MEHMET AKİF ERSOY ÜNİVERSİTESİ
İKTİSADİ VE İDARİ BİLİMLER FAKÜLTESİ DERGİSİ
Mehmet Akif Ersoy University
Journal of Economics and Administrative Sciences Faculty

ISSN: 2149-1658
Cilt: 7 Sayı: 3 s.755-781
Volume: 7 Issue: 3 p.755-781
Kasım 2020 November

INVESTIGATION OF LOGISTIC PERFORMANCE OF G-20 COUNTRIES USING DATA ENVELOPMENT ANALYSIS AND MALMQUIST TOTAL FACTOR PRODUCTIVITY ANALYSIS

VERİ ZARFLAMA ANALİZİ VE MALMQUIST TOPLAM FAKTÖR VERİMLİLİĞİ ANALİZİ İLE G-20 ÜLKELERİ LOJİSTİK PERFORMANSININ İNCELENMESİ

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Makale Türü	Article Type
Araştırma Makalesi	Research Article

Başvuru Tarihi	Application Date
08.09.2020	09.08.2020

Yayına Kabul Tarihi	Admission Date
05.11.2020	11.05.2020

DOI

https://doi.org/10.30798/makuiibf.792066

[*] This manuscript is derived from the master's thesis titled "Comparison of Logistics Performance Index Using Data Envelopment Analysis and Malmquist Total Factor Productivity Analysis Methods: An Application in G-20 Countries" under the supervision of Ömür TOSUN at Akdeniz University, Institute of Social Sciences.

Bu çalışma, Akdeniz Üniversitesi Sosyal Bilimler Enstitüsü'nde Doç. Dr. Ömür TOSUN tarafından yürütülen "Lojistik Performans İndeksinin Veri Zarflama Analizi ve Malmquist Toplam Faktör Verimliliği Analizi Yöntemleri ile Karşılaştırılması: G-20 Ülkelerinde Bir Uygulama" başlıklı yüksek lisans tezinden türetilmiştir.

Abstract

This study aims to make a comparative efficiency analysis of G-20 countries in terms of logistics performance. For this purpose, evaluation criteria have been determined with the help of industry and academic expert opinion and data set of evaluation criteria were obtained from the World Bank database. In this study, the analysis was made according to the CCR and the BCC input-based models by the Data Envelopment Analysis method. First, the efficiency scores of the countries were determined. After, reference groups were determined for the countries under the efficient frontier. Then, analyzes were made to find potential improvement values for the countries under the efficient frontier. Besides, Malmquist Total Factor Productivity Analysis was made in order to determine the efficiency change of countries in the 2007-2016 period. According to the results of the study, it has been determined that the country efficiency values and reference groups differed years. Moreover, it was determined that the most productive period is 2007-2010 and the most inefficient period is 2010-2012. Also, it has been observed that China and India have continuously improved in terms of efficiency types.

Keywords: ***G-20 Countries, Logistics Performance Index, Data Envelopment Analysis, Malmquist Total Factor Productivity Analysis***

Öz

Bu çalışma, G-20 ülkelerinin, lojistik performans açısından karşılaştırmalı etkinlik analizini yapmayı amaçlanmaktadır. Bu amaç doğrultusunda, değerlendirme kriterleri, sektörden ve akademik uzman görüşü yardımıyla belirlenmiş ve değerlendirme kriterlerine ait veri seti Dünya Bankası veri tabanından elde edilmiştir. Çalışmada, Veri Zarflama Analizi ile CCR ve BCC girdi temelli modellere göre analiz yapılmıştır. Böylece öncelikle ülkelerin etkinlik skorları ve etkinlik sınırı altında kalan ülkeler için referans grupları belirlenmiştir. Sonra etkinlik sınırı altında kalan ülkeler için potansiyel iyileştirme değerlerini bulmaya yönelik analizler gerçekleştirilmiştir. Daha sonra ise ülkelerin 2007-2016 süreci içindeki etkinlik değişimini tespit etmek amacıyla Malmquist Toplam Faktör Verimliliği Analizi yapılmıştır. Çalışma sonuçlarına göre ülke etkinlik değerlerinin ve referans gruplarının yıllara göre farklılık gösterdiği saptanmıştır. Bununla birlikte dönemler itibariyle en verimli dönemin 2007-2010, en verimsiz dönemin ise 2010-2012 dönemi olduğu tespit edilmiştir. Tüm bu sonuçlara ek olarak etkinlik türleri açısından Çin ve Hindistan'ın sürekli iyileşme kaydettiği görülmüştür.

Anahtar Kelimeler: ***G-20 Ülkeleri, Lojistik Performans İndeksi, Veri Zarflama Analizi, Malmquist Toplam Faktör Verimliliği Analizi***

GENİŞLETİLMİŞ ÖZET

Çalışmanın Amacı

Bu çalışmada, Dünya Bankası tarafından hazırlanan Lojistik Performans İndeksi (LPI) ışığında, G-20 ülkelerinin, lojistik başarı açısından karşılaştırmalı etkinlik analizi ile değerlendirilmesi amaçlanmıştır.

Araştırma Soruları

Araştırmada, göreceli etkinliği ve etkin olan ülkeleri belirlemek, etkinlik sınırı altında kalan ülkeler için oluşturulan referans ülkeleri, oranlarını ve bu ülkelerin girdi değişkenleri düzeylerini tespit etmek ve iyileştirici öneriler sunmak son olarak analize konu olan ülkelere ilişkin teknik etkinlik, teknolojik etkinlik, saf etkinlik, ölçek etkinliği ve toplam faktör verimliliği değişimlerini incelemek için analizler yapılmıştır.

Literatür Araştırması

LPI değerlendirmesine yönelik yapılan çalışmalar, 2017 yılından itibaren yoğunlaşmaya başlanmıştır. Bu çalışmalar genel itibariyle ülke veya ülke gruplarının LPI skorlarının karşılaştırılması şeklindedir. Ancak bu çalışmaların çoğunda LPI temel altı bileşeni baz alınmış ve LPI skorunun etkileneceği diğer göstergeler gözardı edilmiştir.

Yöntem

Çalışmada, LPI değerlendirme sonuçlarının raporlandığı 2007, 2010, 2012, 2014 ve 2016 yıllarına ait veriler kullanılmıştır ve bu veriler Dünya Bankası veri tabanından 10-15.09.2019 tarihleri arasında elde edilmiştir. Bu verilerin analizi için Veri Zarflama Analizi modellerinden ölçeğe göre sabit getiri varsayımı altında kullanılan CCR modeli ve ölçeğe göre değişken getiri varsayımı altında kullanılan BCC modeli kullanılmıştır. Uygulamada öncelikle Veri Zarflama Analizi yöntemi ile Win4DEAP 2 programı yardımıyla veriler yıllar bazında analiz edilmiştir. Sonra tüm veriler birlikte ele alınarak Malmquist Toplam Faktör Verimliliği analizi yöntemi ile yıllar içindeki değişim incelenmiştir.

Sonuç ve Değerlendirme

Çalışmada tüm yıllarda; ABD, Arjantin, Avustralya, Brezilya, Güney Afrika ve Japonya'nın etkinliği sağladığı ancak Endonezya, Güney Kore ve Rusya'nın etkinlik sınırı altında kaldığı tespit edilmiştir. Bununla birlikte Almanya'nın ölçeğe göre azalan getiriye; Endonezya, Rusya ve Suudi Arabistan'ın ölçeğe göre artan getiriye; ABD, Arjantin, Avustralya, Brezilya, Güney Afrika ve Japonya'nın ölçeğe göre sabit getiriye sahip olduğu saptanmıştır. Arjantin, Güney Afrika ve Japonya'nın referans ülke kümesinde yer aldığı görülmüştür. Bu ülkeler arasında en yüksek sayıda örnek alınan ülkenin ise Güney Afrika olduğu tespit edilmiştir. Etkinlik sınırı altında kalan ülkeler için liman konteynır trafiği değişkeninde ciddi bir iyileştirme ihtiyacı olduğu görülmüştür. Bununla birlikte en verimli dönemin 2007-2010, en verimsiz dönemin 2010-2012 olduğu ve tüm etkinlik türlerinde, Çin ve Hindistan'ın iyileşme kaydettiği gözlenmiştir.

1. INTRODUCTION

The intensification of competition with the effect of globalization has led all countries around the world to use the logistics sector as a strategic force to provide a competitive advantage. This has enabled the logistics industry to play a critical role in the global economy, whether national or international. Thanks to this role, the sector has grown all over the world and has reached essential values. According to the data published by the U.S. Department of Transportation, the growth in the sector is expected to continue in the future (https://www.bts.gov, date of access: 05.06.2020). It is estimated that the logistics sector, which reached a value of more than 5 billion dollars in 2019 (Uluslararası Taşımacılık ve Lojistik Hizmet Üretenleri Derneği [UTİKAD], 2019), will grow by 4.5% during the 2019-2027 forecast period and reach a value of over 15 billion dollars in 2027 (https://www.transparencymarketresearch.com, date of access: 05.06.2020). Such a development of the logistics sector has brought up the need to consider competition among countries in another framework as well as, determination of the dimensions of competition (World Bank, 2007).

At this point, it is of great importance that governments and private sector stakeholders can obtain information about their logistics performance and thus develop strategies to overcome their deficiencies by identifying them, as well as determining the factors and criteria that they should focus on in order to provide a strategic competitive advantage (Gergin and Baki, 2015). For this reason, in this study, using of the Logistics Performance Index (LPI) prepared by the World Bank, it is aimed to evaluate the G-20 countries, which represent approximately 85% of the world economy, 75% of the trade and two-thirds of the population, with comparative efficiency analysis in terms of logistics success. Data Envelopment Analysis (DEA) and Malmquist Total Factor Productivity Analysis (MTFP) methods were used for this evaluation. The DEA is an analysis method that allows measuring simultaneously the performance of equivalent units using multiple inputs and output variables measured at various scales (Cooper, Seiford, Tone, 2007). The MTFP analysis, on the other hand, is a method to measure the efficiency of the DMUs by taking into account the time dimension and thus evaluates the change in efficiency between the two time periods (Cooper, Seiford, Zhu, 2004). Based on the disclosed data, 2007-2016 period is used.

The study generally consists of six-part. After the introduction in the first part of the study, in the second part, general concepts and definitions are given to provide a better understanding of the subject. In the third part, LPI is explained. In the fourth part, the analysis methods used in the study are introduced. In the fifth part of the study, analysis and findings obtained to evaluate the logistics efficiency of G-20 countries are included. In the sixth part, the results of the study are explained. Besides the similarities and differences with the previous studies are discussed in this part. In the last part of the study, the limitations of the study and suggestions for future studies are presented.

2. GENERAL CONCEPTS AND DEFINITIONS

In this section, definitions and concepts related to performance and performance measurement will be given. Thus, it is thought that it will be beneficial to understand the study better.

In general terms, performance is the evaluation of the efforts made to achieve the predetermined goals or to fulfil the task (Bedük, 2010). In other words, performance is the quantitative and qualitative expression of the results obtained in a certain period as a result of a previously planned and intended activity (Akın, 2010). In terms of business, performance is the ability of the business to reach predetermined targets by using the scarce economic resources efficiently (Akın, 2010). On the other hand, performance measurement, which is considered as an analytical process, means that the resources used by an institution in a certain period and the products and services produced in line with the predetermined purposes are monitored and reported to the managers (T.C. Sayıştay Başkanlığı, 2003). The issue that is of vital importance in measuring performance, in general, is seen as the measurement of logistics performance (Çakır, 2017). In this context, logistics performance is the realization of the right product, the right amount, the right condition, the right place, the right time, the right customer and the right cost, which have entered the literature as the seven right of logistics (Ab Talib, Abdul Hamid, Chin, 2016:). Logistics performance measurement, on the other hand, is the comparison of the previously determined logistics targets and the realized results to make a comprehensive evaluation of an institution in terms of logistics (Ling, Duan, Zhang, Zhu, 2013:).

Another concept associated with performance and performance measurement is productivity. Productivity represents the relationship between the output obtained by an institution as a result of its production processes and the input it uses when producing this output, and it expresses the effective use of resources such as labour, capital, energy, and information (Akın, 2010). At the same time, productivity briefly represents the proportional expression between output (product produced) and input (source used) (Demirci, 2018).

The concepts of efficiency and productivity are often confused and used interchangeably. Although both concepts are indicators of performance, they have different meanings. According to Drucker, “productivity is the right thing to do while efficiency is the ability to do the right things” (Drucker, 2018). While productivity is concerned with input and output and focuses on correct implementation production processes, efficiency is concerned with the results and focuses on their effects. Accordingly, efficiency is a performance indicator that determines the degree of achievement of these goals with the efforts of a business to achieve its goals (Akın, 2010). At the same time, efficiency is handled in several types. In the study conducted by Farrell in 1957, the efficiency was examined under three titles as technical efficiency, price efficiency and scale efficiency. Technical efficiency is the success of a business in producing the most output that it can achieve by using the inputs it possesses most optimally (Farrell, 1957). Price efficiency, also called allocation efficiency, is the creation of the most appropriate input composition by looking at the input and output prices that the business will use (Farrell, 1957). Scale efficiency is the success of an enterprise to produce at the most appropriate scale (Farrell, 1957). In other words, scale efficiency is the closeness to the most efficient scale size. Also, scale efficiency is divided into four categories as increasing, decreasing, constant and variable return status (Kayalıdere and Kargın, 2004). Another type of efficiency is technological efficiency. The basic idea of technological efficiency is based on the amount of input composition used in the production process. Technological efficiency, which can be provided in the long term, is achieved by using less machinery and workforce in production processes after technological progress. In order to talk about the increase in technological efficiency, the costs of products produced with the technological progress provided must be less than the costs of products produced with the current technology. Otherwise, resource savings achieved by technological advancement will remain below costs (Özulucan and Özdemir, 2009). Pure efficiency, another type of efficiency, is expressed under the assumption of variable return according to the scale, the distance of the unit from the efficient ferontier (Taşdoğan and Taşdoğan, 2012).

The methods commonly used to evaluate performance are classified under three headings in the literature: ratio analysis, parametric methods and non-parametric methods (Tosun and Aktan, 2010). In this study, the DEA and the MTFP analysis methods, which are non-parametric, will be used.

3. LOGISTIC PERFORMANCE INDEX

World trade is transported between countries with a network of global logistics operators (World Bank, 2010), thereby increasing the importance of the logistics industry in national and international dimensions. Besides, the logistics industry is becoming an essential function that countries use to gain competitive advantage. This situation revealed the necessity of determining success and failures, superiorities and deficiencies with a performance evaluation of countries and determining where they are in this sector in general (World Bank, 2007). This need was met by the World Bank and named as Logistics Performance Index (LPI). In this context, LPI is an interactive benchmarking tool prepared every two years by the World Bank to help determine what countries can do to evaluate and improve their logistics performance (https://lpi.worldbank.org, date accessed: 07.11.2019). LPI shows the countries how they compare with their competitors and reveals the costs caused by low logistics performance (World Bank, 2010).

LPI was prepared for the first time in 2007. Later, various changes were made and prepared six times in 2010, 2012, 2014, 2016 and 2018. LPI is created by the information obtained through an internet-based questionnaire by the operators of the world’s largest logistics service providers or logistics professionals of their agencies. Countries are evaluated by logistics experts from eight trade partners of each country. Overseas of these partners are selected randomly based on the most important import and export market of the participants. In landlocked countries, the selection is made according to nearby transit countries. Furthermore, the selection of country groups varies according to the characteristics of the survey participants' own countries (World Bank, 2014). Country groups are selected according to their income status and whether they are coastal or land countries. Participants evaluate countries according to six basic components. These components that form the basis of LPI are the following (https://lpi.worldbank.org, date accessed: 03.12.2019):

Customs: The issues such as speed, simplicity and predictability of standard processes, in other words, the efficiency of customs procedures and processes carried out by all border control units, including customs administrations,

Infrastructure: The quality of the infrastructure related to trade and transportation, which includes topics such as ports, modes of transportation, information technologies,

Ease of Arranging Shipments: Ease of transportation organization with international competitive costs,

Quality of Logistics Services: Quality and adequacy of essential logistics service providers,

Tracking and Tracing: Evaluation of the shipments in terms of being tracked and traceable,

Timeliness: It refers to the frequency of reaching the recipient of the shipments at a predetermined time.

In 2007, when the first LPI assessment was conducted, unlike in other years, the participants evaluated the countries according to seven basic components. These are; customs, infrastructure, ease of arranging shipments, component of the local logistics industry, tracking and tracing, domestic logistics costs and timeliness (World Bank, 2007).

According to the LPI questionnaire, participants evaluate countries with scores between [1, 5] (lowest to highest). LPI questionnaire assessment scale is shown in Table 1.

Table 1. International LPI Questionnaire Evaluation Scale

LPI Components	1	5
Customs	Very Low	Very High
Infrastructure	Very Low	Very High
Ease of Arranging Shipments	Very Difficult	Very Easy
Quality of Logistics Services	Very Low	Very High
Tracking and Tracing	Very Low	Very High
Timeliness	Hardly Ever	Nearly Always

Source: World Bank, 2014: 51-52.

As a result of the evaluations, the overall score of each country is calculated by taking the average of the participants. Then, the countries are divided into four main groups according to these overall scores. These groups are (World Bank, 2007):

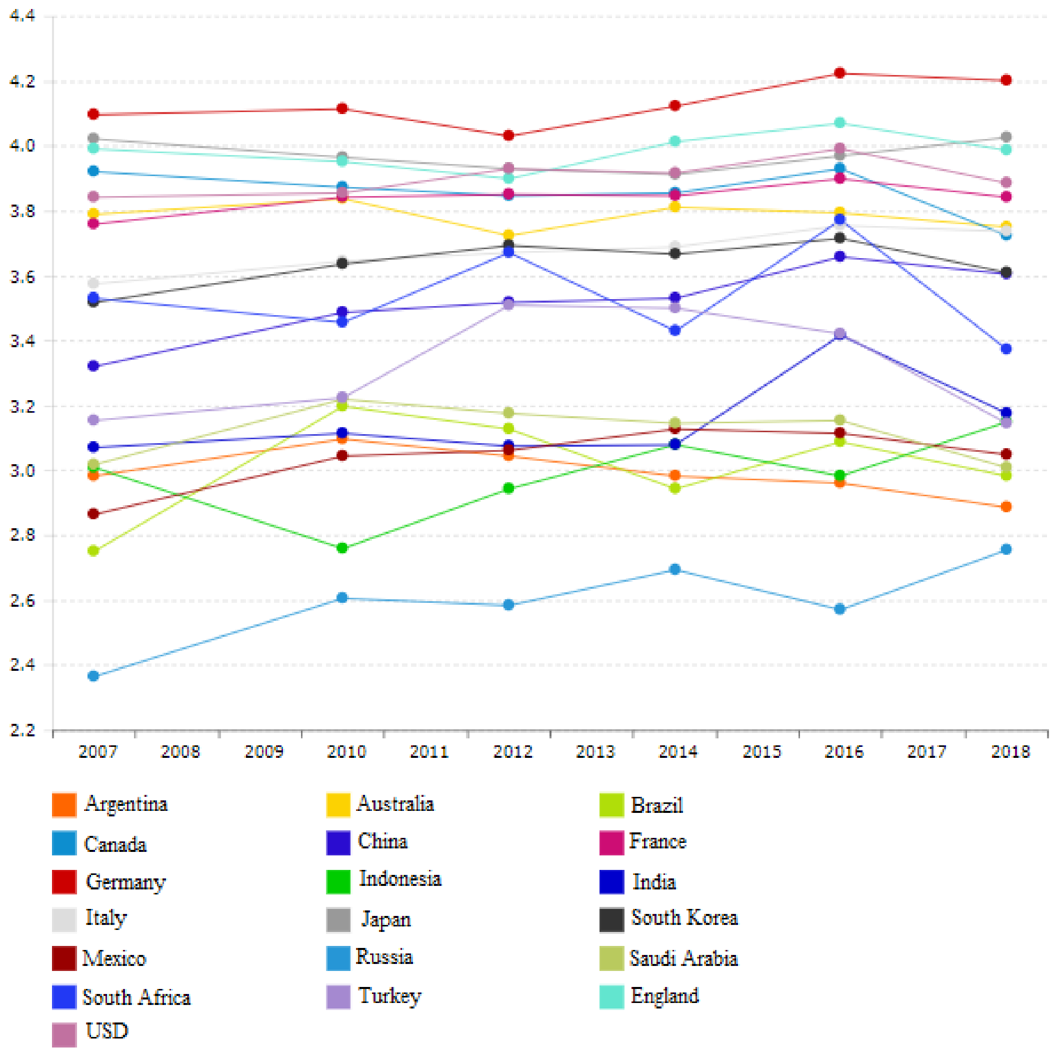
Logistics Friendly Countries: Located at the top of the LPI, high-performance countries, most of which have high-income,

Consistent Performance Countries: Developing economy countries with strong logistics customers,

Partially Performance Countries: This group of countries has not investigated the reasons for poor performance and not addressed this issue yet, Logistics Unfriendly Countries: This group, which is at the bottom of the LPI list, represents the least developed and significantly restricted countries in the field of logistics.

The LPI evaluation results for the period 2007-2018 of the G-20 countries subject to the study are shown in Chart 1.

Chart 1. G-20 Countries LPI Comparison between 2007-2018



Source: https://lpi.worldbank.org, date accessed: 22.02.2020.

In Chart 1, it is seen that Germany's LPI score is in four bands in all years and shows the best performance among G-20 countries. Besides, after Germany, it is seen that the countries showing performance best were Japan in 2007, 2010, 2012 and 2018, England in 2014, England and the USA in 2016. Apart from this, it is seen that Japan shared second place with the USA in 2012. On the other hand, it is noteworthy that the showing worst performance in G-20 country is Russia for all years.

3.1. Review of Literature on the Logistics Performance Index

In this section, the studies on LPI that have been done before are examined. For this, the search was carried out with the keyword word "logistic performance index" from the Google Scholar and the Web of Science database. The studies reached are shown in Table 2.

Table 2. Review of Literature

No	Author(s)	Variables	Method
1	Jane and Laih (2012)	Basic Components of LPI	Polynomial Time Quality Scaling Algorithm and Parsing Algorithm
2	Akçetin, Çelik, Takçı (2013)	Basic Components of LPI	Data Mining
3	Bulis and Skapars (2013)	Basic Components of LPI and International Freight Transport	SWOT Analysis
4	Sofyalıoğlu and Kartal (2013)	Basic Components of LPI	Qualitative Analysis
5	Tartavulea and Petrariu (2013)	Basic Components of LPI	Qualitative Analysis
6	Marti, Puertas, Garcia (2014)	Basic Components of LPI and Trade Data	Gravity Model
7	Puertas, Martí, García, (2014)	Basic Components of LPI	Gravity Model
8	Acar and Alemdar (2015)	Basic Components of LPI	Qualitative Analysis
9	Çemberci, Civelek, Canbolat, (2015)	Basic Components of LPI	Hierarchical Regression Analysis
10	Gergin and Baki (2015)	Basic Components of LPI	AHP and TOPSIS
11	Kaya, Öztürk, Kılıçkaplan (2015)	Basic Components of LPI	Factor Analysis
12	Popa, Belu, Paraschiv, Marinoiu, (2015)	Basic Components of LPI	Qualitative Analysis
13	Aynagöz Çakmak (2016)	Basic Components of LPI	Qualitative Analysis
14	Bakar and Jaafar (2016)	Basic Components of LPI	Factor Analysis
15	Bayraktutan and Özbilgin (2016)	-	Qualitative Analysis
16	Coto-Millan, Fernandez, Pesquera, Agüeros, (2016)	-	Stochastic Boundary Analysis
17	Karakış and Göktolga (2016)	Basic Components of LPI	AHP and VIKOR
18	Ekici, Kabak, Ülengin (2016)	Basic Components of LPI	ANN
19	Keser and Çetin (2016)	Basic Components of LPI	Panel Data Analysis
20	Yu and Hsiao (2016)	Basic Components of LPI	Meta Border DEA Analysis
21	Abbade (2017)	Basic Components of LPI	Factor Analysis, Correlation and Clustering Techniques
22	Başar and Bozma (2017)	Basic Components of LPI	Panel Data Analysis
23	Çakır (2017)	Basic Components of LPI	CRITIC, SAW and Peter's Fuzzy Regression Methods
24	D'Aleo and Sergi (2017a)	Basic Components of LPI and GDP	Panel Data Analysis
25	D'Aleo and Sergi (2017b)	-	Cluster Analysis
26	Danacı and Nacar (2017)	Basic Components of LPI, Export and Import Data	Cluster Analysis
27	Mariano, Gobbo Jr, de Castro Camioto, do Nascimento Rebelatto, (2017)	Basic Components of LPI, GDP and CO2 Emissions	DEA
28	Marti, Martin, Puertas, (2017)	Basic Components of LPI, GDP and Geographical Area	DEA
29	Ölmez and Mutlu (2017)	-	Correlation and Regression Techniques
30	Yapraklı and Ünalan (2017)	Basic Components of LPI	Qualitative Analysis
31	Zaman and Shamsuddin (2017)	-	Panel Data Analysis
32	Aldakhil, Nassani, Awan, Abro, Zaman (2018)	Basic Components of LPI	Panel Data Analysis
33	Chen and Li (2018)	Basic Components of LPI	Panel Data Analysis
34	Çemberci, Civelek, Uca, Artar, Onursal, (2018)	Basic Components of LPI and GDP	Regression Analysis
35	Çelebi and Civelek (2018)	Basic Components of LPI, Global Connectivity Index and Human Development Index Data	Moderator Analysis
36	Erturgut, Koç Ustalı, and Bolat, (2018)	Basic Components of LPI	Qualitative Analysis
37	Kabak, Ülengin, Ekici, (2018)	Basic Components of LPI and Export Data	Scenario-Based Binary Integer Program Method
38	Koh, Wong, Tang, Lim, (2018)	Basic Components of LPI	Panel Data Analysis
39	Liu, Yuan, Hafeez, Yuan, (2018)	Basic Components of LPI	Panel Data Analysis
40	Rezaei, van Roekel, Tavasszy, (2018)	Basic Components of LPI	Best Worst Method
41	Wang, Dong, Peng, Khan,	Basic Components of LPI and Trade Data	Gravity Model

	Tarasov, (2018)		
42	Zaman (2018)	Basic Components of LPI	Basic Component Analysis
43	Bozkurt and Mermertaş (2019)	Basic Components of LPI	Qualitative Analysis
44	Candan (2019)	Basic Components of LPI	Bulanık AHP and Gri İlşkisel Analizi
45	Çelebi (2019)	-	Gravity Model
46	Ekici, Kabak, Ülengin, (2019)	-	Bayesian Network Algorithm
47	Görçün (2019)	Basic Components of LPI	Integrated Entropy and ETAWOS Methods
48	Kısa and Ayçin (2019)	Basic Components of LPI	SWARA and EDAS
49	Güngör, Dursun, Karaoğlan, (2019)	Basic Components of LPI and GDP	Panel Data Analysis
50	Karaköy and Üre (2019)	Scores of LPI, The ratio of Fixed Capital Investments to GDP and The ratio of Foreign Direct Investment to Gross Domestic Product	Causality Analysis
51	Khan et al. (2019)	-	Panel Data Analysis
52	Lagoudis, Madentzoglou, Theotokas, Yip (2019)	Basic Components of LPI	Qualitative Analysis
53	Lin and Cheng (2019)	Basic Components of LPI	Linear Regression Analysis
54	Lu, Xie, Chen, Zou, Tang, (2019)	Basic Components of LPI, CO2 Emission and Transportation Sector Oil Consumption Data	DEA
55	Orhan (2019)	Basic Components of LPI	ENTROPY and EDAS
56	Rashidi and Cullinane (2019)	Basic Components of LPI	DEA
57	Savrun and Mutlu (2019)	Basic Components of LPI	Bibliometric Analysis
58	Şimşek and Yiğit (2019)	Scors of LPI, GDP and Export Data	Panel Data Analysis
59	Takele (2019)	Basic Components of LPI	Descriptive Analysis
60	Yıldız and Tabak (2019)	Basic Components of LPI	Qualitative Analysis
61	Aksungur and Bekmezci (2020)	Basic Components of LPI	Qualitative Analysis
62	Beysenbaev and Dus (2020a)	Basic Components of LPI	Principal Component Analysis
63	Beysenbaev and Dus (2020b)	Basic Components of LPI	Qualitative Analysis
64	Görgün (2020)	Basic Components of LPI	Qualitative Analysis
65	Mercangoz, Yildirim, Yildirim, (2020)	Basic Components of LPI	CORPAS-G
66	Yildirim and Mercangoz (2020)	Basic Components of LPI	Fuzzy AHP and ARAS-G
67	Yıldız et al. (2020)	Basic Components of LPI	Cluster Analysis

It has been determined that studies on LPI evaluation have increased since 2017, and more studies had been carried out, especially in 2019 and 2020. This reveals that awareness of LPI assessment has increased in recent years. Besides, it gives clues that both governments and communities are canalizing researchers to make studies to increase their LPI scores. Also, it has been determined that the studies on LPI are generally in the form of country or community comparison based on LPI sub-component, or comparison of LPI scores within the country groups. Besides, it was observed that some studies focused on comparing LPI with other indices or examining the effects of these indices on each other and determining the relationship between LPI and some economic indicators. In some other studies, it was determined that LPI six basic components were taken as the basis for determining the LPI scores and some MCDM methods were recommended. In this context, it is thought that this study differs from other studies in terms of both examining G-20 countries as a group country and carry outing LPI evaluation by considering a large number of input variables that will affect the LPI score. Also, it is thought that this study will make an essential contribution to the literature since it allows the G-20 countries to see the changes in the efficiency together over the years by using LPI scores and the MTFP analysis.

Looking at the previous studies, by Yu and Hsiao (2016), Mariano et al. (2017), Marti et al. (2017), Lu et al. (2019) and Rashidi and Cullinane (2019) studies conducted have shown that the DEA is widely used. In the studies conducted by Yu and Hsiao (2016) and Rashidi and Cullinane (2019), the logistics performance of OECD countries was evaluated and LPI basic components were used as a variable. Besides, in the studies conducted by Mariano et al. (2017) and Lu et al. (2019), and environmental LPI has been proposed. Similarly, CO2 emission values with LPI basic components were used in both studies. Differently, also, GDP and data of transportation sector oil consumption were used. In the study by Marti et al. (2017), the DEA approach was proposed to calculate LPI. In the study, different variables such as LPI basic components, income and geographic area were used. In the studies conducted, when the obtained results were compared with the LPI scores, the positive relationship between the results was revealed. Although this study is similar to the current studies as a method, it is possible to state that the study differs in terms of variables with the DMU used in the evaluation. Also, this study differs from the current studies in terms of examining the efficiency change in the 2007-2016 period.

4. METHODOLOGY

4.1. Data Envelopment Analysis and Historical Development

The DEA is a method that allows measuring the performance of homogeneous units by using input and output variables that are measured at different scales. The units analyzed in the method are called the decision-making unit (DMU). In general, a DMU is considered as the asset responsible for converting inputs into outputs and whose performance will be evaluated (Cooper et al., 2007). The DEA produces a single score that allows comparison for each DMU. This score is among [0, 1] and "1" indicates the efficient frontier this the most efficient DMU (Sevkli, Lenny Koh, Zaim, Demirbag, Tatoglu, 2007). The relative efficiency between the unit showing the "best practices" among the DMUs and the others can also be determined (McMillan and Datta, 1998). Moreover, the DEA can calculate the efficient and inefficient values of each DMU by specifying its quantity and source. With this aspect, it helps to produce healing policies for determining the source of inefficient (Bakırcı, Ekinci, Şahinoğlu, 2014).

The foundation of the DEA is based on the studies carried out by Debreu in 1951 and Farrell in 1957 (Bayrak, 2019). In his study in 1957, Farrell proposed a model that can calculate the efficiency of firms by using a large number of input and output data (Farrell, 1957). With this model, studies on efficiency measurement have gained a new dimension and led to the emergence of the DEA. This model, put forward by Farrell, was developed by Charnes, Cooper and Rhodes in 1978 and a new model was created. According to this model, which is called the CCR model, the total efficiency was measured for the first time under the assumption of constant returns to scale (Charnes, Cooper, Rhodes, 1978). When it came to 1984, a new model was created by developing the CCR model by Banker, Charnes and Cooper. Know as the BCC model, both technical efficiency and scale efficiency can be calculated (Banker, Charnes, Cooper, 1984). Studies after this date continued with the development of these models, which form the basis of the DEA, in line with the needs arising in real-life problems. Today, the DEA has become an important method used to measure performance in many areas such as health, education, finance, production in the public and private sectors, to determine the relatively efficient and inefficient of the units and to determine their quantities and resources (Gökşen, Doğan, Özkarabacak, 2015).

4.1.1. Data Envelopment Analysis Models

The DEA has been developed in line with the needs since its emergence. Also, various DEA models have been created by researchers. If these models are classified briefly, they are primarily divided into two groups according to constant returns to scale and variable return to scale. Then both groups are categorized as input-based and output-based within themselves. At this point, deciding which model to use in analysis is of great importance in terms of results. Some factors should be taken into account in making this decision. For example, it is crucial at this point which efficiency value the researcher wants to calculate. If it is desired to calculate the total efficiency of the DMUs used in the analysis under the assumption of constant returns to scale, the use of the CCR model should be preferred. If the technical efficiency and the scale efficiency of the DMUs are to be calculated under the assumption of a variable return to scale, then the BCC model should be preferred (Özden, 2008). Another factor to consider when determining the method to be used in the research is the researcher's control power over the variables. If there is little or no control over input variables, an output-based model should be used; if there is little or no control over output variables, an input-based model should be used (Cook and Seiford, 2009).

The CCR model is described as the most basic structure of the DEA. The total efficiency values of DMUs are calculated under the assumption of constant returns to scale using the model. This model can be used in two ways based on input and output (Demirci, 2018). With the BCC model, technical efficiency and scale efficiency of DMUs can be calculated under the assumption of variable returns to scale. The BCC model, just like the CCR model, can be used on both input and output basis (Demirci, 2018).

4.1.2. Application Stages of Data Envelopment Analysis

The steps to be followed in the DEA applications are listed below (Lorcu, 2008; Bakırcı et al., 2014; Demirci, 2018):

Definition and Selection of Decision-Making Units

The first stage of the DEA is the definition and selection of DMUs. This step is significant for the accuracy of the analysis results. The DMUs used in the analysis should be homogeneous. In other words, all DMUs subject to the analysis should obtain the same output variables by using the same input variables. At the same time, the analyzed DMUs must have a sufficient number. There are different opinions about what the number of DMUs should be in the literature, m: number of inputs, s: number of outputs and n: number of DMUs; the first of these views is that $n \geq mak\{m \times s, 3(m + s)\}$

(Cooper et al., 2007). According to the other view, it should be $n \geq 2(m + s)$ (Yildirim and Önder, 2015). Final opinion is $n \geq m + s + 1$ (Düzakın and Demirtaş, 2005).

Selection of Input and Output Variables

The efficiency of DMUs is calculated based on the input and output variables used in the analysis. Therefore, the selection of input and output variables is critical. While making this selection, standard input and output variables should be determined for all DMUs.

Determination of Data Envelopment Analysis Model, Its Application and Interpretation of Results

After selecting input and output variables, the DEA model to be used should be determined. Determining the DEA model is related to the assumptions such as what kind of efficiency the researcher wants to calculate, the controllability of input and output variables. The descriptions about the selection of the DEA model have been mentioned while describing the DEA models above.

4.2. Malmquist Total Factor Productivity Index

The Malmquist Total Factor Productivity (MTFP) index was first introduced by Malmquist (1953). Later It has been studied and developed by authors such as Caves, Christensen, Diewert, (1982), Fare and Grosskopf (1992), Fare, Grosskopf, Norris, Zhang, (1994) (Cooper et al., 2004). The MTFP index allows measuring the efficiency of DMUs by taking into account the time dimension and thus to evaluate the change in efficiency between two time periods (Cooper et al., 2004). In the method, the efficiency change of DMUs is divided into two components as technical change and technological change and it is calculated by multiplying these two (Coelli, Rao, O'Donnell, Battese, 2005). Technical efficiency change consists of pure efficiency and scale efficiency. According to this, while pure efficiency is investigating the change of efficiency in terms of management, the scale efficiency investigates whether the DMUs operate at the most appropriate scale (Tosun and Aktan, 2010: 117). The method also provides information about technological change. Technological change is based on the idea that the product costs produced by the technological progress provided should be less than the product costs produced by the current technology and it questions this in terms of DMUs (Özulucan and Özdemir, 2009).

The MTFP index of bigger than one indicates an increase in productivity meaning, a growth in the $t + 1$ period compared to the t period, and if it is less than one, the decrease in the productivity, in other words, there is a shrink in the $t + 1$ period compared to the t period (Tosun and Aktan, 2010). If there is no change in input and output variables between periods, this shows that there will be no change in the MTFP index (Fare et al., 1994).

5. APPLICATION

In this study, it is aimed to make comparative efficiency analysis of G-20 countries, which are among the biggest economies of the world, using the DEA and the MTFP analysis methods in terms of logistics performance. In the analysis, an input-based model was used because the control power was less on the output variable. Thus, it was tried to reach the current output value by using the least input. In line with this purpose, analyzes were made primarily to determine the relative efficiency and to identify efficient countries. Then, reference sets created for the countries under the efficient frontier were determined and the levels of input variables were determined for these countries. At the same time, suggestions for improving these variables were presented. Then, technical efficiency, technological efficiency, pure efficiency, scale efficiency, and TFP changes for all countries have been examined.

5.1. Identification of Decision-Making Units

While determining the number of DMUs used in the study, the work of Golany and Roll is used (Yildirim and Önder, 2015). Accordingly, G-20 countries were included in the scope of the analysis as DMU. Although the European Union Commission is among the G-20 countries, it is not included in the analysis because it expresses a commission rather than a country. As a result, DMUs were used in the analysis. The DMUs used in the analysis are shown in Table 3.

Table 3. Decision-Making Units Used in Analysis

No	Country Name	Country Code
1	United States of America	USA
2	Germany	GER
3	Argentina	ARG
4	Australia	AUS
5	Brazil	BRA
6	China	CHI
7	Indonesia	INDO
8	France	FRA
9	South Africa	SAF
10	South Korea	SKOR
11	India	IND
12	England	ENG
13	Italy	ITA
14	Japan	JAP
15	Canada	CAN
16	Mexico	MEX
17	Russia	RUS
18	Saudi Arabia	SARAB
19	Turkey	TUR

5.2. Selecting Input and Output Variables

While determining the variables used in the research, the opinions of the industry and academic experts were consulted. In this regard, firstly, individual internet usage of countries, foreign direct investments, GDP, GNP, the number of passengers carried by airway, amount of cargo carried by the airline, high technology exports, GDP per capita, GNP per capita, port container traffic, goods and service exports, goods and services imports, population, total trade volume, total workforce and newborn mortality rates as the input variables were determined. LPI general score values of the countries were used as the output variable. Then, in order to evaluate the relationship between the variables preliminarily, correlation analysis was performed using 2007 data. According to the correlation analysis results in high, medium and low correlations can be seen between the variables. In the analysis, variables showing medium and low correlation were used. Moreover, when deciding which variables to use, trial and error method was also used. As a result, the variables used in the study are shown in Table 4.

Table 4. Variables Used in Analysis

No	Variables	Type
1	Gross Domestic Product	Input
2	Number of Passengers Carried by Airline	Input
3	Amount of Freight Carried by Airline	Input
4	Container Port Traffic	Input
5	Total Volume of Trade	Input
6	Export/Import Coverage Ratio	Input
7	Labour/Population Ratio	Input
8	Logistics Performance Index	Output

5.3. Collection of Data

The data of 2007, 2010, 2012, 2014 and 2016, in which LPI evaluation results were reported, were used in the study. Observations of input and output variables used in the study were obtained from the World Bank.

In the study, the CCR model and the BCC model are used. Firstly, the data were analyzed based on years (2007, 2010, 2012, 2014, 2016) with the help of the DEA method and the Win4DEAP 2 program. After this analysis, all the data used in the application were handled together and the change over the years was examined by the MTFP analysis method.

5.4. Evaluation of Findings

In the study, the efficiency indicators obtained as a result of the analysis made according to the CCR and the BCC input-based models are shown in Table 5.

Table 5. Efficiency Values of Countries

Countries	CCR Efficiency Analysis					BCC Efficiency Analysis				
	2007	2010	2012	2014	2016	2007	2010	2012	2014	2016
USA	1	1	1	1	1	1	1	1	1	1
GER	0,867	0,889	0,806	0,857	0,876	1	1	1	1	1
ARG	1	1	1	1	1	1	1	1	1	1
AUS	1	1	1	1	1	1	1	1	1	1
BRA	1	1	1	1	1	1	1	1	1	1
CHI	0,652	0,742	1	0,777	0,804	0,667	0,745	1	0,793	0,819
INDO	0,860	0,805	0,859	0,936	0,833	0,907	0,932	0,993	0,979	0,887
FRA	1	1	1	1	0,989	1	1	1	1	1
SAF	1	1	1	1	1	1	1	1	1	1
SKOR	0,868	0,920	0,871	0,858	0,777	0,871	0,973	0,882	0,863	0,782
IND	0,933	0,927	0,951	0,925	1	0,997	0,963	1	1	1
ENG	1	1	0,980	1	1	1	1	1	1	1
ITA	0,929	1	1	1	0,921	0,999	1	1	1	1
JAP	1	1	1	1	1	1	1	1	1	1
CAN	0,999	1	1	1	1	1	1	1	1	1
MEX	1	0,958	0,926	1	0,879	1	1	1	1	0,970
RUS	0,643	0,652	0,645	0,678	0,624	0,821	0,800	0,799	0,800	0,778
SARAB	0,932	0,945	0,830	0,853	0,837	1	1	0,953	0,932	0,939
TUR	1	1	1	1	0,972	1	1	1	1	1
Mean	0,931	0,939	0,940	0,941	0,922	0,961	0,969	0,980	0,967	0,957

In the analysis results made according to the CCR input-based model in Table 5; the USA, Argentina, Australia, Brazil, Saudi Africa and Japan have emerged as efficient countries in all years.

On the other hand, Germany, Indonesia, South Korea, Russia and Saudi Arabia were the countries that remained under the efficient frontier for all years. While France and Turkey remained under the efficient frontier only in 2016, Canada only in 2007 and England only in 2012, they were efficient in other years. China was efficient only in 2012 and India only in 2016. Besides, while Italy remained under the efficient frontier in 2007 and 2016, it was efficient in other years. Finally, Mexico was efficient in 2007 and 2014 but remained under the efficient frontier in other years.

In the analysis results made according to the BCC input-based model in Table 5; It is noteworthy that more countries are efficient than the number of efficient countries obtained with the analysis made according to the CCR input-based model. Accordingly, the USA, Germany, Argentina, Australia, Brazil, France, Saudi Africa, England, Japan, Canada and Turkey were efficient in all years. On the other hand, Indonesia, South Korea and Russia remained under the efficient frontier in all years. Also, Italy remained under the efficient frontier only in 2007 and Mexico only in 2016. However, China was efficient only in 2012. India remained under the efficient frontier in 2007 and 2010 and was efficient in other years. On the contrary, Saudi Arabia was efficient in 2007 and 2010 but remained under the efficient frontier in other years.

Scale efficiency values of countries and their returns to scale are shown in Table 6.

Table 6. Scale Efficiency and Returns to Scale of Countries

Countries	**Scale Efficiency and Returns to Scale**									
	2007		**2010**		**2012**		**2014**		**2016**	
USA	1	Constant	1	Constant	1	Constant	1	Constant	1	Constant
GER	0,867	Decreasing	0,889	Decreasing	0,806	Decreasing	0,857	Decreasing	0,876	Decreasing
ARG	1	Constant	1	Constant	1	Constant	1	Constant	1	Constant
AUS	1	Constant	1	Constant	1	Constant	1	Constant	1	Constant
BRA	1	Constant	1	Constant	1	Constant	1	Constant	1	Constant
CHI	0,978	Increasing	0,996	Increasing	1	Constant	0,980	Increasing	0,982	Increasing
INDO	0,948	Increasing	0,865	Increasing	0,865	Increasing	0,956	Increasing	0,940	Increasing
FRA	1	Constant	1	Constant	1	Constant	1	Constant	0,989	Decreasing
SAF	1	Constant	1	Constant	1	Constant	1	Constant	1	Constant
SKOR	0,997	Decreasing	0,945	Decreasing	0,987	Decreasing	0,995	Decreasing	0,994	Increasing
IND	0,935	Increasing	0,963	Increasing	0,951	Increasing	0,925	Increasing	1	Constant
ENG	1	Constant	1	Constant	0,980	Decreasing	1	Constant	1	Constant
ITA	0,930	Decreasing	1	Constant	1	Constant	1	Constant	0,921	Decreasing
JAP	1	Constant	1	Constant	1	Constant	1	Constant	1	Constant
CAN	0,999	Decreasing	1	Constant	1	Constant	1	Constant	1	Constant
MEX	1	Constant	0,958	Increasing	0,926	Increasing	1	Constant	0,907	Increasing
RUS	0,783	Increasing	0,815	Increasing	0,806	Increasing	0,847	Increasing	0,802	Increasing
SARAB	0,932	Increasing	0,945	Increasing	0,870	Increasing	0,915	Increasing	0,891	Increasing
TUR	1	Constant	1	Constant	1	Constant	1	Constant	0,972	Increasing
Mean	0,967		0,967		0,957		0,972		0,962	

Based on the results, the scale efficiency of the countries, it was revealed that Germany, Indonesia, South Korea, Russia and Saudi Arabia remained under the efficient frontier all the years subject to analysis. However, the USA, Argentina, Australia, Brazil, South Africa and Japan were efficient. It was observed that other countries were efficient in some years and remained below the efficient frontier in some years. When the returns to scale of the countries are analyzed, it is determined that Germany has a decreasing return to scale, Russia and Saudi Arabia have an increasing return to scale, USA, Argentina, Australia, Brazil, South Africa and Japan have constant returns to scale. It has been observed that the status of returns to scale of other countries varies according to years.

The reference groups determined for the countries under the efficient frontier are shown in Table 7.

Table 7. Reference Countries

No	Countries	Reference Countries									
		CCR Model					BCC Model				
		2007	2010	2012	2014	2016	2007	2010	2012	2014	2016
1	USA	1	1	1	1	1	1	1	1	1	1
2	GER	1-12-19	1-12-19	6-19	3-8-19	1-4-9	2	2	2	2	2
3	ARG	3	3	3	3	3	3	3	3	3	3
4	AUS	4	4	4	4	4	4	4	4	4	4
5	BRA	5	5	5	5	5	5	5	5	5	5
6	CHI	1-4-14-19	1-4-14-19	6	1-14-19	1-9-14	1-4-5-14-19	1-4-5-14-19	6	1-3-5-14-19	1-3-11-14
7	INDO	3-9-19	3-13-19	3-5-9-13	3-4-9	3-4-9-11-14	3-9-19	3-13-19	3-9-11-16	3-5-9	3-9-11-19
8	FRA	8	8	8	8	4-9-12-15	8	8	8	8	8
9	SAF	9	9	9	9	9	9	9	9	9	9
10	SKOR	4-19	9-13-19	6-9	8-9-19	1-4-9	4-9-19	4-9-13	6-9-14-15	4-8-9-15-19	3-4-9-19
11	IND	4-20	12-15-19	9-19	4-9-13-19	11	1-5-19	1-19	11	11	11
12	ENG	12	12	14-15-19	12	12	12	12	12	12	12
13	ITA	4-12-14-19	13	13	13	3-4-9	4-9-14-19	13	13	13	13
14	JAP	14	14	14	14	14	14	14	14	14	14
15	CAN	4-9-16	15	15	15	15	15	15	15	15	15
16	MEX	16	3-9-13-15	3-9-13	16	4-9	16	16	16	16	3-4-9-11
17	RUS	3-4-9-19	3-4-5-9	3-9-19	3-9-19	3-9-14	3-16-19	3-9-16-19	3-9-19	3-9-19	3-9-11
18	SARAB	9-19	9	9	9-19	4-9	18	18	9-19	9-11	3-9-11-19
19	TUR	19	19	19	19	1-4-9-12	19	19	19	19	19

It was observed that based on both models Argentina, South Africa and Japan were included in the reference country group in all years subject to the analysis. Also, among these countries, South Africa was found to be the most referenced country. That shows that when the input and output variables used in the analysis are taken into consideration, the input variables are sufficient for the current output variable level. For this reason, it is revealed that the countries that are below the efficient frontier take these countries as examples in order to be efficient. In other words, it is determined that they try to resemble these countries in terms of the amount of the input variable.

The change in efficiency scores as of the periods subject to the analysis was calculated by the MTFP analysis. The values for this are shown in Table 8.

Table 8. Efficiency Exchange by Periods

Periods	Technical Efficiency Change	Technological Efficiency Change	Pure Efficiency Change	Scale Efficiency Change	TFP Change
2007-2010	1,011	0,988	1,010	1,001	0,999
2010-2012	0,988	0,998	1,000	0,988	0,986
2012-2014	1,016	0,965	0,998	1,018	0,981
2014-2016	0,988	1,034	0,994	0,994	1,022
MIN	0,988	0,965	0,994	0,988	0,981
MAX	1,016	1,034	1,010	1,018	1,022
MEAN	1,001	0,996	1,000	1,000	0,997
Standard Deviation	0,015	0,029	0,007	0,013	0,018

From Table 8, it can be observed that there was an increase in the efficiency of all countries in terms of technical efficiency, pure efficiency and scale efficiency in the period 2007-2010. Whereas there was a decrease in efficiency in terms of technological efficiency and TFP. Moreover, it was determined that there was no change in pure efficiency in all countries in the period of 2010-2012, and there was an adverse change in technical efficiency, technological efficiency, scale efficiency and TFP scores. In the 2012-2014 period, although there was an improvement in technical efficiency and scale efficiency in all countries, it was observed that there was a decrease in technological efficiency, pure efficiency and TFP. From 2014 to 2016, it was seen that all countries' technological efficiency and TFP scores improved, technical efficiency, pure efficiency and in scale efficiency decreased.

Table 9 shows the change in the types of efficiency between 2007 and 2016.

Table 9. MTFP Analysis Efficiency Averages for the 2007-2016 Period

Countries	Technical Efficiency Change	Technological Efficiency Change	Pure Efficiency Change	Scale Efficiency Change	TFP Change
USA	1,000	0,998	1,000	1,000	0,998
GER	1,008	0,991	1,000	1,008	1,000
ARG	1,000	0,915	1,000	1,000	0,915
AUS	1,000	0,995	1,000	1,000	0,995
BRA	1,000	1,019	1,000	1,000	1,019
CHI	1,054	1,009	1,053	1,001	1,064
INDO	0,995	1,002	0,996	0,999	0,998
FRA	1,000	0,996	1,000	1,000	0,996
SAF	1,000	1,020	1,000	1,000	1,020
SKOR	0,978	0,991	0,978	1,000	0,969
IND	1,018	1,004	1,001	1,017	1,022
ENG	1,000	0,990	1,000	1,000	0,990
ITA	1,014	0,985	1,000	1,014	0,999
JAP	1,000	1,015	1,000	1,000	1,015
CAN	1,000	1,003	1,000	1,000	1,003
MEX	0,968	1,003	0,992	0,979	0,971
RUS	1,003	1,022	1,000	1,003	1,025
SARAB	0,973	1,011	0,992	0,981	0,984
TUR	1,000	0,963	1,000	1,000	0,963
MIN	0,968	0,915	0,978	0,979	0,915
MAX	1,054	1,022	1,053	1,017	1,064
MEAN	1,000	0,996	1,001	1,000	0,997

Standard Deviation	0,018	0,024	0,014	0,009	0,031

According to Table 9, it was determined that China and India had experienced an improvement in all types of efficiency through 2016; on the other hand, South Korea did not experience any change in scale efficiency and other types of efficiency. Brazil, South Africa, Japan and Canada are identified as countries experiencing increased technological efficiency and TFP change. On the other hand, the same type of efficiency in the U.S., Argentina, Australia, France, England and Turkey have been identified as missing. In other countries, it was observed that there was sometimes positive progress and sometimes negative progress in these five periods (2007, 2010, 2012, 2014, 2016).

6. CONCLUSION

Determining the performance of the logistics sector, which is used today as a significant competitive advantage in terms of world trade, is a critical issue. Correctly measuring and comparing the logistics performance will be beneficial in developing new strategies by governments and private sector stakeholders. Therefore, in this study, it is aimed to make a comparative efficiency analysis of G-20 countries, in terms of logistics success.

In the study, an analysis made according to the CCR and the BCC input-based models to determine the efficient countries It was determined that the USA, Argentina, Australia, Brazil, South Africa and Japan provided efficiency according to both models. On the other hand, Indonesia, South Korea and Russia are under the efficient frontier in all years. However, looking at the LPI scores, it is seen that Germany is the country that provides the highest performance among the G-20 countries in all the years in which the evaluation is made. Nevertheless, according to the results of the analysis made according to the CCR input-based model, Germany remained below the efficient frontier in all years. That shows that considering the input and output variables used in the analysis, Germany can use less input amounts to reach the current output variable. In other words, the amount of input variables in Germany is higher than the current output variable level, and this causes Germany to remain under the efficient frontier.

Further analysis made to determine the scale efficiency of the countries and the status of returns to scale, which showed that the scale efficiency results were similar to the results of the efficiency analysis made according to the CCR input-based model. Moreover, in all years Germany's decreasing return to scale; Indonesia, Russia and Saudi Arabia's increasing return to scale; It has been determined that USA, Argentina, Australia, Brazil, South Africa and Japan have constant returns to scale.

In the study, reference countries for the countries below the efficient frontier; it has been observed that Argentina, South Africa and Japan are included in the reference country group in all years. The country with the highest number of samples among these countries was determined to be South Africa.

In the study, as a result of the analysis made according to the CCR input-based model in order to determine the input levels of the countries below the efficient frontier and the potential improvement values, the variables that need the highest rate of improvement; is port container traffic in 2007, 2010, 2014 and 2016 and GDP in 2012. For the BCC input-based model, variables that need the highest rate of improvement; is also port container traffic in all the years. As a result of the evaluation of all years, according to both models, it was seen that there is a need for a significant improvement in the port container traffic variable for the countries below the efficient frontier. It was also observed that this variable was quite high when compared with the current output level. In other words, it has been determined that there is no efficiency at the current output level for this variable.

When the efficiency change is analyzed by the MTFP analysis, it has been determined that the most productive period is 2007-2010 and the most inefficient period is 2010-2012. At the same time, when the change in efficiency types for the 2007-2016 period is analyzed, it has been observed that China and India have improved in all periods for all efficiency types.

The data used in this study is limited to the years 2007, 2010, 2012, 2014 and 2016, when the results of the LPI evaluation were published. Besides, the variables used in the analysis were determined according to the opinions of the industry and academic experts. Therefore, the results of the analysis are limited to these variables and it may be recommended to use different variables by different experts. In future studies, other years when LPI evaluation results are published can be added to the study and variables can be expanded with different expert opinions. Also, different countries and country groups can be analyzed. While making these analyzes, different programs such as DEA Solver, DEAP, EMS can be used.

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