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Comparative Network Efficiency Analysis of the Airlines in Turkey After Deregulation*

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ABSTRACT

Deregulation has significantly developed the civil air transport industry in an ever-globalizing world. Even though deregulation has caused significant structural transformations in airline companies, the effect of deregulation effect on the production, marketing efficiency, and competitiveness of airline carriers worldwide, especially in Turkey, has not been fully revealed yet. Therefore, this study aims to analyze the efficiency of Turkish air carriers after the deregulation process in Turkish civil aviation by dividing the efficiency into production and market efficiency. Production and marketing efficiencies of airlines were estimated using the window network data envelopment analysis methodology. Efficiency analysis results showed production efficiency at 0.887, marketing efficiency at 0.764, and system efficiency at 0.796. Results also indicate that low-cost airlines have a higher production efficiency score (0.918) than full-service airlines (0.825). In comparison, the marketing efficiency of full-service airlines (0.879) is higher than that of low-cost carriers (0.708). The study determined that the system efficiency does not change according to the business model. The system efficiency score of the full-service provider airlines with a larger market share is higher and more balanced. The close and dynamic monitoring of the air transport market and the continuation of operations under a business model incorporating an appropriate marketing mix will increase the marketing efficiency of the airlines.

Keywords
Airline efficiency, Network DEA, Window analysis, Production-marketing efficiencies

JEL Classification
D40, D61, H21, G14

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Serbestleşme Sonrası Türkiye'deki Havayollarının Karşılaştırmalı Ağ Etkinliği Analizi

ÖZ

Serbestleşme/Deregülasyon, giderek küreselleşen dünyada sivil hava taşımacılığı sektörünü önemli ölçüde geliştirmiştir. Her ne kadar serbestleşme havayolu işletmelerinde önemli yapısal dönüşümlere neden olsa da deregülasyonun dünya genelinde ve özellikle Türkiye'de havayolu şirketlerinin üretim, pazarlama verimliliği ve rekabet gücü üzerindeki etkisi henüz tam olarak ortaya konmamıştır. Bu nedenle bu çalışma, Türk sivil havacılığındaki serbestleşme süreci sonrasında Türk havayolu işletmelerinin etkinliğini, üretim ve pazar etkinliği olarak ikiye ayırarak analiz etmeyi amaçlamaktadır. Havayolu şirketlerinin üretim ve pazarlama etkinlikleri pencere ağı veri zarflama analizi metodolojisi kullanılarak tahmin edilmiştir. Etkinlik analizi sonuçları üretim etkinliğinin 0.887, pazarlama etkinliğinin 0.764 ve sistem etkinliğinin 0.796 olduğunu göstermiştir. Sonuçlar ayrıca düşük maliyetli havayolu şirketlerinin tam hizmet veren havayolu şirketlerinden (0.825) daha yüksek bir üretim etkinliği skoruna (0.918) sahip olduğunu göstermektedir. Buna karşılık, tam hizmet sunan havayolu işletmelerinin pazarlama etkinliği (0,879) düşük maliyetli taşıyıcılarınkinden (0,708) daha yüksektir. Çalışmada, sistem etkinliğinin iş modeline göre değişmediği de tespit edilmiştir. Pazar payı yüksek olan tam hizmet sağlayıcı havayollarının sistem etkinliği skoru daha yüksek ve daha dengelidir. Hava taşımacılığı pazarının yakından ve dinamik bir şekilde izlenmesi ve uygun bir pazarlama karması içeren bir iş modeli altında faaliyetlerin sürdürülmesi, havayollarının pazarlama etkinliğini artırmasına imkân sunabilir.

Anahtar Kelimeler
Havayolu Etkinliği, Ağ VZA, Üretim-Pazarlama Etkinliği

JEL Kodu
D40, D61, H21, G14

1. Introduction

Today, people travel within their own country or to other parts of the world for various reasons such as work, vacation, tourism, education, etc. Travelling by fast and affordable vehicles is an important issue for both countries and individuals (Dickinson & Lumsdon, 2010). Technological developments in recent years have led to the prominence of civil air transport, which provides fast traveling at an affordable cost. As a natural result of globalization, regions wanted to integrate with every field, and this interaction led to increased human mobility (Button, 2001). In addition, the increasing opportunity cost of time has naturally led people to travel fast. This tendency causes increasing demand for civil air transportation and has led to new routes allowing airlines to access new markets. With the effect of these developments, the liberalization process in civil aviation started with the growth of airline companies in the USA's domestic market. This process was called liberalization or deregulation of civil aviation (Goetz & Vowles, 2009). The first reaction was made by the USA at the end of the 1970s and completed in the late 1980s. This deregulation process provided US airlines with free market entry and defined their fares. However, this development resulted in a significant decline in the market shares of bigger airlines (Ramamurti & Sarathy, 1997; Williams, 2017).

On the contrary, this movement provided increased employment, enplaned passenger numbers, flight frequencies, air traffic capacities, and globalizing flight networks (Goetz & Vowles, 2009). While these developments occurred in the USA, other regions/countries, and the European Union (EU) wanted to deregulate their civil aviation. The EU started slowly to deregulation in the late 1980s, and it progressed gradually until 1997. Also, the results of deregulation brought similar achievements for the EU (Button, 2001). In Turkey, civil aviation was deregulated gradually as the EU by Civil Aviation Law in 1983 (Yalçınkaya, 2019). With this regulation, private entrepreneurs entered the civil aviation sector.

Meanwhile, in 1996, some terms were added to re-regulate domestic markets to protect the national flag carrier of Turkey (Turkish Airlines) by the Directorate General of Civil Aviation. These new terms affected the entrepreneurs negatively. In 2003, the decision of the Directorate General of Civil Aviation 1996 was canceled by the Minister of Transportation. Then, the deregulations' positive effects began to be seen in Turkey (Yalçınkaya, 2019). However, one more step had to be taken to complete this process corporately. This step is about slot allocation. Until 2010, the slot allocation was coordinated by Turkish Airlines. An air carrier was decided to the slot for all domestic carriers, affecting the corporate structure of Turkish civil aviation. Therefore, this authority was delegated to a public institution (General Directorate of State Airports Authority) (Yalçınkaya & Taşcı, 2020). In the meantime, Turkish civil aviation was able to become fully corporate. The step was taken in 2010. This research examines the efficiency of airline companies in Turkey after the aviation authorities have assumed their duties within the framework of institutionalization. This study examines the efficiency of airline companies in Turkey after the aviation authorities have assumed their duties within the framework of institutionalization. In this framework, it contributes to the literature as a study analyzing Turkish civil aviation. With the completion of corporate deregulation, this study aims to reveal the effects of deregulation of civil aviation on the structure of the Turkish civil aviation market by combining network data envelopment analysis (DEA) methods.

Accordingly, this study sets out to make three contributions to the literature related to the deregulation of Turkish civil aviation:

- Economic theory will provide the context for an overview of the corporate deregulation of Turkish civil aviation.
- This study provides a new approach by combining two (window and network) DEA models to analyze the industry.
- This study spotlights the advantages and disadvantages of Turkish carriers in the market for competition.

Turkey shows differences in geographic location for domestic flights from the USA and the EU. Because both domestic markets are broader than Turkey, this broadness brings many new domestic markets with its demand, which is necessary for airlines to survive. In our research period, airlines still operate in Turkey's domestic market and have similar market shares between periods.

2. Historical Background of Turkish Civil Aviation

Globalization's march forward over the past century is often regarded as a significant political and economic achievement. Economists and policymakers saw increased world trade as a good thing (Krugman & Wells, 2018). Therefore, the world air transport industry has experienced a period of gradual economic liberalization. First, the USA started deregulating the civil aviation industry in 1978 by signing a law (Dobson, 2017). Then, the United Kingdom and European Union (EU) followed up USA's deregulation process (Dobson, 2007). Then, the deregulation in aviation was expanded all over the world.

Following the developments in the world, Turkey officially started its corporate civil aviation operations by establishing the Turkish Airplane Society in 1925. In 1933, it started to serve as "Turkish Air Mail" with a small fleet. Until 1954, the management of civil aviation institutions was subordinated to the Ministry of National Defense. Since then, it has been transferred to the Ministry of Transport. In line with the decisions taken in the 1980s, the development of economic growth supported by the free market transition also positively affected Turkish civil aviation. This transition supported legislating the Turkish Civil Aviation Law No. 2920 in 1983. Also, The General Directorate of State Airports Authority (1984) and the General Directorate of Civil Aviation (1987), which continue their activities today, was organized during this period. As a result of these developments, the Turkish civil aviation industry started to grow, and this deregulation initiative allowed new players to enter the market. However, most of the civil air transportation carried out by Turkish Airlines (THY) in these periods harmed the development of competition in practice (Çetin & Benk, 2011). Government interventions such as price controlling, market entries, Etc., in the Turkish civil aviation industry continued to 2003. In 2001, the price tariffs were determined by air carriers, and in 2003, the domestic market entry in Turkish civil aviation was allowed to private air carriers (Gerede, 2010). With these developments, the domestic market was deregulated. However, one more regulation was required to deregulate Turkish civil aviation completely. Slot allocation is the final gap in completing the deregulation process. Since 1992, the slot allocation has been made by THY. This authority is a contradictory issue to the free market structure, and it is crucial prevention for private air carriers from competing in the domestic market. In 2010, the slot allocation authority was transferred to the public authority-General Directorate of Civil Aviation, to complete the deregulation process in Turkish civil aviation (Yalçınkaya & Taşcı, 2020). Thus, it can say that Turkey's civil aviation deregulation process has been completed compared to other deregulated countries. This process provided some positive results in deregulated countries (Barrett, 1989; Pryke, 1991; Goetz & Vowles, 2009; Duygun vd. , 2013b; Cao vd. , 2015; Martini vd. , 2019). Similar positive effects were realized in Turkish civil aviation. Cetin ve Eryigit (2018) indicated that deregulation has contributed to Turkish civil aviation under two main headings. First, the removal of the barrier to entry into the industry has created dynamic competitive conditions with new air carriers starting to serve. This amendment led to the realization of the second stage, and increased competition conditions drove prices down and resulted in a rapid increase in demand. In line with the current data announced worldwide, air transport's contribution to foreign trade is 2% on average, while its contribution in Turkey is 10% on average. Figure 1 shows the industry's contribution to foreign trade comparatively.

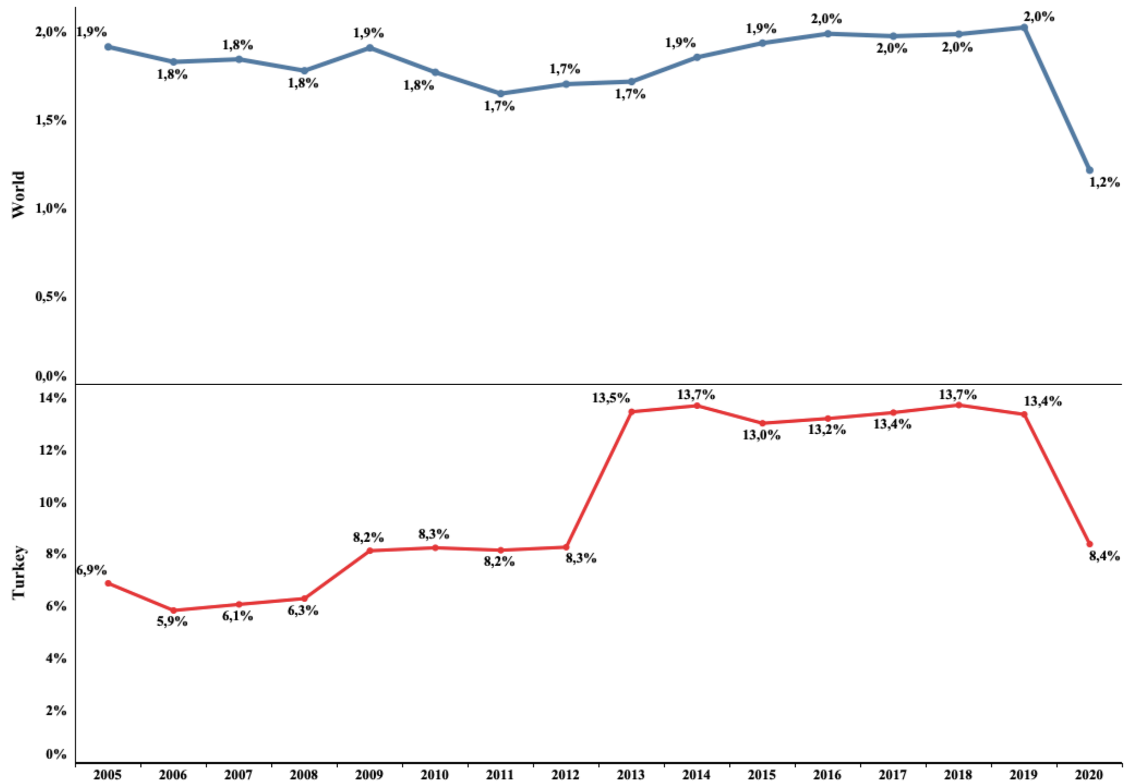
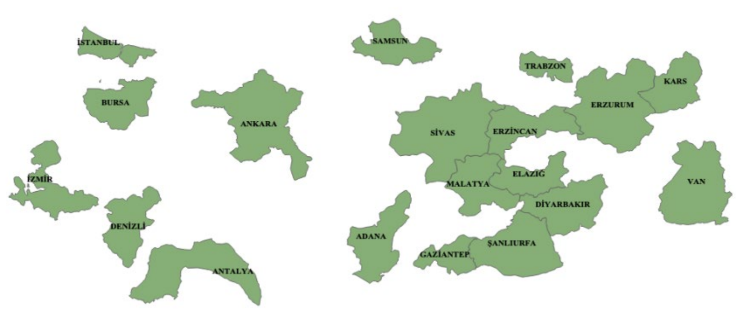


Figure 1. World and Turkish Air Transportation Shares in Total Export (DTÖ)

The deregulation process has increased the number of airports served in Turkey. As shown in Figure 2, by the investments made in the last 30 years, the number of airports providing domestic air transportation services has increased from 20 to 56. Before the deregulation, only Istanbul Atatürk Airport had high air traffic volume. Afterward, the air traffic volume increased, especially in Ankara, Izmir, Antalya, and the second airport in Istanbul (Sabiha Gokcen) (DHMİ).

1991



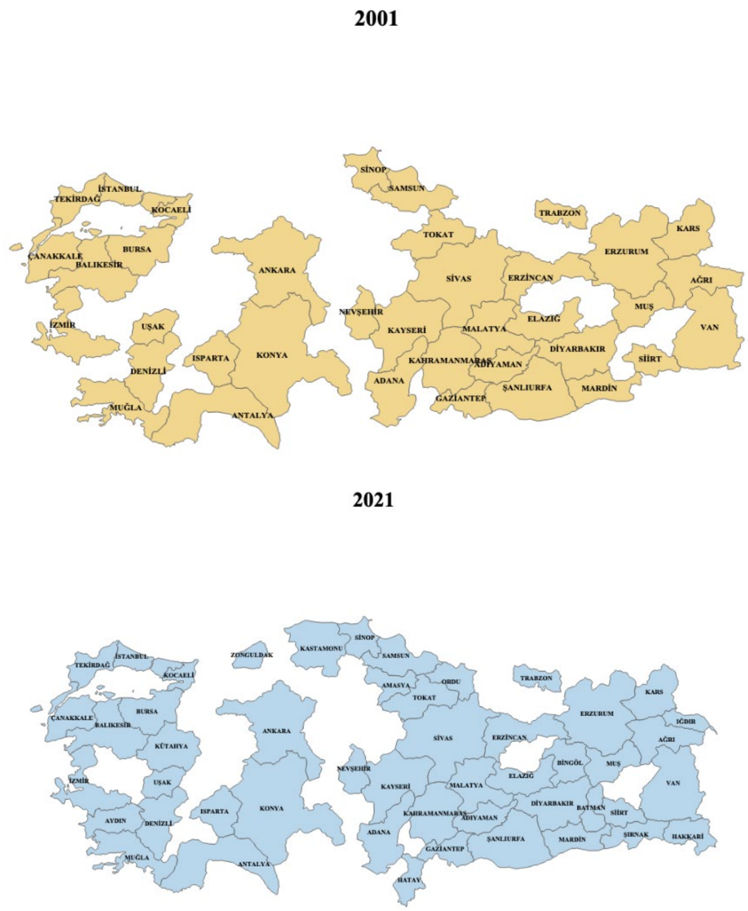


Figure 2. Airports Development in Turkey (DHMİ)

3. Literature Review

Economics is a social science that deals with producing, distributing, and consuming goods and services. Economics focuses on behavior, interactions between economic agents, and how the economy works. As a branch of science, economics concerns how economic agents allocate scarce resources and how these choices affect society (Acemoglu vd. , 2019). Within this scope, air carriers are trying to realize the maximum production that can be achieved with their current capacities, that is, passenger and cargo transportation. The main goal of airlines is to increase their efficiency and achieve economic efficiency. Efficiency, a measure of the ability to transform inputs into output, is crucial in air transport. Therefore, efficiency analyses are developed and applied in many sectors, such as aviation. However, all of the efficiency and productivity analysis studies until today depend on the efficiency definitions outlined by Farrell (1957). Charnes vd. (1978), Banker vd. (1984), Byrnes vd. (1984), Kao (1995), Färe ve Grosskopf (1996), Seiford ve Zhu (1999) and Färe vd. (2007) were developed analysis by their models. Among the studies applying radial DEA models, there are about three classes of methodologies: one is to directly apply standard CCR (Charnes vd. , 1979) or BCC (Banker vd. , 1984) models, and the other is to combine standard DEA models with other methods, especially a combination of parametric and nonparametric methods, and finally to apply modified or expanded DEA models. In this direction, studies on the global and regional (USA-European (EU) and Asian-African) scales in the air transportation industry are examined. Also, different classic and Network DEA studies in the civil aviation industry are shown in Table 1 to Table 3.

Performing analysis with more than one input and output in each air carrier with the classical DEA causes only the general efficiency scores to be adhered to in evaluating the carriers. It is stated in the literature that this situation does not reveal the internal relations within the "black box"(Cui & Yu, 2021). Hence, new models such as network DEA models are applied in DEA to explain the effects of internal and external factors on efficiency. All studies are divided into two groups classic and network. Global markets studies have tried to determine the efficiency level of international carriers. These studies focused on the carriers' structure to define which factors affect the level of efficiency and productivity. The structure contains airlines' business model types, corporate and fleet management, and type of ownership (public or private). The global market studies examined international air carriers as a decision-making unit (DMU). Most included only THY from Turkey as a global air carrier DMU. However, these analyses may not implicitly explain the Turkish air transportation industry implicitly. Second, the US and EU civil aviation DEA studies are investigated. This is the most studied group in DEA studies, and the most different models are applied for two reasons. First, the deregulation process started in the US and expanded to the EU and other regions. Second, available data can be reached for these regions. The final group is Asian and African, and the newest models are applied in these studies. Also, the studies examined the periods close to the present and focused on the efficiency analyses after the countries' civil aviation deregulation (Good vd. , 1995; Alam vd. , 2001; Barros & Peypoch, 2009; Duygun vd. , 2013a). These studies also examined the same structural properties.

Table 1

Summary of DEA Studies for Global Markets

Model Type	Source	Sample Data	Period	Methodology
Classic DEA	Barbot vd. (2008)	49 International Airlines	2005	DEA, TFP
	Merkert ve Hensher (2011)	58 International Airlines	2007-2009	DEA, Tobit
	Lee ve Worthington (2014)	42 International Airlines	1994-2011	DEA, Bootstrap
	Arjomandi ve Seufert (2014)	48 International Airlines	2007-2010	DEA
	Min ve Joo (2016)	59 International Airlines	2010	DEA
	Kottas ve Madas (2018)	62 International Airlines	2012-2016	DEA
	Kiracı ve Asker (2019)	45 International Airlines	2010-2016	DEA, Tobit
	Asker (2021b)	31 International Airlines	2016-2019	DEA
	Asker (2022)	17 International Low-cost Airlines	2013-2017	Fuzzy DEA
Network DEA	Sengupta (1999)	14 International Airlines	1988-1994	Dynamic DEA
	Gramani (2012)	34 Brazil and USA Airlines	1997-2006	2-Stage DEA
	Chang ve Yu (2014)	16 International Low-cost Airlines	2008	SBM-Network DEA
	Li vd. (2016)	22 International Airlines	2008-2012	3-Stage SBM-Network DEA
	Yu vd. (2019)	13 China and India Airlines	2008-2015	Dynamic Network DEA
	Asker (2021a)	36 International Airlines	2013-2018	2-Stage DEA
	Yu ve See (2023)	29 International Airlines	2018	Network DEA

Table 2

Summary of DEA Studies for US and European Markets

Model Type	Source	Sample Data	Period	Methodology
Classic DEA	Graham vd. (1983)	US 200 Domestic Markets	1980-1981	OLS-2SLS and Herfindahl Index
	Distexhe ve Perelman (1994)	33 US-EU Airlines	1977-1988	DEA
	Good vd. (1995)	16 US-EU Airlines	1976-1986	DEA
	Alam ve Sickles (1998)	11 US Airlines	1970-1990	DEA
	Fethi (2000)	17 EU Airlines	1991-1995	DEA
	Alam vd. (2001)	47 US Domestic Markets	1979-1992	Probit Regression
	Radačić vd. (2005)	Croatian Airlines	1992-2004	DEA, TFP
	Tsoukalas (2007)	12 US Airlines	1995-2006	Regressions
	Barros ve Peypoch (2009)	27 EU Airlines	2000-2005	2-Stage DEA
	Assaf (2011)	18 UK Airlines	2004-2007	DEA - Malmquist Index and Tobit
	Barros ve Couto (2013)	23 EU Airlines	2000-2011	DEA- Luenberger and Malmquist Indexes
	Barros vd. (2013)	11 US Airlines	1998-2010	B-Convex DEA
	Duygun, Kutlu, vd. (2016)	35 US Airlines	1999-2009	DEA, Kalman Filter
	Choi (2017)	14 US Airlines	2006-2015	DEA, Bootstrap
	Balliauw vd. (2018)	8 US Cargo Airlines	1990-2014	SFA
Network DEA	Lu vd. (2012)	30 US Airlines	2006	2-Stage DEA
	Lozano ve Gutiérrez (2014)	16 EU Airlines	2007	Network-SBM DEA
	Mallikarjun (2015)	27 US Airlines	2012	3-Stage DEA
	Duygun, Prior, vd. (2016)	87 EU Airlines	2000-2010	Network DEA

Table 3

Summary of DEA Studies for Asian and African Markets

Model Type	Source	Sample Data	Period	Methodology
Classic DEA	Cao vd. (2015)	29 Chinese Airlines	2005-2009	DEA, Malmquist Index
	Jain ve Natarajan (2015)	12 Indian Airlines	2006-2010	DEA
	Chen vd. (2018)	11 Chinese Airlines	2006-2016	DEA, Malmquist Index
	Mhlanga vd. (2018)	7 African Airlines	2012-2016	DEA, Tobit
	Sakthidharan ve Sivaraman (2018)	5 Indian Airlines	2013-2014	DEA
	Wang vd. (2019)	16 Asian Airlines	2012-2016	DEA and Grey Model
Network DEA	Chiou ve Chen (2006)	15 Taiwan Domestic Markets	2001	2-Stage DEA
	Tavassoli vd. (2014)	11Iranian Airlines	2010	SBM Network DEA
	Barros ve Wanke (2015)	29 African Airlines	2010-2013	2-Stage TOPSIS and N. Networks
	Wanke vd. (2015)	35 Asian Airlines	2006-2012	2-Stage TOPSIS and MCMC
	Chen vd. (2017)	13 Chinese Airlines	2006-2014	Stochastic Network DEA
	Soltanzadeh ve Omrani (2018)	7 Iranian Airlines	2010-2012	Dynamic Network DEA

As shown in Table 1, Table 2 and Table 3, it is seen in the literature that there is a transition from classical methods to new, integrated and networked data envelopment analysis methods that can have effects on each other in order to examine the efficiency of enterprises in more detail. In this study, serial network data envelopment analysis method is preferred as the current approach method within the framework of this trend. It contributes to the field as the first study conducted with this new approach in the Turkish civil air transportation industry.

4. Methodology and Data

Network DEA models can divide the system into multiple processes and sections, considering the relationships between component processes and products. As a general feature of network DEA models, it is stated that a process can be divided into multiple stages rationally (Färe vd. , 2007; Cook vd. , 2010; Cooper vd. , 2011; Cook & Zhu, 2014). In this context, different systems (different structures classified as serial structure, parallel structure, and serial-parallel structure) can be used in Network DEA models. It is stated that Decision Making Units (DMUs) can perform several different functions in any process and can also be serially divided into different stages (Färe vd. , 2014). In such cases, some components play essential roles in producing outputs with intermediate outputs from their previous components. For this reason, the traditional DEA model does not impose constraints on the relationships between the intermediate stages while measuring the overall performance of the DMU together with the performance of its components. However, it is stated that if it consists of a series of subunits connected in series, such an approach is unlikely to provide insight into the interrelationships between the inefficiencies of the stages (Yu & Chen, 2016). In this context, the activities of airline companies operating in Turkey will be examined in two different stages. The general framework of the 2-stage serial Network DEA Model with input-oriented and CCR, which was created with reference to the studies of Kao ve Hwang (2008) and Kao ve Hwang (2010), is as follows:

$$\mathrm{E_k} = \max \sum_{\mathrm{r=1}}^{\mathrm{s}} \upsilon_{\mathrm{r}} \times \mathrm{Y_{rk}} \tag{4.1}$$

$$\text{i: Inputs } (\mathrm{i} = 1, \ldots, \mathrm{m})$$

$$\text{r: Outputs } (\mathrm{r} = 1, \ldots, \mathrm{s})$$

$$\text{p: Intermediate Output/Input } (\mathrm{p} = 1, \ldots, \mathrm{t})$$

$$\text{j: DMU } (\mathrm{j} = 1, \ldots, \mathrm{n})$$

Subjects to:

$$\sum_{\mathrm{i=1}}^{\mathrm{m}} \nu_i \times \mathrm{X_{ik}} = 1 \tag{4.2}$$

$$\sum_{r=1}^{s} \upsilon_r \times Y_{rj} - \sum_{i=1}^{m} \nu_i \times X_{ij} \leq 0\ ,\ j = 1, \ldots, n \quad \textbf{(4.3)}$$

$$\sum_{p=1}^{q} W_p \times Z_{pj} - \sum_{i=1}^{m} \nu_i \times X_{lj} \leq 0\ ,\ j = 1, \ldots, n \quad \textbf{(4.4)}$$

$$\sum_{r=1}^{s} \upsilon_r \times Y_{rj} - \sum_{p=1}^{s} W_p \times Z_{pj} \leq 0\ ,\ j = 1, \ldots, n \quad \textbf{(4.5)}$$

$$U_r, \nu_i, W_l \geq \varepsilon$$

$$r = 1, \ldots, s;\ i = 1, \ldots, m;\ p = 1, \ldots, q$$

Efficiencies:

$$E_k^{1.Stage} = \frac{\sum_{p=1}^{q} W_p \times Z_{pk}}{\sum_{i=1}^{m} \nu_i \times X_{ik}} \quad \textbf{(4.6)}$$

$$E_k^{2.\ Stage} = \frac{\sum_{r=1}^{s} \upsilon_r \times Y_{rk}}{\sum_{p=1}^{q} W_p \times Z_{pk}} \quad \textbf{(4.7)}$$

$$E_k^{Systen} = \frac{\sum_{r=1}^{s} \upsilon_r \times Y_{rk}}{\sum_{i=1}^{m} \nu_i \times X_{ik}} \quad \textbf{(4.8)}$$

In the equations, efficiencies are shown as 1st Stage, 2nd Stage and system. X_{ij} and Y_{rj} respectively where j=1,…,n, inputs of decision making unit (THY, Pegasus and Sun Express), i=1,…,m, intermediate output/input p=1,…,q and r=1,..,s denotes their outputs. I= (1, 2,…, m), O= (1, 2,…, s), and M= (1, 2,…, t) index sets of inputs, outputs, and intermediate inputs/outputs and $I^p \subset$ I, $O^p \subset$ O, and $M^p \subset$M indicate the corresponding index sets for the process p. In the equation, u_r , v_i and w_l are the factors, ε also is the small non-Archimedean number. The network DEA model is also figured out in Figure 2.

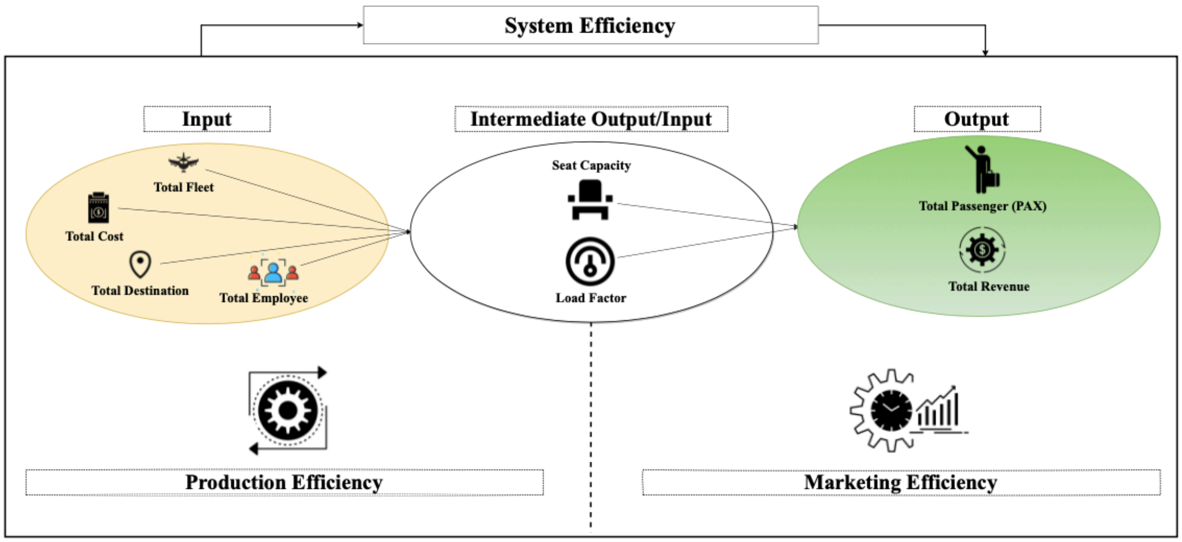


Figure 3. 2-Stage Serial Network DEA Model

The efficiencies of the examined airlines were put forward in two stages production and marketing. Window analysis, which was applied by Charnes vd. (1985) for the aircraft efficiency analysis of the US Air Force, is added to Network DEA in the study in order to increase the number of decision-making units. Window analysis works on the principle of moving averages. Based on the proposal by Halkos ve Tzeremes (2009), efficiency measures are created over time by treating each DMU as different in a different period. As a result, it is possible to compare an airline's production and marketing activities in a certain period with its own activities in other periods. This approach makes it possible to examine the Turkish air transport industry, where few decision-making units exist. Asmild vd. (2004) suggested that each window width should be between three and five, reducing the impact of changes in competitive or economic conditions and allowing for a fairer comparison. In this direction, Asmild vd. (2004) recommended window width (one window width is three years) is taken as reference and shown in Figure 4.

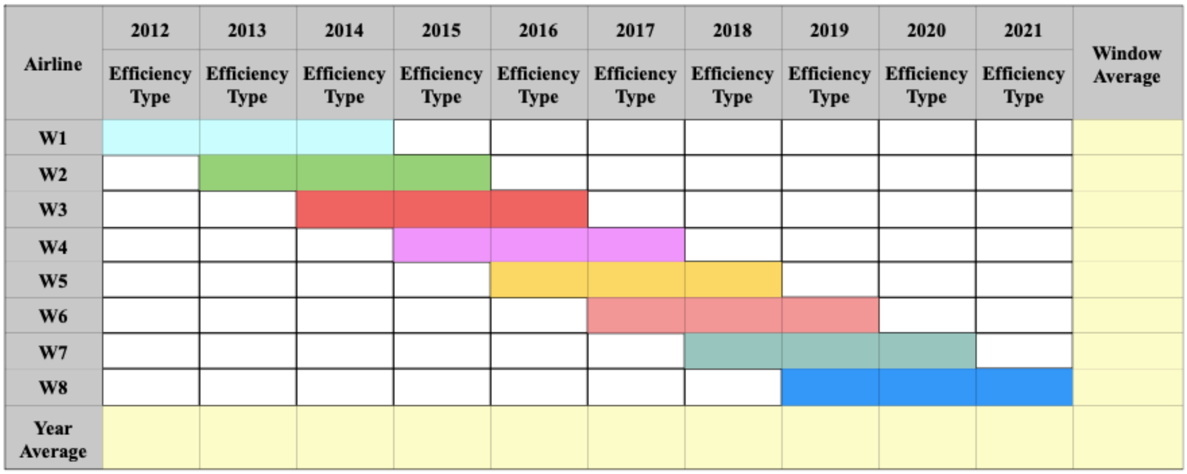


Figure 4. Window-Network DEA Analysis Chart

In line with this framework, the Window-Network DEA Model's solution is solved using version 38.3 of the GAMS program. The variables applied in the Window-Network DEA Model are shown in Figure 3 and Table 4. Input, intermediate output/input, and output data are selected based on the data used in the studies reviewed. The first stage is the production stage which produces the capacity to sell to the airlines' customers. The input variables (fleet, cost, destination, and employee) that will provide the intermediate output are selected to realize this stage. The second stage is the marketing stage, where intermediate input is transformed into the revenue and the number of carried passengers. The data is available starting from 2012 for all three carriers (THY, Pegasus, Sun Express) on the investor relations websites (Lufthansa; Pegasus; THY).

Table 4

Input and Output Variables

Variables	Explanation	Unit
	Input	
Total Fleet	Total number of aircraft in the operations	Number/Year
Total Cost	Total cost of Airlines in the operations	TRY/Year
Total Destination	Total number of markets flown in a year.	Number/Year
Total Employee	Total number of employees	Number/Year
	Intermediate Output/Input	
Seat Capacity	Total number of seats supplied	Number/Year

Load Factor	How much capacity is used	Percentage/Year
	Output	
Carried Passengers (PAX)	Total number of passengers carried	Number/Year
Total Revenue	Total revenue of airline	TRY/Year

5. Findings and Discussion

With the Window Network DEA model, the production efficiency status of the air carriers in the first and second stages, and the system are shown in detail in Appendix-1 and Appendix-2, and the stages' results are presented by taking the averages of the periods in Figure 5 to Figure 7. These results reveal that the level of efficiency varies according to the business models that airlines use for capacity production. Pegasus and Sun Express, which are similar cost management applications (low-cost business model), are more effective in production efficiency than THY, which offers full service. According to THY, Pegasus and Sun Express, which implement the cost-oriented strategy, can generally maintain their production efficiency levels at a certain level. In addition, the socio-economic cases experienced during the review period are also shown. It has been determined that other socio-economic cases, apart from Covid-19, do not seriously affect the production efficiencies of airlines.

At the second stage, efficiency scores are determined based on the number of passengers the airlines carry with the capacity they offer and how they generate revenue. The success of cost management in production efficiency has turned into the success of THY, which has a high market share at this stage, shown in Figure 6. The airline, which dominates the market in marketing efficiency, has achieved more effective and stable efficiency scores. Although socio-economic cases do not seriously affect production efficiency, it is seen that every airline has a negative impact on marketing effectiveness. The direct effect of the input factors on the output has been analyzed in the system efficiency, and it reveals different results compared to the 2-stage analysis. First, it is seen that the business model implemented by the airlines does not significantly affect the system efficiency much. Another difference is that it is observed that the efficiency scores of the airlines with a high market share are higher and more balanced. Finally, socio-economic events affect airlines at different levels and there is a difference in efficiency development during the recovery process.

According to the results of the study, it is observed that the airlines try to maintain their levels in the first stage where production efficiency is measured, and the production efficiency scores of Pegasus and Sun Express airlines are at similar levels. In THY, on the other hand, it is noteworthy that the size of the score changes between periods in production efficiency is a little high. In general, it can be said that they maintain their current efficiency level. On the other hand, when the change between periods is evaluated with the effect of socio-economic events, it has been concluded that there is much more variability in the second stage, where the marketing efficiency is measured.

The general stable structure provided by THY in its marketing activities has turned into volatile structure in Pegasus and Sun Express airlines. It has been shown that the airline with the highest market share in system efficiency has shown more stable results, and it is understood from the scores that the negative impact level of socio-economic cases experienced during the review period has also deepened according to market power. The effects of the business models implemented by the airlines on production, marketing and system activities are also revealed for Turkish carriers. While production efficiency is high, marketing efficiency is low in low-cost airlines (Pegasus and Sun Express), where cost control is tight, and all services provided except passenger transportation are paid by adopting a lean service approach. On the other hand, while the production efficiency is more variable in the airline (THY), which discriminates the lean transportation service and offers the transportation service to the customers as a full service with different cabin services, the marketing and system efficiency is more stable under normal conditions. Lu vd. (2014)researched airlines operating in the USA in their studies and revealed that airlines achieved more stable scores in the production efficiency stage, while they stated that this did not happen in marketing efficiency scores. The efficiency structure of the emerging business models for Turkey is similarly demonstrated in the USA. Therefore, they stated to the airline managements that the part that needs to be developed and improved should be on the revenue generation side. Duygun, Prior, vd. (2016) researched airlines in the European region with a two-stage network DEA within the framework of the 2007 global economic crisis. It has been shown that the efficiency scores of the first stage, called production efficiency, were at similar levels in the pre-crisis and post-crisis periods, supporting the result of this study. Due to the recent Covid-19, many industries have been adversely affected. In the study conducted by da Silveira Pereira ve de Mello (2021) for Brazil, they stated that the operations carried out due to human mobility were adversely affected by Covid-19. The same results also negatively affected airlines in Turkey and other regions in this industry.

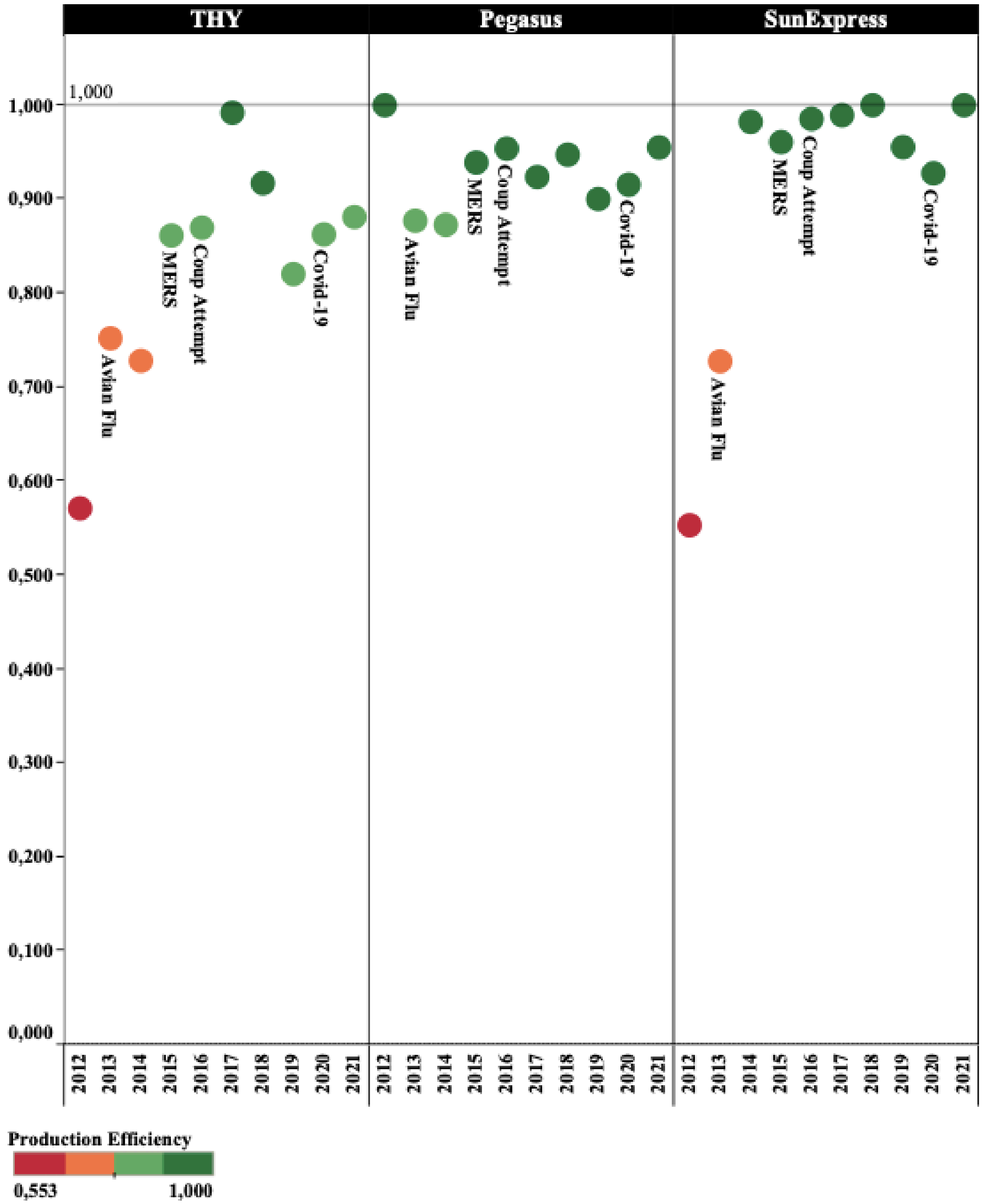


Figure 5. Production Efficiency (1-Stage) Results

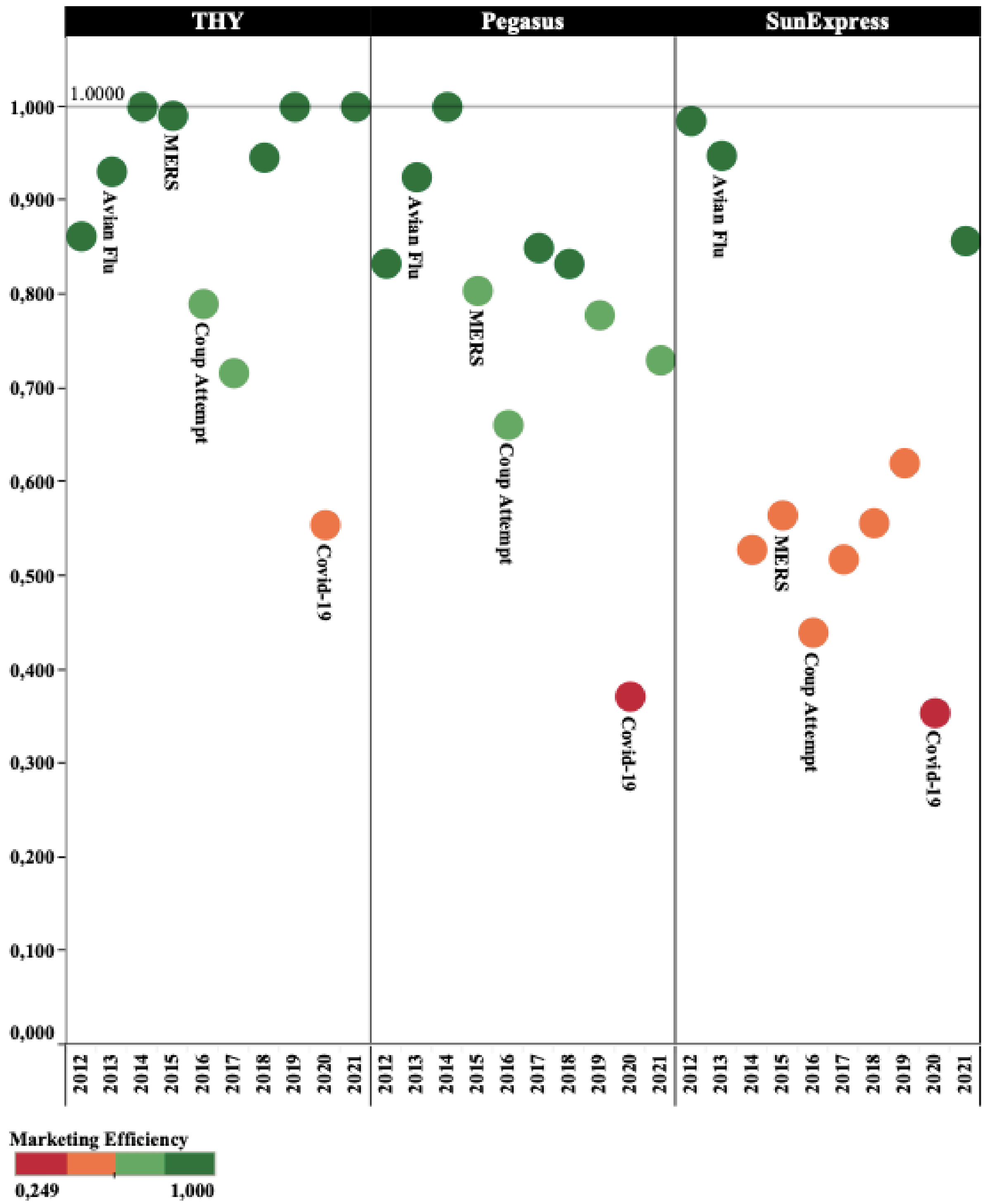


Figure 6. Marketing Efficiency (2-Stage) Results

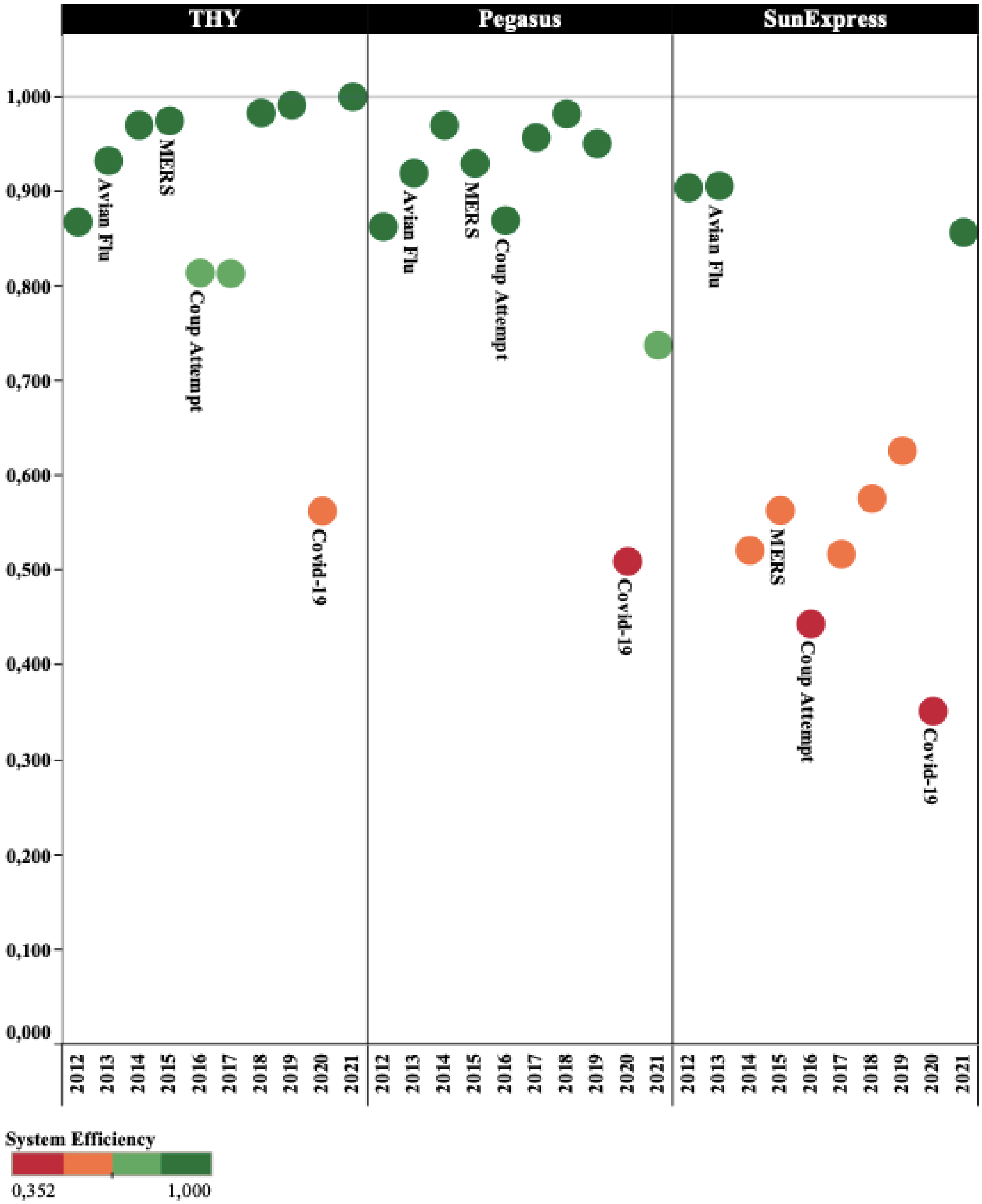


Figure 7. System Efficiency Results

6. Conclusion

The research conducted an efficiency analysis of the air carriers established in Turkey and operating in scheduled commercial passenger air transport. Window analysis was integrated into the modeling to represent the market structure of the network DEA model more accurately. With integrating this analysis to the model, the small number of DMUs could be increased. In this way, the discrepancy between the number of DMUs and the number of inputs and outputs was eliminated. In this context, the combined use of window and network DEA models in a holistic structure was applied for the first time to the air carriers in the Turkish civil air transport industry. This modeling aimed to evaluate the efficiency structure of Turkish civil air transportation in two stages, namely production and marketing activities. For this purpose, the analysis was carried out with the data available after the corporate deregulation of the Turkish civil air transportation industry. The study also considered the business models of airlines in the efficiency analysis. In this context, it has been decided that the DEA results of the air carriers made with the classical modeling (system efficiency) differ from those obtained with the analysis made with the window-network DEA modeling. The system efficiency results do not provide the opportunity to examine in detail, considering the strategic structures of the airlines. The 2-stage window-network DEA analysis reveals the different focuses of the airlines in their production and marketing activities according to their strategic and business model applications. The results show that the production efficiency of Pegasus and Sun Express airlines, which provide transportation services as a low-cost, is higher and more stable.

On the other hand, the marketing efficiency of THY, the country's flag carrier with a high market share and carrying more passengers, is more effective than that of others. The results also show the effects of socio-economic cases in this study. The IATA (2020) report indicates fragile structure of the world's air transportation industry in the face of socio-economics factors. This study shows that Turkey has the similar negative results. A balanced distribution of regional revenue may ensure that revenue declines are less adversely affected in the face of these shocks. Since the flight networks of Pegasus and Sun Express airlines are more limited than THY, these shocks can negatively impact these two airlines.

In conclusion, the research findings allowed the Turkish air carriers to test how they manage competition and strategies domestically. Firstly, it reveals that airlines' production efficiency varies according to the business models they apply in the factors they use for capacity generation. Secondly, the airline that dominates the market has a more efficient and stable marketing efficiency. By integrating network data envelopment analysis with window analysis, the efficiency analysis of a small number of Turkish air carriers was conducted for the first time and contributed to the literature. For future studies, this modeling can also determine the environmental efficiencies of the Turkish air carriers.

Appendix-1

Detailed Production and Marketing Efficiency Results

THY	2012		2013		2014		2015		2016		2017		2018		2019		2020		2021		Average	
	PE	**ME**	**PE**	**ME**	**PE**	**ME**	**PE**	**ME**	**PE**	**ME**	**PE**	**ME**	**PE**	**ME**	**PE**	**ME**	**PE**	**ME**	**PE**	**ME**	**PE**	**ME**
W1	0,571	0,862	0,555	0,931	0,601	1,000															0,576	0,931
W2			0,949	0,931	0,968	1,000	1,000	0,986													0,972	0,972
W3					0,615	1,000	0,633	0,986	0,648	0,875											0,632	0,954
W4							0,951	1,000	0,988	0,888	1,000	0,888									0,980	0,925
W5									0,973	0,607	0,988	0,636	0,974	1,000							0,978	0,748
W6											0,988	0,625	0,974	0,954	0,976	1,000					0,979	0,860
W7													0,803	0,884	0,726	1,000	0,907	0,590			0,812	0,825
W8															0,759	1,000	0,818	0,519	0,881	1,000	0,819	0,840
Average	0,571	0,862	0,752	0,931	0,728	1,000	0,861	0,991	0,870	0,790	0,992	0,716	0,917	0,946	0,820	1,000	0,863	0,555	0,881	1,000	0,825	0,879

Pegasus	2012		2013		2014		2015		2016		2017		2018		2019		2020		2021		Average	
	PE	ME	PE	ME	PE	ME	PE	ME	PE	ME	PE	ME	PE	ME	PE	ME	PE	ME	PE	ME	PE	ME
W1	1,000	0,833	0,759	0,925	0,711	1,000															0,823	0,919
W2			0,995	0,925	0,992	1,000	0,985	0,931													0,991	0,952
W3					0,915	1,000	0,919	0,931	1,000	0,821											0,945	0,917
W4							0,913	0,550	0,937	0,479	0,921	0,745									0,924	0,591
W5									0,924	0,683	0,925	0,896	0,924	1,000							0,924	0,860
W6											0,925	0,908	0,924	1,000	0,930	0,709					0,926	0,872
W7													0,994	0,498	0,939	0,642	1,000	0,281			0,978	0,474
W8															0,831	0,983	0,831	0,462	0,955	0,730	0,872	0,725
Average	1,000	0,833	0,877	0,925	0,873	1,000	0,939	0,804	0,954	0,661	0,924	0,850	0,947	0,833	0,900	0,778	0,916	0,372	0,955	0,730	0,928	0,778

Sun Express	2012		2013		2014		2015		2016		2017		2018		2019		2020		2021		Average	
	PE	ME	PE	ME	PE	ME	PE	ME	PE	ME	PE	ME	PE	ME	PE	ME	PE	ME	PE	ME	PE	ME
W1	0,553	0,985	0,474	0,948	0,967	0,528															0,665	0,820
W2			0,981	0,948	0,980	0,528	1,000	0,576													0,987	0,684
W3					1,000	0,528	0,934	0,576	1,000	0,492											0,978	0,532
W4							0,948	0,542	1,000	0,479	1,000	0,690									0,983	0,570
W5									0,956	0,348	0,984	0,438	1,000	0,596							0,980	0,461
W6											0,984	0,425	1,000	0,572	0,996	0,631					0,993	0,543
W7													1,000	0,501	0,905	0,604	0,988	0,357			0,964	0,487
W8															0,965	0,626	0,867	0,351	1,000	0,857	0,944	0,611
Average	0,553	0,985	0,728	0,948	0,982	0,528	0,961	0,565	0,985	0,440	0,989	0,518	1,000	0,556	0,955	0,620	0,928	0,354	1,000	0,857	0,908	0,637

Appendix-2

Detailed System Efficiency Results

THY	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
	System	System	System	System	System	System	System	System	System	System	
W1	0,868	0,939	1,000								0,936
W2		0,926	0,970	1,000							0,965
W3			0,940	0,969	0,895						0,935
W4				0,955	0,895	0,916					0,922
W5					0,653	0,680	0,986				0,773
W6						0,845	0,983	0,991			0,940
W7							0,980	0,991	0,606		0,859
W8								0,992	0,520	1,000	0,837
Average	0,868	0,933	0,970	0,975	0,814	0,814	0,983	0,991	0,563	1,000	0,891

Pegasus	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
	System	System	System	System	System	System	System	System	System	System	
W1	0,863	0,884	0,913								0,887
W2		0,955	0,997	0,926							0,959
W3			1,000	0,963	0,926						0,963
W4				0,900	0,846	0,945					0,897
W5					0,837	0,945	0,946				0,909
W6						0,981	1,000	0,903			0,961
W7							1,000	0,949	0,505		0,818
W8								1,000	0,515	0,738	0,751
Average	0,863	0,920	0,970	0,930	0,870	0,957	0,982	0,951	0,510	0,738	0,869

Sun Express	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
	System	System	System	System	System	System	System	System	System	System	

W1	0,904	0,870	0,511								0,762
W2		0,942	0,528	0,576							0,682
W3			0,526	0,561	0,492						0,526
W4				0,554	0,492	0,690					0,579
W5					0,348	0,438	0,596				0,461
W6						0,425	0,572	0,629			0,542
W7							0,561	0,624	0,353		0,513
W8								0,627	0,351	0,857	0,612
Average	0,904	0,906	0,522	0,564	0,444	0,518	0,576	0,627	0,352	0,857	0,627

References

Acemoglu, D., Laibson, D., & List, J. (2019). *Microeconomics* (2 ed.). Pearson.

Alam, I. M. S., Ross, L. B., & Sickles, R. C. (2001). Time series analysis of strategic pricing behavior in the US airline industry. *Journal of Productivity Analysis*, *16*(1), 49-62.

Alam, I. M. S., & Sickles, R. C. (1998). The relationship between stock market returns and technical efficiency innovations: evidence from the US airline industry. *Journal of Productivity Analysis*, *9*(1), 35-51.

Arjomandi, A., & Seufert, J. H. (2014). An evaluation of the world's major airlines' technical and environmental performance. *Economic Modelling*, *41*, 133-144.

Asker, V. (2021a). Havayolu işletmelerinde iki aşamalı veri zarflama analizi ile etkinlik ölçümü. *MANAS Sosyal Araştırmalar Dergisi*, *10*(4), 2373-2385.

Asker, V. (2021b). Havayolu Stratejik İşbirliklerinde Veri Zarflama Analizi İle Finansal Performansın İncelenmesi. *Journal of Aviation*, *5*(2), 181-191.

Asker, V. (2022). DÜŞÜK MALİYETLİ HAVAYOLU İŞLETMELERİNDE BULANIK VERİ ZARFLAMA ANALİZİ İLE FİNANSAL VE OPERASYONEL ETKİNLİK ÖLÇÜMÜ. *Dicle Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, *12*(23), 1-25.

Asmild, M., Paradi, J. C., Aggarwall, V., & Schaffnit, C. (2004). Combining DEA window analysis with the Malmquist index approach in a study of the Canadian banking industry. *Journal of productivity analysis*, *21*(1), 67-89.

Assaf, A. (2011). A fresh look at the productivity and efficiency changes of UK airlines. *Applied Economics*, *43*(17), 2165-2175.

Balliauw, M., Meersman, H., Onghena, E., & Van de Voorde, E. (2018). US all-cargo carriers' cost structure and efficiency: A stochastic frontier analysis. *Transportation Research Part A: Policy and Practice*, *112*, 29-45.

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some models for estimating technical and scale inefficiencies in data envelopment analysis. *Management science*, *30*(9), 1078-1092.

Barbot, C., Costa, Á., & Sochirca, E. (2008). Airlines performance in the new market context: A comparative productivity and efficiency analysis. *Journal of Air Transport Management*, *14*(5), 270-274.

Barrett, S. D. (1989). Deregulating European aviation—A case study. *Transportation*, *16*(4), 311-327.

Barros, C. P., & Couto, E. (2013). Productivity analysis of European airlines, 2000–2011. *Journal of Air Transport Management*, *31*, 11-13.

Barros, C. P., Liang, Q. B., & Peypoch, N. (2013). The technical efficiency of US Airlines. *Transportation Research Part A: Policy and Practice*, *50*, 139-148.

Barros, C. P., & Peypoch, N. (2009). An evaluation of European airlines' operational performance. *International Journal of Production Economics*, *122*(2), 525-533.

Barros, C. P., & Wanke, P. (2015). An analysis of African airlines efficiency with two-stage TOPSIS and neural networks. *Journal of Air Transport Management*, *44*, 90-102.

Button, K. (2001). Deregulation and liberalization of European air transport markets. *Innovation: The European Journal of Social Science Research*, *14*(3), 255-275.

Byrnes, P., Färe, R., & Grosskopf, S. (1984). Measuring productive efficiency: an application to Illinois strip mines. *Management science*, *30*(6), 671-681.

Cao, Q., Lv, J., & Zhang, J. (2015). Productivity efficiency analysis of the airlines in China after deregulation. *Journal of Air Transport Management*, *42*, 135-140.

Cetin, T., & Eryigit, K. Y. (2018). Estimating the Economic Effects of Airline Deregulation. *Journal of Transport Economics and Policy (JTEP)*, *52*(4), 404-426.

Chang, Y. C., & Yu, M. M. (2014). Measuring production and consumption efficiencies using the slack-based measure network data envelopment analysis approach: the case of low-cost carriers. *Journal of Advanced Transportation*, *48*(1), 15-31.

Charnes, A., Clark, C. T., Cooper, W. W., & Golany, B. (1985). A developmental study of data envelopment analysis in measuring the efficiency of maintenance units in the US air forces. *Annals of Operations Research*, *2*, 95-112.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European journal of operational research*, *2*(6), 429-444.

Charnes, A., Cooper, W. W., & Rhodes, E. (1979). Measuring the efficiency of decision-making units. *European journal of operational research*, *3*(4), 339-338.

Chen, Z., Tzeremes, P., & Tzeremes, N. G. (2018). Convergence in the Chinese airline industry: A Malmquist productivity analysis. *Journal of Air Transport Management*, *73*, 77-86.

Chen, Z., Wanke, P., Antunes, J. J. M., & Zhang, N. (2017). Chinese airline efficiency under CO2 emissions and flight delays: A stochastic network DEA model. *Energy Economics*, *68*, 89-108.

Chiou, Y.-C., & Chen, Y.-H. (2006). Route-based performance evaluation of Taiwanese domestic airlines using data envelopment analysis. *Transportation Research Part E: Logistics and Transportation Review*, *42*(2), 116-127.

Choi, K. (2017). Multi-period efficiency and productivity changes in US domestic airlines. *Journal of Air Transport Management*, *59*, 18-25.

Cook, W. D., & Zhu, J. (2014). Data envelopment analysis: A handbook of modeling internal structure and network.

Cook, W. D., Zhu, J., Bi, G., & Yang, F. (2010). Network DEA: Additive efficiency decomposition. *European journal of operational research*, *207*(2), 1122-1129.

Cooper, W. W., Seiford, L. M., & Zhu, J. (2011). Handbook on data envelopment analysis.

Cui, Q., & Yu, L.-T. (2021). A Review of Data Envelopment Analysis in Airline Efficiency: State of the Art and Prospects. *Journal of Advanced Transportation*, *2021*.

Çetin, T., & Benk, S. (2011). Regulation, deregulation, and competition in the Turkish airline industry. In *The political economy of regulation in Turkey* (pp. 193-214). Springer.

da Silveira Pereira, D., & de Mello, J. C. C. S. (2021). Efficiency evaluation of Brazilian airlines operations considering the Covid-19 outbreak. *Journal of Air Transport Management*, *91*, 101976.

DHMİ. https://www.dhmi.gov.tr/Sayfalar/FaaliyetRaporlari.aspx

Dickinson, J., & Lumsdon, L. (2010). *Slow travel and tourism*. Routledge.

Distexhe, V., & Perelman, S. (1994). Technical efficiency and productivity growth in an era of deregulation: the case of airlines. *Swiss Journal of Economics and Statistics*, *130*(4), 669-689.

Dobson, A. (2007). *Globalization and Regional Integration: The origins, development and impact of the single European aviation market*. Routledge.

Dobson, A. (2017). *A history of international civil aviation: from its origins through transformative evolution*. Routledge.

DTÖ. *Uluslararası Ticaret Verileri*. Retrieved 27.02.2022 from https://stats.wto.org

Duygun, M., Kutlu, L., & Sickles, R. C. (2016). Measuring productivity and efficiency: a Kalman filter approach. *Journal of productivity analysis*, *46*(2), 155-167.

Duygun, M., Prior, D., Shaban, M., & Tortosa-Ausina, E. (2016). Disentangling the European airlines efficiency puzzle: A network data envelopment analysis approach. *Omega*, *60*, 2-14.

Duygun, M., Shaban, M., Sickles, R. C., & Weyman-Jones, T. (2013a). Efficiency and productivity change in the European airlines industry in the post liberalization era. *Online: http://rsickles*.

Duygun, M., Shaban, M., Sickles, R. C., & Weyman-Jones, T. (2013b). Efficiency and productivity change in the European airlines industry in the post liberalization era. *Online: http://rsickles*. .

Färe, R., & Grosskopf, S. (1996). Productivity and intermediate products: A frontier approach. *Economics letters*, *50*(1), 65-70.

Färe, R., Grosskopf, S., & Whittaker, G. (2007). Network dea. In *Modeling data irregularities and structural complexities in data envelopment analysis* (pp. 209-240). Springer.

Färe, R., Grosskopf, S., & Whittaker, G. (2014). Network Dea II. In *Data Envelopment Analysis* (pp. 307-327). Springer.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society: Series A (General)*, *120*(3), 253-281.

Fethi, M. D. (2000). *Efficiency and productivity growth in the European airlines industry: applications of Data Envelopment Analysis, Malmquist Productivity Index and Tobit Analysis*. University of Leicester (United Kingdom).

Gerede, E. (2010). The Evolution of Turkish Air Transport Industry: Significant Developments and the Impacts of 1983 Liberalization. *Journal of Management & Economics*, *17*(2).

Goetz, A. R., & Vowles, T. M. (2009). The good, the bad, and the ugly: 30 years of US airline deregulation. *Journal of Transport Geography*, *17*(4), 251-263.

Good, D. H., Röller, L.-H., & Sickles, R. C. (1995). Airline efficiency differences between Europe and the US: implications for the pace of EC integration and domestic regulation. *European journal of operational research*, *80*(3), 508-518.

Graham, D. R., Kaplan, D. P., & Sibley, D. S. (1983). Efficiency and competition in the airline industry. *The Bell Journal of Economics*, 118-138.

Gramani, M. C. N. (2012). Efficiency decomposition approach: A cross-country airline analysis. *Expert Systems with Applications*, *39*(5), 5815-5819.

Halkos, G. E., & Tzeremes, N. G. (2009). Exploring the existence of Kuznets curve in countries' environmental efficiency using DEA window analysis. *Ecological Economics*, *68*(7), 2168-2176.

IATA. (2020). IATA Economics' Chart of the Week. https://www.iata.org/en/iata-repository/publications/economic-reports/what-can-we-learn-from-past-pandemic-episodes/

Jain, R. K., & Natarajan, R. (2015). A DEA study of airlines in India. *Asia Pacific Management Review*, *20*(4), 285-292.

Kao, C. (1995). Some properties of Pareto efficiency under the framework of data envelopment analysis. *International journal of systems science*, *26*(9), 1549-1558.

Kao, C., & Hwang, S.-N. (2008). Efficiency decomposition in two-stage data envelopment analysis: An application to non-life insurance companies in Taiwan. *European journal of operational research*, *185*(1), 418-429.

Kao, C., & Hwang, S.-N. (2010). Efficiency measurement for network systems: IT impact on firm performance. *Decision Support Systems*, *48*(3), 437-446.

Kiracı, K., & Asker, V. (2019). Etkinlik ve etkinliği belirleyen faktörler: havayolu şirketleri üzerine ampirik bir inceleme. *Eskişehir Osmangazi Üniversitesi İktisadi ve İdari Bilimler Dergisi*, *14*(1), 25-50.

Kottas, A. T., & Madas, M. A. (2018). Comparative efficiency analysis of major international airlines using Data Envelopment Analysis: Exploring effects of alliance membership and other operational efficiency determinants. *Journal of Air Transport Management*, *70*, 1-17.

Krugman, P., & Wells, R. (2018). *Microeconomics* (5 ed.). Worth Publishers.

Lee, B. L., & Worthington, A. C. (2014). Technical efficiency of mainstream airlines and low-cost carriers: New evidence using bootstrap data envelopment analysis truncated regression. *Journal of Air Transport Management*, *38*, 15-20.

Li, Y., Wang, Y.-z., & Cui, Q. (2016). Has airline efficiency affected by the inclusion of aviation into European Union Emission Trading Scheme? Evidences from 22 airlines during 2008–2012. *Energy*, *96*, 8-22.

Lozano, S., & Gutiérrez, E. (2014). A slacks-based network DEA efficiency analysis of European airlines. *Transportation Planning and Technology*, *37*(7), 623-637.

Lu, W.-M., Hung, S.-W., Kweh, Q. L., Wang, W.-K., & Lu, E.-T. (2014). Production and marketing efficiencies of the US airline industry: a two-stage network DEA approach. In *Data Envelopment Analysis* (pp. 537-568). Springer.

Lu, W.-M., Wang, W.-K., Hung, S.-W., & Lu, E.-T. (2012). The effects of corporate governance on airline performance: Production and marketing efficiency perspectives. *Transportation Research Part E: Logistics and Transportation Review*, *48*(2), 529-544.

Lufthansa. *Annual Reports*. Retrieved 01.03.2022 from https://investor-relations.lufthansagroup.com/en/publications.html

Mallikarjun, S. (2015). Efficiency of US airlines: A strategic operating model. *Journal of Air Transport Management*, *43*, 46-56.

Martini, G., Scotti, D., & Volta, N. (2019). Global Airline Productivity, 1980–2013. In *Airline Economics in Europe*. Emerald Publishing Limited.

Merkert, R., & Hensher, D. A. (2011). The impact of strategic management and fleet planning on airline efficiency–A random effects Tobit model based on DEA efficiency scores. *Transportation Research Part A: Policy and Practice*, *45*(7), 686-695.

Mhlanga, O., Steyn, J., & Spencer, J. (2018). The airline industry in South Africa: drivers of operational efficiency and impacts. *Tourism Review*.

Min, H., & Joo, S.-J. (2016). A comparative performance analysis of airline strategic alliances using data envelopment analysis. *Journal of Air Transport Management*, *52*, 99-110.

Pegasus. *Annual Reports*. Retrieved 01.03.2022 from https://www.pegasusyatirimciiliskileri.com/tr/operasyonel-ve-finansal-veriler/faaliyet-raporlari

Pryke, R. (1991). American deregulation and European liberalisation. In *Transport in a free market economy* (pp. 220-241). Springer.

Radačić, Ž., Tatalović, M., Mišetić, I., & Furlan, I. (2005). Application of Total Productivity Model within Croatia Airlines. *Promet-Traffic&Transportation*, *17*(5), 253-260.

Ramamurti, R., & Sarathy, R. (1997). Deregulation and globalization of airlines. *The International trade journal*, *11*(3), 389-432.

Sakthidharan, V., & Sivaraman, S. (2018). Impact of operating cost components on airline efficiency in India: A DEA approach. *Asia Pacific Management Review*, *23*(4), 258-267.

Seiford, L. M., & Zhu, J. (1999). Profitability and marketability of the top 55 US commercial banks. *Management science*, *45*(9), 1270-1288.

Sengupta, J. K. (1999). A dynamic efficiency model using data envelopment analysis. *International Journal of Production Economics*, *62*(3), 209-218.

Soltanzadeh, E., & Omrani, H. (2018). Dynamic network data envelopment analysis model with fuzzy inputs and outputs: An application for Iranian Airlines. *Applied Soft Computing*, *63*, 268-288.

Tavassoli, M., Faramarzi, G. R., & Saen, R. F. (2014). Efficiency and effectiveness in airline performance using a SBM-NDEA model in the presence of shared input. *Journal of Air Transport Management*, *34*, 146-153.

THY. *Annual Reports*. https://investor.turkishairlines.com/tr/mali-ve-operasyonel-veriler/faaliyet-raporlari

Tsoukalas, G. (2007). *Convergence in the US airline industry: a unit cost and productivity analysis* Massachusetts Institute of Technology].

Wang, C.-N., Tsai, T.-T., Hsu, H.-P., & Nguyen, L.-H. (2019). Performance evaluation of major Asian airline companies using DEA window model and grey theory. *Sustainability*, *11*(9), 2701.

Wanke, P., Barros, C. P., & Chen, Z. (2015). An analysis of Asian airlines efficiency with two-stage TOPSIS and MCMC generalized linear mixed models. *International Journal of Production Economics*, *169*, 110-126.

Williams, G. (2017). *The airline industry and the impact of deregulation*. Routledge.

Yalçınkaya, A. (2019). Türk havayolu taşımacılığı sektörünün tarihsel gelişimi ve devlet müdahaleleri (1933-2006).

Yalçınkaya, A., & Taşcı, D. (2020). Devletin Kurumsal Girişimciliği: Türk Havayolu Taşımacılığı Alanında Slot Tahsisine İlişkin Ardışık ve Çelişik Kurumsal İşler (1992-2010). *Anadolu Üniversitesi Sosyal Bilimler Dergisi*, *20*(2), 173-196.

Yu, H., Zhang, Y., Zhang, A., Wang, K., & Cui, Q. (2019). A comparative study of airline efficiency in China and India: A dynamic network DEA approach. *Research in Transportation Economics*, *76*, 100746.

Yu, M.-M., & Chen, L.-H. (2016). Assessment of transportation performance: a network structure. In *Data Envelopment Analysis* (pp. 17-43). Springer.

Yu, M.-M., & See, K. F. (2023). Evaluating the efficiency of global airlines: A new weighted SBM-NDEA approach with non-uniform abatement factor. *Research in Transportation Business & Management*, *46*, 100860.