	1.000	0.632	0.583
Van Ferit Melen	1.000	0.884	1.000	1.000	0.884
Erzurum	**1.187**	0.932	0.916	1.396	1.106
Hatay	**1.188**	0.829	1.000	1.188	0.984
Konya	**1.181**	0.833	0.969	1.219	0.984
Samsun- Çarşamba	0.501	0.938	1.000	0.500	0.469
Elazığ	**1.330**	0.898	1.000	1.330	1.194
Malatya	**1.093**	0.915	1.000	1.093	0.999

Source: Produced by Authors via DEAP 2.1 Program

According to the Malmquist Total Factor Productivity index, the efficiency of Antalya, Muğla Dalaman, Diyarbakır, Samsun-Çarşamba airports decreased in 2015-2016 period. The highest value increase in terms of efficiency value, technological efficiency value, scale efficiency value and total factor productivity value was observed at Muğla Milas Bodrum Airport. In terms of pure activity value, it has been determined that İzmir Adnan Menderes Airport has the highest value.

4 CONCLUSIONS

The aim of this study is to measure the productivity and efficiency of the airports and to determine the course of the efficiency change over the years. In this respect, according to the ranking made in 2017, the largest 19 airports in terms of passenger traffic were included in the analysis. The efficiency measurement of the related airports for the years 2012-2016 was carried out by DEA. In addition, the Malmquist total factor productivity index was used to determine the change in the total factor productivity of the related airports.

When the results of the analysis are examined, it is seen that 5 airports between the years 2012-2014, 4 airports between the years 2015-2016 were efficient according to the output-oriented CCR model. According to the output-oriented BCC model, 10 airports in 2012,2015 and 2016, 11 airports in 2013 and 9 airports in 2014 have been determined as efficient. It is considered that the airports that are not efficient cannot efficiently convert input variables into output variables.

Another aim of the study is to calculate the total factor productivity change between the years 2012 and 2016 of the related airports by the malmquist total factor productivity index. According to the results of the analysis, it was observed that the efficiency of 14 airports increased and the efficiency of 5 airports decreased in 2012-2013 period. In terms of total factor productivity, it has been determined that all airports other than 2 airports have increased their Total Factor Productivity. In the period of 2013-2014, it was observed that all the airports other than the 6 airports increased their Total Factor Productivity value. In terms of the value of the efficiency, the efficiency value of 11 airports increased. In the period of 2014-2015, the efficiency of all airports other than 4 airports decreased and the Total Factor Productivity value decreased in only 6 airports. In 2015-2016 period, the Total Factor Productivity value of 11 airports decreased. In the period of 2012-2016, an increase in Total Factor Productivity value of most of the airports was observed. In the same way, the increase in technological efficiency, pure activity and scale efficiency were determined.

In the measurement of efficiencies of airports based on DEA method included in the research, in the years 2012, 2013 and 2014, there was an increase in the number of efficient airports, in 2015 there was a decrease in the number of efficient airports and evantually another increase was observed in 2016. In the same way, the efficiency of airports was observed in the period of 2012-2013 and 2013-2014 according to the malmquist TFP index. However, during 2014-2015, the efficiency of most of the airports decreased. In 2015-2016 period, a recovery was observed in the efficiency values of the airports. In this respect, similar results were obtained with both DEA method and TFP method.

It is thought that this study will guide the relevant airport managers in terms of both operational and financial efficiency. In addition, it is considered that it will help to determine the public policies applied to the related airports.

Although the studies carried out through data envelopment analysis seem to provide great convenience both in terms of interpretation and application, the existence of constraints due to the structure of the method can be expressed as the weakness of the method. Since the DEA measures relative efficiency, the results do not reflect the exact efficiency or inefficiency of the relevant decision-making units. Decreasing or increasing the number of decision-making units, number of input and output variables can lead to differentiation of the results. Moreover, DEA and Malmquist total factor efficiency index methods are only valid for the period in which they are applied. The decision-making unit that is efficient in any period may not be efficient in another period. In this study, the efficiency of the 19 largest airports in terms of passenger traffic in Turkey is aimed to be measured. In the following studies, the efficiency of the private sector and publicly operated airports can be measured to determine whether there is a difference in terms of ownership.

References

[1] DHMİ. 2017, Annual Report 2016. Ankara: General Directorate of State Airports Authority.

[2] Barros, C. P., and Dieke, P., 2007, "Performance evaluation of Italian airports: Data envelopment analysis," Journal Of Air Transport Management, pp. 184-191.

[3] Lam, S. W., Low, J. M., and Tang, L. C., 2009, "Operational efficiencies across asia pacific airports," Transportation Research Part E: Logistics and Transportation Review, 45(4), pp. 654-665.

[4] Yazgan, A. E., and Karkacıer, O., 2015, "Veri zarflama analizi ile etkinlik ölçümleri ve havalimani işletmeciliği sektöründe bir uygulama," Journal of Alanya Faculty of Business/Alanya Isletme Fakültesi Dergisi, 7(2).

[5] Avcı, T., and Aktaş, M., 2015, "Türkiye'de faaliyet gösteren havalimanlarinin performanslarinin değerlendirilmesi," Journal of Alanya Faculty of Business/Alanya Isletme Fakültesi Dergisi, 7(3).

[6] Ülkü, T., 2015, "A comparative efficiency analysis of Spanish and Turkish airports," Journal of Air Transport Management, 46, pp. 56-68.

[7] Bolat, B., Temur, G. T., and Gürler, H., 2016, "Türkiye'deki havalimanlarinin etkinlik tahmini: veri zarflama analizi ve yapay sinir ağlarinin birlikte kullanimi," Ege Academic Review, 16.

[8] Peker, İ., and Birdoğan, B., 2016, "Veri zarflama analizi ile Türkiye havalimanlarinda bir etkinlik ölçümü uygulamasi," Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 18(2), pp. 72-88.

[9] Asker, V., 2016, "The measurement of airports operational effectiveness: an application of the major 10 airports in Turkey," Transport & Logistics: the International Journal, 2016; Volume 16, Issue 41, December 2016, ISSN 2406-1069

[10] Zarraga, A. E. R., de Viñaspre, F. P. P., and Molinero, C. M., 2017, "The Impact of the 2008 economic crisis in the efficiency of Spanish airports: A DEA analysis," Documentos de Trabajo FUNCAS, (794), 1.

[11] Tracey, T., 2018, "Does operational efficiency depend on the airport's size?" International Journal of Management Science and Business Administration, 4(4), pp. 28-37.

[12] Murillo-Melchor, C., 1999, "An analysis of technical efficiency and productivity changes in Spanish airports using the malmquist index," International Journal of Transport Economics/Rivista internazionale di economia dei trasporti, pp. 271-292.

[13] Gillen, D., and Lall, A., 2001, Non-parametric measures of efficiency of US airports," International Journal of Transport Economics/Rivista internazionale di economia dei trasporti, pp. 283-306.

[14] Fung, M. K. Y., Wan, K. K. H., Van Hui, Y., and Law, J. S., 2008, "Productivity changes in Chinese airports 1995–2004," Transportation Research Part E: Logistics and Transportation Review, 44(3), pp. 521-542.

[15] Ar, İ. M., 2012, "Türkiye'deki havalimanlarinin etkinliklerindeki değişimin incelenmesi: 2007-2011 dönemi için malmquist-tfv endeksi uygulamasi," Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi, 26(3-4).

[16] Fragoudaki, A., Giokas, D., and Glyptou, K., 2016, “Efficiency and productivity changes in Greek airports during the crisis years 2010–2014,” Journal of Air Transport Management, 57, pp. 306-315.

[17] Keskin, B., and Ulas, E., 2017, “Does privatization affect airports performance? A comparative analysis with AHP-TOPSIS and DEA,” In New Trends in Finance and Accounting, pp. 335-345

[18] Bakırcı, F., 2006, “Üretimde etkinlik ve verimlilik ölçümü veri zarflama analizi teori ve uygulama,” İstanbul: Atlas Yayınları.

[19] Fanchon, P., 2003, “Variable selection for dynamic measures of efficiency in the computer industry,” International Advances in Economic Research, 9(3), pp. 175-188.

[20] Cook, W. D., and Seiford, L. M., 2009, “Data envelopment analysis (DEA) – thirty years on,” European Journal Of Operational Research, 192(1), pp. 1-17.

[21] Golany, B., and Roll, Y., 1989, “An application procedure for DEA,” Omega, 17(3), pp. 237-250.

[22] Dyson, R. G., Allen, R., Camanho, A. S., Podinovski, V. V., Sarrico, C. S., and Shale, E. A., 2001, “Pitfalls and protocols in DEA,” European Journals Of Operational Research, 132(2), pp. 245-259.

[23] Cooper, W. W., Seiford, L. W., and Tone, K., 2000, “Data envelopment analysis A comprehensive text with models, application, references and DEA-solver software,” Boston: Kluwer Academic.

[24] Karahan, A., and Özgür, E., 2009, “Hastanelerde performans yönetim sistemi ve veri zarflama analizi,” Ankara: Nobel Yayın Dağıtım.

[25] Coelli, T. J., Rao, D. S., O'Donnell, C. J., and Battese, G. E., 2005, “An introduction to efficiency and productivity analysis,” New York: Springer.

[26] Cooper, W. W., Seiford, L. M., and Zhu, J., 2011, “Handbook on data envelopment analysis history, models and interpretations,” International Series in Operations Research & Management Science, 164, pp. 1-39.

[27] Karacabey, A. A., 2002, “Türk bankalarindaki üretim değişiklikleri ve nedenleri,” İktisat İşletme ve Finans, 17(191), pp. 68-78.

[28] Fare, R., Grosskopf, S., Norris, M., and Zhang, Z., 1994, “Productivity growth, technical progress, and efficiency change in industrialized countries,” The American Economic Review, pp. 66-83.

[29] Bazargan, M., and Vasigh, B., 2003, “Size versus efficiency: A case study of US commercial airports,” Journal of Air Transport Management, 187-193.

[30] Martin, J., and Roman, C., 2001, “An Apllication Of Dea to Measure The Efficiency Of Spanish Airports Prior To Privatization,” Journal Of Air Transportation Management, pp. 149-157.