

# Measuring Foreign Trade-Logistics Efficiency: A DEA Approach and the Malmquist Index



Mehmet Fatih Acar and Alev Özer Torgalöz

**Abstract** With the effect of globalization, the importance of logistics activities has increased for both countries and companies. In particular, governments have aimed to improve their logistics performance in recent years. The World Bank has started to publish the Logistics Performance Index (LPI) since 2007, evaluating countries regarding their logistics activities. LPI has six sub-dimensions: “customs,” “infrastructure,” “international shipment,” “quality of logistics services,” “tracking/tracing,” and “timeliness.” This study aims to investigate the logistics performance of the member countries of the Organization for Economic Cooperation and Development (OECD) in respect to foreign trade. For this, LPI sub-dimensions, foreign direct investment, and export volumes are considered to measure the efficiencies. In this research, LPI and foreign trade values belongs to OECD member countries for 2007–2018 period are analyzed with using Data Envelopment Analysis (DEA) and Malmquist Index (MI). The main motivation of this study is to examine the changes in the foreign trade-logistics efficiencies of the OECD member countries from 2007 to 2018. This research can be regarded as being among the first studies in this context and provides a perspective for countries to improve their logistics efficiencies. Furthermore, the case of Turkey is investigated in detail to point out how developing countries can evaluate themselves compared to the developed ones. In conclusion, according to the results, some countries appear performing better in terms of logistics efficiencies related to foreign trade values. Moreover, the comparison analyses reveal that Turkey’s efficiency is at a low level, and it needs to make necessary technical and legal arrangements for all dimensions

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of LPIs. Required steps which can be rearranged for Turkey are also discussed at the end of the study.

**Keywords** Logistics Performance Index (LPI) · Data envelopment analysis · Turkey · Organization for Economic Cooperation and Development (OECD)

## 1 Introduction

Foreign trade transactions are critical for the economic development of countries (Malkowska & Malkowski, 2021). With the increase of global trade, logistics and supply chain operations have become very important factors for exporters and importers (Chu et al., 2015). Therefore, the logistics sector is gradually growing (Akdoğan & Durak, 2016). In today's competitive business environment, governments and companies should give importance to logistics operations to respond quickly for the demands of the market. Moreover, companies and governments need to pay attention to logistics processes to be more efficient in terms of time and cost.

Logistics is basically the management and controlling of transfer of goods, services, and information from producers to consumers (De Souza et al., 2007). Effectively managed and well-organized supply chains enable customers to receive products or services in a safe, fast, and cost-effective way. Therefore, firms should be aware of the importance of logistics to increase both their financial profits and reputation in their markets. According to Christopher (1992), in today's business world competition is not among firms but among supply chains. Therefore, not only transfer activities but also various supply chain management operations such as production planning and inventory management have become primary functions for enterprises. In this regard, transportation infrastructure, laws, the quality of personnel, the capacities of the warehouses, and using of different transport channels determine the supply chain performance for states and companies.

With the Logistics Performance Index (LPI) published by the World Bank since 2007, it has become easier to compare and analyze the logistics efficiencies of countries. This index provides information and overview on customs regulations, logistics costs, and transport infrastructure for different countries (Arvis et al., 2018). LPI basically measures the logistics performance of countries with six different dimensions via a survey. These dimensions are customs, infrastructure, international shipments, quality of logistics services, tracking/tracing, and timeliness. Customs is related with the efficiency levels of customs procedures of logistics activities. Infrastructure refers to the quality level of transport infrastructure. International shipments indicate competitive prices for international transfers within the market. Logistics quality and competence show the adequacy and quality of logistics services in a country. Tracking/tracing refers to the controllability of the shipment in terms of time and place. Finally, timeliness is an indicator of whether the delivery is on planned and expected time or not (Arvis et al., 2018).

In this study, foreign trade-logistics efficiencies based on LPI scores are analyzed using Data Envelopment Analysis (DEA) for OECD member countries. Since these

countries play an important role in the global economy, investigating their foreign trade-logistics efficiencies provides valuable insight and information. Meanwhile, only data of OECD member countries are included in this study to meet the homogeneity for the data set. For this study, homogeneity is important as DEA determines the efficiency scores of decision-making units (DMUs) relatively. In other words when the efficiency of any DMU is calculated by using DEA methodology, other DMUs' performances play an important role. In addition, DEA calculates the efficiency as the ratio of weighted outputs to weighted inputs. If there is no homogeneity, it can be problematic to calculate efficiencies, because DMUs with low inputs and low outputs may appear more efficient. Therefore, if all countries are considered, some underdeveloped or developing countries may rank upper in efficiency rankings.

The purpose of this research is to point out how inefficient countries can improve themselves compared to the efficient ones. In this study, Turkey is determined as a case study to provide advice for developing countries and discuss their needs. There are some reasons for why we specifically choose Turkey. First, Turkey is a developing country and is commonly expected to be inefficient compared to developed OECD members. Second, it is a member of the OECD, and its European Union (EU) participation process still continues. In short, Turkey is a developing country, and its economy has faced significant changes.

The Malmquist Index (MI) provides information about the change in logistics efficiencies over different periods. Therefore, in this study, Malmquist Index (MI) is calculated for all OECD member countries to investigate the change of foreign trade-logistics efficiency for different years. There are many studies about the logistics efficiencies within the related literature, however, most of them consider specific LPI provided only for a particular year. The main motivation of this study is to examine the changes in the foreign trade-logistics efficiencies of OECD member countries by considering all LPI values from 2007 to 2018. Therefore, the study can be regarded as being among the first ones in this context and it contributes to the literature by showing how foreign trade-logistics efficiencies of countries have changed over the time with giving MI values. In addition, this study points out how a developing country can compare its foreign trade-logistics efficiencies with those of developed countries.

The research questions of this study are as follows: (1) Which OECD countries perform better in terms of foreign trade-logistics efficiency?, (2) Which countries have a very low foreign trade-logistics efficiency?, (3) Which countries have high and low levels of improvement in terms of foreign trade-logistics efficiency over the years?, (4) What is the situation of Turkey about foreign trade-logistics efficiency compared to other OECD countries?, and (5) Which types of precautions should be taken by Turkish policy makers with regard to the logistics efficiency?

The rest of the paper is organized as follows. Section 2 provides an extensive literature review about the studies on logistics performance. Sections 3 and 4 present the background information and application of the proposed model, respectively. The obtained results are illustrated and discussed in Sects. 5 and 6. Finally, Sect. 7 provides concluding remarks and future research directions.

## 2 Literature Review

Logistics efficiency is a critical issue within the operations management literature. Many studies have evaluated logistics operations at the micro-level. However, only a limited number of studies have discussed the performance of logistics activities at the macro-level (Rashidi & Cullinane, 2019).

This study uses the competitive advantage theory to explain the importance of logistics for trade and economies in a broader perspective. Porter's (1990) national competitive advantage theory basically argues that the main pillar of a country's development depends on whether it has competitive advantage within international markets or not (Ren & Ma, 2018). The reason why we focus on logistics is that it provides countries with a competitive advantage within the global trade. In fact, having a well-established logistics infrastructure and logistics system can be considered as supporting factors for a favorable or superior economic position. Bhatnagar and Teo (2009) regarded logistics management as criteria that enhances competitive positioning as a part of the value chain proposed by Porter (1985). In this context, the foreign trade-logistics efficiencies of countries can be seen as a competitive advantage for all countries, especially for the developing ones. Similarly, Puertas et al. (2014) stated that logistics is very important in exporting nations.

As mentioned above, LPI has been published by the World Bank since 2007 and these data have been used in various studies in the literature (Martí et al., 2017; Onsel Ekici et al., 2019; Rashidi & Cullinane, 2019). This index offers a wide range of different perspectives regarding the logistics operations of countries (Arvis et al., 2018). Moreover, different techniques have been applied for the data of LPI in the literature. For example, Quariguasi et al. (2009) examined logistics networks and efficiencies in Germany by taking environmental and economic conditions into consideration. In addition, Kabak et al. (2019) investigated the relationship between countries' logistics performances and competitiveness and their methodology included Bayesian Net (BN), Partial Least Square (PLS), and Importance-Performance Map Analysis (IPMA). This study points out the importance of "Business Sophistication," "Financial Market Development," "Infrastructure," "Good Market Efficiency," and "Higher Education and Training" which mostly affect the logistics performance. Myers et al. (2004) demonstrated that job skills have a positive effect on performances of logistics managers, however, they were unable to provide similar evidence for both experience and education. Fechner (2010) stated that the infrastructure is very critical for the improvement of logistics operations in countries. Furthermore, Martí et al. (2014) investigated the effects of LPI sub-scales on trade performance for developing countries and the research highlighted the importance of all LPI sub-dimensions on international trade. In addition, D'Aleo and Sergi (2017) examined the relationship between LPI and the Global Competitiveness Index (GCI) using panel data analysis. In a study by Sternad et al. (2018) DEA was used to analyze the logistics efficiency of EU countries. Similarly, Mesjasz-Lech (2019) demonstrated the importance of LPI for

entrepreneurship within the fields of transportation and storage in EU. Liu et al. (2018) investigated the effects of logistics performance on environmental damage. In the study, it was shown that LPI sizes are significantly associated with CO<sub>2</sub> emissions. In addition, Luttermann et al. (2020) pointed out a positive relationship between logistics performance and FDI as a result of a panel data analysis for 20 Asian countries.

Min and Kim (2010) constructed a mixed logistics and environmental sustainability index using DEA method. Similarly, Lu et al. (2019) evaluated green transportation and logistics practices with an Environmental Logistics Performance Index (ELPI) for 112 selected countries. According to their research, there is a strong correlation between ELPI and LPI. Moreover, Yu and Hsiao (2016) presented an alternative way for countries to evaluate the LPI. In their studies, meta-boundary data envelopment analysis (Meta-DEA-AR) model was applied to evaluate the LPI scores, and recommendations were made for certain countries. In addition, Coto-Millán et al. (2013) analyzed the relationship between the logistics performance and economic growth of countries. Ekici et al. (2019) evaluated the effects of the Global Competitiveness Index (GCI) on the LPI and provided a general framework for policy makers on how they can improve their countries' logistics performance and showed that digitalization and supply chain analytics are crucial for countries to increase their logistics efficiencies. In addition, Richey et al. (2007) emphasized the impact of technology on logistics performance in their research. Likewise, Erkan (2014) examined the effect of technology with Global Competitiveness Index (GCI) and LPI and revealed that the technological infrastructure and market size affect LPI.

There are also different studies about LPI and Turkey within the related literature. In recent years, various statistical methods have been used for LPI-based comparative analyzes between Turkey and other countries. Ekici et al. (2016) investigated the relationship between LPI and Global Competitiveness Index (GCI) with using the Artificial Neural Network (ANN) for Turkey. In that research, fixed broadband Internet was found to be the most important topic for Turkey, as the fixed broadband Internet had a significant positive impact on the growth of logistics. With their methodology, Ekici et al. (2016) showed how resources of countries could be used to improve logistics competitiveness. Iris and Tanyas (2011) evaluated the LPI values of Turkey and discussed the necessary points to improve the performance in related fields. Danaci and Nacar (2017) compared Turkey and EU countries with considering the LPI and found a statistically significant relationship between the logistics performance and Gross Domestic Product (GDP). Guner and Coskun (2012) examined the relationship between economic/social factors and LPI. They found a significant correlation between them. Unalan and Yaprakli (2016) examined the Turkey's ranking in terms of LPI. They stated that Turkey's performance has improved but there is no significant change has been observed in the rankings over the years. Uca et al. (2015) studied the relationship between GDP and LPI and they revealed a significant relationship among customs, infrastructure, and GDP. In addition, Erdogan (2015) evaluated the situation of Turkey according to the LPI and discussed how to improve Turkey's logistics performance. Orhan (2019)

compared Turkey and EU countries based on LPI results by using Entropy-weighted Edas methodology. Gungor et al. (2019) analyzed the LPI scores for Mediterranean economies and the research highlighted the importance of infrastructure and customs to have high level of GDP. Moreover, in their bibliometric analysis, Pekmezci and Mutlu (2018) provided a detailed and comprehensive literature review about Turkey and LPI.

In many studies, DEA has been frequently used to measure logistics efficiency. Since DEA allows using many inputs and outputs, it is used in this study to assess the foreign trade-logistics performances of selected countries. Although there are various studies about the LPI within the literature (e.g., Rashidi & Cullinane, 2019) many of them have investigated the logistics efficiencies for a specific time-period. However, this current research measures the changes in the foreign trade-logistics efficiencies of the OECD member countries for a period between 2007 and 2018. Therefore, we can argue that this research contributes to the logistics literature by calculating the Malmquist Index to observe the change of foreign trade-logistics efficiencies. Furthermore, this study suggests how a developing country can evaluate itself in comparison to the developed countries with respect to foreign trade-logistics efficiency based on the example of Turkey.

### 3 Methodology

In this study, the Data Envelopment Analysis (DEA) measures the logistics efficiencies of countries. This method bases on a mathematical programming, and it has been developed by Charnes et al. (1978) to find the relative efficiency of decision-making units (DMUs) with respect to each other. Units are often referred to as decision-making units (DMU) in DEA terminology. DEA is a popular tool to evaluate the relative efficiencies of different DMUs and is often used in many academic studies due to some advantages. The first advantage is to offer a comparable efficiency score for each DMU. In particular, it allows assessment between DMUs by defining a frontier to define efficient and inefficient units. Many inputs and outputs with different units can be analyzed in DEA together. In addition to these, there is no any prerequisite the nature of the production function for this method. Finally, DEA reveals comparative efficiency performance that permits to evaluate all input and output levels (Sevкли et al., 2007).

#### 3.1 The CCR-DEA Model

The most popular DEA models are CCR (Charnes et al., 1978) and BCC (Banker et al., 1984) models. In this research, the CCR model is applied because overall productivity is considered and constant returns to scale are presumed. Nevertheless,

BCC model considers pure technical efficiency and assumes variable returns to scale.

DEA model can be input- or output-oriented. Input-oriented models investigate the efficiency levels by deciding how much input should be utilized to obtain a specific output level for any DMU to become efficient. However, an output-oriented model aims to determine the suitable levels of outputs for a DMU to become efficient according to inputs. Briefly, if making changes on inputs is more proper than changes on outputs, input-oriented analysis is better to apply, however, if making changes on the outputs is more suitable, then output-oriented analysis should be chosen. In this research, the input-oriented DEA model is considered to determine how logistic performance can be improved by changing the level of current inputs.

To illustrate the basic DEA-CCR model mathematically, let us assume that each decision-making unit (DMUs) uses  $m$  inputs to produce  $n$  outputs at a given technology level. While  $X_{ij}$  represents the  $i$ th ( $i = 1, 2, \dots, m$ ) input of the  $m$  inputs of the  $j$ th DMU ( $j = 1, 2, \dots, k$ ),  $Y_{sj}$  represents the  $s$ th ( $s = 1, 2, \dots, n$ ) output of the  $n$  outputs produced by  $j$ th DMU. The variables  $U_r$  ( $r = 1, 2, \dots, n$ ) and  $W_i$  ( $i = 1, 2, \dots, m$ ) are the weights of each output and input, respectively. The efficiency of DMU(o) can be written as follows: the efficiency of any decision unit is the ratio of the weighted output to the weighted input quantity. The representation of efficiency as a mathematical model is given below.

$$\text{Max} = \frac{\sum_{r=1}^n u_r Y_{r0}}{\sum_{i=1}^m w_i X_{i0}} = 1 \tag{1}$$

$$\frac{\sum_{r=1}^n u_r Y_{rj}}{\sum_{i=1}^m w_i X_{ij}} \leq 1 \quad j = 1, 2 \dots k \tag{2}$$

$$u_r \text{ and } w_i \geq 0 \quad (r = 1, 2, \dots, n) \text{ and } (i = 1, 2, \dots, m) \tag{3}$$

The CCR model is shown below. In this algorithm, the score of the most efficient DMU is 1.

$$\text{Max} = \sum_{r=1}^0 \mu_r Y_{r0} \tag{4}$$

Constraints;

$$\sum_{i=1}^m w_i X_{i0} = 1 \tag{5}$$

$$\sum_{r=1}^n \mu_r Y_{rj} - \sum_{i=1}^m w_i X_{ij} \leq 0 \quad (6)$$

$$\mu_r \text{ and } w_i \geq 0 \quad (r = 1, 2, \dots, n) \text{ and } (i = 1, 2, \dots, m) \quad (7)$$

### 3.2 Malmquist Index

Normally, DEA methods finds the efficiency of DMUs for a sole time. However, in this study, DEA-based Malmquist productivity index developed by Färe et al. (1994) is operated to measure the efficiency change of a DMU among time stages. The Malmquist index is equal to the product of “Catch-up” and “Frontier-shift.” The catch-up term is the ratio of the observed DMU efficiency score in different time periods. It shows the relationship between periods  $t_1$  and  $t_2$ . Moreover, the frontier-shift term implies the change in the efficient frontiers for specific DMU between the time periods  $t_1$  and  $t_2$ . The frontier-shift is calculated as the geometric mean of frontier-shift effects for periods  $t_1$  and  $t_2$ . The Malmquist Index (MI) is generated by Färe et al. (1994) between periods  $t_1$  and  $t_2$  is given as follows:

$$MI = \left[ \frac{\delta^{t_1}((x_o, y_o)^{t_2})}{\delta^{t_1}((x_o, y_o)^{t_1})} \times \frac{\delta^{t_2}((x_o, y_o)^{t_2})}{\delta^{t_2}((x_o, y_o)^{t_1})} \right]^{1/2} \quad (8)$$

where  $\delta^{t_1}((x_o, y_o)^{t_2})$  shows the distance between the period  $t_2$  observation to period  $t_1$  technology.  $MI > 1$  displays a rise in total product productivity of the observed DMU from the period  $t_1$  to  $t_2$ . Likewise,  $MI = 1$  and  $MI < 1$  imply no change and a decrease in total product productivity, respectively. Further discussion on the calculation of Malmquist index is given in Tone (2004).

## 4 The Analysis of the Model

In this section, details of DEA model used in this research are explained. Moreover, DEA results are given for OECD member countries.

### 4.1 Construction of DEA Model

OECD is one of the most important organizations within the global economy and therefore it was selected as target set in this study to satisfy homogeneity. Inputs of this analysis are sub-dimensions of LPI, these are “customs,” “infrastructure,”



“international shipment,” “quality of logistics services,” “tracking/tracing,” and “delivery on time.” In addition to this, outputs of DEA are the inward foreign direct investment (FDI) and export volumes. The value of outputs is chosen in terms of percentage of national Gross Domestic Product (GDP). The sources of data are the official website of World Bank and OECD. The inward FDI stock is the investment amount in the related country by foreign investors. As suggested in the literature (Martí et al., 2017), a monotone decreasing transformation (five minus the original values) is applied, because DEA computes the efficiency scores with considering the ratio weighted outputs to weighted inputs. If not, in the DEA results, efficient countries’ score may be so low due to high scores of inputs. The Malmquist Index (MI) provides information about the change in efficiency at different times. For this reason, in this study, Malmquist Index (MI) values are shown for all OECD member countries to examine the change in foreign trade-logistics efficiency in different periods.

## 4.2 DEA Results for OECD

In this research, for data set of The Organization for Economic Co-operation and Development (OECD) countries, the CCR-input based DEA are used with DEA-Solver 13 software. Data of six different time periods (for 2007, 2010, 2012, 2014, 2016, and 2018) are evaluated in this study. Table 1 provides information about the highest foreign trade-logistics efficiency values among OECD countries for the relevant years. For instance, Belgium, Ireland, Netherlands, and Switzerland appear as the most efficient countries in 2007. Meanwhile, Chile (0.97) follows these countries. Looking at the 2007–2018 period, some countries outshine in terms of foreign trade-logistics efficiency. In this point, Ireland, Netherlands, Austria, and Belgium are frequently listed among the five most efficient ones. Furthermore, Netherlands and Ireland are found as the most efficient places for each year.

Table 2 displays the lowest foreign trade-logistics efficiency values for related countries during the 2007–2018 period. For instance, in 2007, Colombia (0.12) has the lowest efficiency score, followed by Greece (0.22), Mexico (0.22), Turkey (0.23), and the USA (0.25), respectively. Looking at the 2007–2018 period in a general, results show that some countries have frequently listed among the last five countries in terms of foreign trade-logistics efficiency such as Colombia, Turkey, Japan, and the USA. In particular, Colombia has the lowest foreign trade-logistics efficiency scores in many times.

As a result of the analysis, the USA and Japan are among the inefficient countries. The main reason is that these two countries are the main sources of global FDI investments. In short, the outward FDI values of these two countries are very high. Since inward FDI values are considered as output in the analyses, it is acceptable for these two countries to be among the inefficient countries. In fact, these countries are important actors within the global trade.

**Table 1** Top five countries with the highest logistics efficiency values by years for OECD

2007		2010		2012		2014		2016		2018	
Countries	Eff. score	Countries	Eff. score	Countries	Eff. score	Countries	Eff. score	Countries	Eff. score	Countries	Eff. score
Belgium	1.00	Belgium	1.00	Belgium	1.00	Austria	1.00	Austria	1.00	Belgium	1.00
Ireland	1.00	Ireland	1.00	Czech Republic	1.00	Ireland	1.00	Belgium	1.00	Ireland	1.00
Netherlands	1.00	Netherlands	1.00	Estonia	1.00	Netherlands	1.00	Ireland	1.00	Netherlands	1.00
Switzerland	1.00	Switzerland	1.00	Ireland	1.00	Hungary	0.94	Netherlands	1.00	Switzerland	0.89
Chile	0.97	Chile	0.87	Netherlands	1.00	Belgium	0.93	Czech Republic	0.96	Denmark	0.77

**Table 2** The five countries with the lowest logistic efficiency value by years for OECD

2007		2010		2012		2014		2016		2018	
Countries	Eff. score	Countries	Eff. score	Countries	Eff. score	Countries	Eff. score	Countries	Eff. score	Countries	Eff. score
USA	0.25	Greece	0.23	New Zealand	0.28	Italy	0.28	New Zealand	0.19	Japan	0.23
Turkey	0.23	Japan	0.22	Turkey	0.23	USA	0.24	Japan	0.17	Israel	0.22
Mexico	0.22	USA	0.19	USA	0.22	Japan	0.22	USA	0.15	Turkey	0.20
Greece	0.22	Turkey	0.14	Japan	0.18	Turkey	0.18	Turkey	0.15	USA	0.19
Colombia	0.12	Colombia	0.12	Colombia	0.14	Colombia	0.15	Colombia	0.12	Colombia	0.18

**Table 3** The best and worst MI values

Countries	(MI)
<i>Top three countries with highest improvement in efficiency according to MI2</i>	
Colombia	1.50
Latvia	1.22
Lithuania	1.21
<i>Bottom three countries with lowest reduction in efficiency according to MI2</i>	
Israel	0.35
Chile	0.34
Canada	0.34

**Table 4** DEA results of Turkey for OECD data set

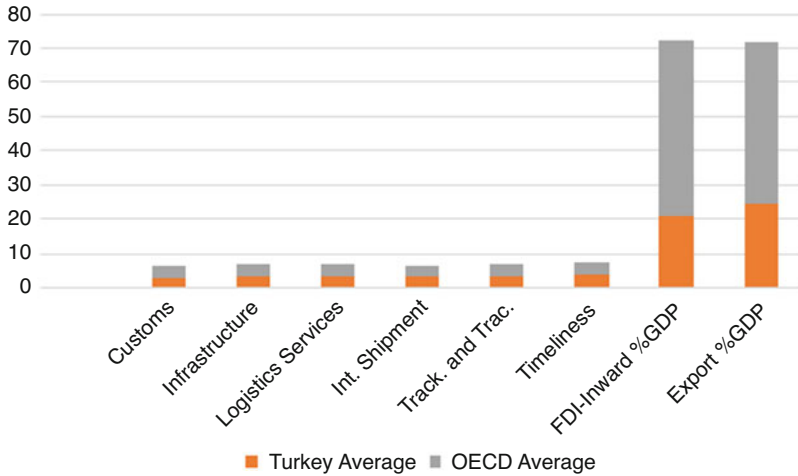
	2007	2010	2012	2014	2016	2018
Efficiency score	0.23	0.14	0.23	0.18	0.15	0.20
Ranking	33	35	33	35	35	34
Catch-up effect		0.71	1.69	0.86	0.82	1.41
Frontier effect		1.17	0.81	1.28	1.01	0.87
MI1		0.83	1.37	1.10	0.82	1.24
MI2						1.30

At the end of Malmquist analysis, three different scores are obtained for each country based on the data. These are catch-up effect, frontier-shift, and Malmquist index. As mentioned above, catch-up reflects the change in efficiency between two different periods. The frontier-shift term measures the change in the efficient frontiers for the any decision-making unit between two different periods. Malmquist index is calculated as the product of catch-up and frontier-shift effect.

The MI value in Table 3 shows the way of change for the foreign trade-logistics efficiency of countries from 2007 to 2018. The countries with the highest and lowest MI values for OECD countries are given below. Colombia has the highest MI value (1.50). It is followed by Latvia (1.22) and Lithuania (1.21), respectively. Among OECD countries, these has been the top three countries that have increased their foreign trade-logistics efficiency from 2007 to 2018. Moreover, the countries with the biggest reduction in foreign trade-logistics efficiency are the Israel (0.35), Chile (0.34), and Canada (0.34).

Table 4 includes the foreign trade-logistics efficiency value, ranking related to efficiency scores, catch-up effect, frontier effect, and Malmquist Index (MI) of Turkey for 2007–2018 period. MI1 reveals the Malmquist Index value for two consecutive years, however, MI2 gives the direct Malmquist value from 2007 to 2018.

Turkey's foreign trade-logistics efficiency value has decreased over the years, for example, it is 0.23 in 2007 and 0.29 in 2018. In addition, Turkey's foreign trade-logistics efficiency score is quite low as 0.14 in 2010. There is no serious fluctuation for Turkey's ranking among OECD countries, for instance; Turkey's



**Fig. 1** Average LPI and foreign trade values for Turkey and OECD during 2007–2018

ranking changes between 33 and 35 over the years. Catch-up Effect, Frontier Effect, and MI1 and MI2 values are also given in Table 4. MI1 values are bigger than 1 in 2012 and 2014. It means that, for 2012 and 2014, Turkey’s foreign trade-logistics efficiencies have improved compared to the previous year. Although the catch-up effect of Turkey (0.86) is below 1 in 2014, foreign trade-logistics efficiency of Turkey has risen compared to 2012 with the contribution of frontier effect. However, in many years, MI1 value has remained below 1 except 2012 and 2014. Moreover, MI2 value is 1.30 which is higher than 1. This implies that Turkey’s foreign trade-logistics efficiency has increased from 2007 to 2018.

During 2007–2018 period, the average values for each of the sub-index of LPI of Turkey and OECD members are shown in Fig. 1 The results show that for all sub-indices, Turkey’s average scores are lower than the average scores of OECD countries. Furthermore, Turkey’s average percentage values of export and foreign direct investment to GDP are lower than those of OECD. This situation also points to the reason for Turkey’s inefficiency compared to OECD countries.

Table 5 shows the projection of input values of Turkey for the period 2007–2018. This value means how many percentages should be increased or decreased for Turkey’s input values to be efficient in terms of foreign trade-logistics efficiency. As mentioned above, a monotone decreasing transformation (five minus the original values) is applied for the inputs (LPI sub-dimensions) of analysis, as recommended by the literature. Therefore, the input values in this research are not the same as the LPI sub-dimension scores, in contrast, they have been inverted. In this case, there is a need to interpret the values shown in Table 5. Table 5 emphasizes that all input values should be reduced by a certain percentage. In this context, Turkey’s input values for each year should be lower and this situation implies that the score of LPI sub-dimensions should be higher. Because the input values in the analysis are found

**Table 5** Projection values for inputs of Turkey during 2007–2018

Year	Customs Diff. (%)	Infrastructure Diff. (%)	Logistics quality and competence Diff. (%)	International shipments Diff. (%)	Tracking and tracing Diff. (%)	Timeliness Diff. (%)
2007	-77.38	-77.38	-86.97	-79.36	-81.73	-82.69
2010	-86.38	-86.70	-86.33	-86.33	-87.79	-92.95
2012	-80.39	-77.17	-77.17	-78.16	-78.17	-77.17
2014	-84.44	-81.88	-82.19	-81.67	-86.56	-83.05
2016	-84.54	-84.97	-86.33	-84.54	-85.90	-86.53
2018	-79.30	-79.30	-83.00	-79.30	-79.82	-82.31

with the formula of five minus the original LPI sub-dimension scores. In conclusion, projection values says that Turkey should improve its LPI sub-dimensions values in each year.

## 5 Discussion

In recent years, logistics has become a very important topic for both countries and companies as well as their supply chains. In today's competitive environment, supply chains compete with other supply chains (Christopher, 1992). In this sense, as stated previously, the Logistics Performance Index (LPI) published by the World Bank is a good source of data for countries to evaluate themselves.

Logistics efficiencies can positively affect a country's domestic and foreign trade. International shipment and customs sub-factors of LPI are directly related to import and export transactions. Therefore, the impact of qualifications of the LPI on any country's foreign trade is inevitable. Moreover, LPI sub-criterion such as infrastructure and quality of logistics services also can determine the speed and cost of logistics operations. For this reason, higher logistics efficiencies lead to lower costs. When considering that one of the factors affecting inflation the most is logistics costs, efficiencies in transportation operations are crucial for the national and household economies. In addition, LPI is also critical for the image of countries. Sub-factors such as timeliness and tracing/tracking are directly related to logistics quality of countries. These advantages contribute to an increase in investments like Foreign Direct Investment.

In the research, by considering the OECD member countries and using DEA and Malmquist method, it is attempted to measure the foreign trade-logistics efficiencies and the changes over the time. Analyses show that Ireland and the Netherlands appear among the most efficient countries in many years. Countries aiming to improve in terms of logistics should carefully examine the transportation operations implemented in these most efficient countries and imitate similar practices according to their own needs. Turkey and Colombia appear among the countries with lowest logistics efficiency values. These countries need to develop seriously in terms of transportation activities.

According to the Malmquist Index, the countries improving the most are Colombia, Latvia, and Lithuania. Therefore, countries that want to improve their logistics operations should also take the logistics applications in these countries into consideration. Countries that have a low logistics efficiency can determine a roadmap for themselves by examining the law systems, legal regulations, infrastructure, and tax/incentive systems in these three countries. In addition, the frequently observed countries that have not improved over time in the analysis reveal as Israel, Chile, and Canada. These countries should also study their logistics competencies. Moreover, all countries should investigate these three countries to determine why they are falling behind in order not to make the same mistakes.

## 6 Policy Implications for Turkey

In this study, using the LPI data, logistics efficiencies of Turkey have been compared with the OECD countries. When the DEA and MI results are evaluated, Turkey has had a low performance. For this reason, Turkey should develop its performance with respect to the six sub-LPI dimensions. First, for the customs sub-dimension, the relevant laws and regulations should be revised to make customs operations more efficient. Moreover, the bureaucratic procedures in customs should be made easier and shorter. In addition, customs tax rates should be reviewed, and the customs gates should be increased. For the infrastructure sub-dimension, related investments should be continued rapidly, and unfinished projects should be completed in a short time. For example, ongoing constructions in Turkey such as Galataport in Istanbul and Çandarlı Port in Izmir projects are quite crucial for the international trade. Moreover, new projects such as logistics villages should be developed, and legal arrangements should continue to facilitate logistics activities. Regarding the quality of logistics services and the ease of delivery arrangement sub-dimensions, authorized institutions should find solutions for market needs, especially in rail and maritime transport. Furthermore, Turkish government should ensure the usage of various alternatives for effective logistics operations. As an example, the Cabotage Law (seaway transportation law) can be updated to benefit more from maritime transportation. In addition, authorized corporations should take legal steps to make railways operated by private companies. For the tracking and tracing sub-dimension, Turkey should also improve its situation. First, necessary infrastructures such as satellite communication, telecommunication, radio frequency systems should be completed flawlessly by the state. The private sector should be encouraged to follow-up and monitor logistics operations and new sanctions should be introduced for some sectors such as food and medicine. Especially in cold chain activities, companies should be audited more carefully. Furthermore, various credit and incentive systems should be implemented by the government to encourage private organizations to make new investments on their logistics operations. Finally, in terms of the timeliness sub-dimension, the state and the private sector have duties as for other fields. Firstly, within the scope of public activities, infrastructure needs such as roads and bridges should be met quickly. Moreover, to accelerate the processes, legal steps that slow down logistics operations such as customs and tax should be reviewed in accordance with today's needs and conditions. In addition, companies should pay more attention to business ethics in this regard and provide training to their employees on ethics. Besides, companies should impose sanctions on their employees if necessary and should be responsive in terms of on time delivery.



## 7 Conclusion

In earlier times, logistics was only concerned with the transportation activities. With the increasingly competitive environment, it has gained a wider perspective. Normally, buyers and sellers engage in logistics activities to transport products. Therefore, logistics can be considered as an essential part of commercial life. Studies by Langley et al. (2008), Mangan et al. (2008), and Rushton et al. (2009) have provided a definition for logistics from a broader perspective. These studies suggest that logistics is an integration of information, packaging, storage, and transportation system.

Today, the correct and timely transportation of products is more important than the past due to the international trade. Especially with the increasing internet facilities, demands of companies and consumers have largely increased. Therefore, governments are rapidly making infrastructure investments such as ports, terminals, and highways to provide efficiency in international trade. Moreover, different projects such as intermodal transportation and logistics villages are frequently organized nowadays. All these developments facilitate the trade of goods and significantly reduce supply chain costs. Trade logistics is significant to improve regional and international trade (Pavcnik, 2002). Today's competitive market conditions have made logistics more important than ever, as developing countries increasingly compete for access to the international markets in efficient ways (Devlin & Yee, 2005). As stated by the World Bank's report (2010), countries' policies and logistics procedures directly affect foreign trade performance. In this context, the Logistics Performance Index (LPI) published by the World Bank is a good data source for research. This index allows to make comparisons for countries and can provide guidance for politicians and academics to evaluate trade performances.

In this research, it was aimed to analyze foreign trade values of OECD countries according to the six different LPIs and provide an understanding of how developing countries can improve their positions by comparing their own logistics performance with the developed ones'. Foreign trade-logistics efficiency was calculated by using DEA. Sub-dimensions of LPI are considered as inputs, while percentage values of foreign direct investment and export to GDP are assumed as outputs for OECD countries. The results revealed that Ireland and the Netherlands have high performances in terms of foreign trade-logistics efficiency. In addition, it is observed that Colombia and Turkey had very low levels of foreign trade-logistics efficiency. According to the Malmquist Index results, it was found that Colombia, Latvia, and Lithuania made very good improvement. Conversely, Israel, Chile, and Canada could not improve their transportation capabilities over the time. Therefore, the practices of these countries should be carefully examined by the field experts. These inferences can provide a roadmap for the developing countries regarding their logistics systems. Moreover, with the case of Turkey, it is emphasized how developing countries' self-evaluations could be made for relevant improvements. Turkey's logistics efficiency is lower than many OECD countries and this study reveals which regulations are necessary to improve Turkey's logistics performance.

As with all studies, this research has some limitations. One limitation is about using non-parametric method and only considering the developed and developing countries when calculating the logistics efficiencies. In future research, more countries can be included to generate foreign trade-logistics efficiency values and parametric efficiency methods like Stochastic Frontier can be used to compare countries' efficiencies.

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