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Analysis of the Environmental Performances of EU Countries and Türkiye

AB Ülkeleri ve Türkiye' nin Çevresel Performanslarının Analizi

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Abstract: *The paper aims to evaluate the environmental performance efficiency of (European Union (EU) countries and to calculate Türkiye's position among these countries. The performance of EU countries and Türkiye for the period 2010-2022 is assessed using the variables of Gross Domestic Product (GDP), Greenhouse Gas Emissions (GHG), Material Flows (MF) and Tree Cover Loss (TCL). For this purpose, Decoupling Analysis and Malmquist Total Factor Productivity Index (MTFPI) were applied. As a result of the analysis, there was no productivity change in Lithuania, Slovakia, Sweden and Türkiye. In the same period, there is an increase in productivity change for 12 countries and a decrease for 12 countries. In general, total factor productivity increased in 1 country and decreased in 27 countries during the study period. The country with the highest increase in technical productivity change, in other words technological development, was Hungary with 3.7 percent. According to the decoupling elasticities of these 28 countries, the decoupling elasticity indices of GHG and MF are positive for Türkiye and Greece. For Croatia, Cyprus, Estonia, France, France, Germany, Portugal and Spain, the decoupling index of GHG and MF from GDP is negatively elastic for that period. For the decoupling index of TCL from GDP, Germany shows an elasticity greater than one in that period.*

Keywords: *Performance, Decoupling, Malmquist Index*

Özet: *Bu çalışma, Avrupa Birliği (AB) ülkelerinin çevresel performans verimliliğini değerlendirmeyi ve Türkiye'nin bu ülkeler arasındaki konumunu hesaplamayı amaçlamaktadır. AB ülkeleri ve Türkiye'nin 2010-2022 dönemi performansı Gayri Safi Yurtiçi Hasıla (GSYH), Sera Gazı Emisyonları (SGE), Malzeme Akışları (MA) ve Ağaçla Kaplı Alan Kaybı (AKAK) değişkenleri kullanılarak değerlendirilmiştir. Bu amaçla, Decoupling (Ayrıştırma) Analizi ve Malmquist Toplam Faktör Verimliliği (MTFV) Endeksi uygulanmıştır. Analiz sonucunda Litvanya, Slovakya, İsveç ve Türkiye'de verimlilik değişimi yaşanmamıştır. Aynı dönemde 12 ülke için verimlilik değişiminde artış, 12 ülke için ise azalış söz konusudur. Genel olarak, toplam faktör verimliliği çalışma dönemi boyunca 1 ülkede artmış, 27 ülkede ise azalmıştır. Teknik verimlilik değişiminde, diğer bir deyişle teknolojik gelişmede en fazla artış gösteren ülke yüzde 3,7 ile Macaristan oldu. Bu 28 ülkenin ayrışma esnekliklerine göre, SGE ve MA ayrışma esneklik endeksleri Türkiye ve Yunanistan için pozitiftir. Hırvatistan, Kıbrıs, Estonya, Fransa, Almanya, Portekiz ve İspanya için SGE ve MA'nin GSYH'den ayrışma endeksi o dönem için negatif esnektir. TCL'nin GSYH'den ayrışma endeksi için, Almanya söz konusu dönemde birden büyük bir esneklik göstermektedir.*

Anahtar kelimeler*: Çevresel Performans, Ayrışma, Malmquist İndeksi*

1. Introduction

Our world faces various problems such a climate change, global warming, desertification, melting of glaciers, flooding, food shortages as a result of natural processes and human factors (Lee, 2023). Action is required for a sustainable ecosystem integrity. It is important for countries to cooperate on environmental issues. The European Union encourages member states to work on environmental protection and environmental awareness through its policies.

In 2005, Türkiye started negotiations for full membership to the EU and is a country with a growing economy and a young population (European Commission, 2023). Turkiye, which is a party to many environmental conventions, became a party to the United Nations Framework Convention on Climate Change (UNFCCC) in 2004 and to the Kyoto Protocol in 2009. The Paris Agreement, which sets the framework for the post-2020 climate change regime, was adopted at the 21st Conference of the Parties of the UNFCCC held in Paris in 2015. At COP 21, for the first time, all countries committed to greenhouse gas emission reductions on a global scale for the post-2020 period. Within the scope of these protocols, there is a commitment to reduce greenhouse gas emissions. It is also significant to measure Türkiye's environmental performance both within the scope of the EU membership process and in line with the increasing environmental and renewable energy investments in recent years.

There are various studies in the past research that measure and evaluate the environmental status of countries. In these studies, environmental performance of countries has been evaluated with various methods using different input and output variables. Conducting the study with recent data covering the period including the covid-19 pandemic will contribute to the literature. At the same time, by analyzing the efficiency change of countries in the relevant period. It will also reveal their decoupling in detail. Data Envelopment Analysis (DEA), which is used to evaluate the relative efficiency of structures with different units of measurement measured at different scales in a multiple input/output environment, is the most important of these methods (Karaman, 2017). DEA is a method that organizes input and output variables through distance functions between variables. Environment the most fundamental variable in performance measurement is economic growth and the results of economic growth. Therefore, the Decoupling Method is used to measure whether there is any link between economic growth and environmental issues (Juknys, 2005). The basis of the decoupling method is based on calculating an elasticity value between variables that cause environmental pressure (variables such as GHG, TCL) and the economy. In this way, the existence and direction of pressure on the environment while economic growth occurs are determined. At the same time, MTFPI is used to reveal the source of efficiency changes of units (Fischer-Kowalski, 2011).

This article is designed around four main sections. Following the introduction, the second section presents a literature review on measuring the environmental performance of countries using DEA, Decoupling Method and MTFPI. In the third section, data, selected variables and methodology are explained and detailed information about the application results is given. DEAP 2.1 computer package programme was used for the analyses in the study (Coelli, 1996). In the last section, summarized evaluation and recommendations regarding the results are given.

2. Literature Review

Considering the previous studies; DEA and Malmquist Index have been the most frequently used methods in measuring environmental performance. In addition, decomposition analysis is one of the methods used to reveal the relationship between environmental pressure and economic growth.

When the environmental performance of countries between 2000-2022 is analyzed, it is seen that variables such as gross domestic product, CO2 emissions, material flows, SO2, NO2, energy consumption are frequently used. Especially in recent studies, it is seen that variables such as GHG, MF and TCL are considered as environmental indicators.

In general, GDP, GHG, MF and TCL variables, which are different from the variables used in previous studies to analyze the relationship between economic indicators and environmental indicators and which we think will best express environmental pressure, are used. Therefore, thanks to this study, it will be ensured to identify the decision-making units (DMU; for this study, countries are considered as countries) that establish the best relationship between the inputs and outputs of environmental indicators, that is, the countries that are efficient and to identify the excess or deficiency in the indicators of inefficient countries.

In this study, DEA, Malmquist Index and Decoupling Analysis have been used together to conduct a comprehensive analysis of the countries. In this way, the effectiveness of environmental indicators of countries on certain indicators and the pressure of economic growth on the environment were revealed. The results of this study with recent updated data sets contribute to the literature. It is thought that the results obtained from the study will be the underlying data when determining environmental policies.

The evaluation of countries through environmental indicators has also been the subject of previous studies. When these studies are examined, the frequently used variables and study details summarized in the Table 1 below.

Table 1. DEA, MTFPI and Decoupling method studies in the literature

Year	Authors	Methodology	Country/ Countries	Time	Variables
2005	Tapio	Decoupling (Tapio, 2005)	EU Countries (15)	1970-2001	Gross domestic product, CO_2 emissions
2006	Zhou et al.	DEA (Zhou, 2006)	OECD Countries (30)	1998-2002	Gross domestic product, CO_2 emissions, population
2009	Sözen A, Alp İ.	DEA (Sözen, 2009)	EU Countries (27) and Türkiye	1998-2005	Energy consumption by sector, Greenhouse gas emissions, F, CO_2, CO, SO_2, NO_2
2016	Wan et al.	Decoupling (Wan, 2016)	China	2000-2014	Economic growth, CO_2 emissions
2017	Bampatsou et al.	Decoupling (Bampatsou ,2017)	EU Countries (13)	1990-2011	GDP, Greenhouse gas emissions, material flows and land use
2019	Shuai C, Chen X, Wu Y, et al.	Decoupling (Shuai, 2019)	The World	2000-2014	GDP, Carbon intensity, carbon emission per capita and total carbon emission
2020	Wang et al.	Decoupling (Wang, 2020)	China	2001-2016	CO_2 emissions and economic growth
2020	Matsumoto et al.	DEA and Malmquist Index (Matsumoto ,2020)	EU Countries (27)	2000-2017	Labor force (population), Capital, Energy consumption, Gross domestic product, PM2.5, CO_2, Waste
2021	Bodur S, Küpeli M, Alp İ.	Decoupling (Bodur, 2021)	EU Countries (27) and Türkiye	1990-2017	GDP, Greenhouse gas emissions, material flows and land use

3. Methodology and Data

3.1. Data and variables

The selection of variables in performance measurement is an important stage that affects the results of the analysis. For this reason, a literature review was conducted to select the variables and the variables frequently preferred in performance measurement and the results obtained were taken into consideration. GDP and GHG are the most important parameters. In addition to these, TCL and MF have been identified as important variables.

The data and data sources used within the scope of the study are explained in Table 2. Relevant datasets for *2010-2022 were obtained from open sources and descriptive statistics for these variables are given in Table 3.*

Table 2. Data sources

Variables	Function of Variables in the Model	Data Sources
Gross domestic product (GDP)	Output	World Bank - World Development Indicators (World Bank, 2023)
Greenhouse gas emissions (GHG)	Input	OECD Statistics (OECD Statistics, 2023)
Material flows (MF)	Input	United Nations Environment Programme (WU Global Material Flows Database, 2023)
Tree cover loss (TCL)	Input	Yale University - EPI Data Set (EPI database, 2022)

Table 3. Descriptive statistics related to the data in the study

Variables	Mean	Std. Deviation	Minimum	Maximum
GDP	219984,73	787928,07	8623,36	6879314,56
GHG	152198,47	201126,82	1846,96	933505,37
MF	30400000000	418700000000	18707884774	200000000000
TCL	0,0070923637	0,0104190121	0,0005544916	0,0883086779

3.2. Data envelopment analysis

DEA is based on Farrell's single input/output technical efficiency measurement in 1957. In 1978, the CCR model improved by Charnes, Cooper and Rhodes, which allows analysis in a multiple input and multiple output environment, introduced DEA to the literature (Charnes, 1993). Since inputs are important in this study, the input-oriented CCR model is used for the performance of the countries (Cooper, 2004).

DEA models are divided into two as input-oriented and output-oriented. Output-oriented models are used if it is possible to intervene in outputs, and input-oriented models are used if it is possible to intervene *in inputs. According to the results, it is determined to what extent the inputs should be changed. Therefore, since inputs are important in this study and it is possible to make changes in inputs, it is appropriate to use the input-oriented CCR model to measure the performance of countries.*

$$\max \theta_0 = \sum_{r=1}^{s}(u_r\ y_{r0}) \,/\, \sum_{i=1}^{m}(v_i\ x_{i0})$$

$$\sum_{r=1}^{s}(u_r\ y_{rj}) \,/\, \sum_{i=1}^{m}(v_i\ x_{ij}) \leq \quad j=1, \ldots, n \qquad (1)$$

$$u_r,\ v_i \geq 0 \quad (r=1, \ldots, s \quad i=1,\ldots, m)$$

The model of the input-oriented CCR model adapted to the linear programming model is as follows:

$$\theta_0 = \max \sum_{r=1}^{s}(u_r\ y_{r0})$$

$$\sum_{i=1}^{m}(v_i\ x_{i0}) = 1$$

$$\sum_{r=1}^{s}(u_r\ y_{rj}) - \sum_{i=1}^{m}(v_i\ x_{ij}) \leq 0 \quad j=1,\ldots, n \qquad (2)$$

$$u_r,\ v_i \geq 0 \quad (r=1,\ldots,s \quad i=1,\ldots,m)$$

Xij : the quantity of input i used by the j. decision-making unit
Yrj : r. quantity of output produced by the j. decision-making unit
ur : weight given to output r.
vi : weight given to i. input

3.3. Decoupling method

The decoupling model is used to determine whether there is any link between economic growth and environmental problems. The decoupling model used in this study was developed by Tapio (Tapio, 2005). This model, the decoupling indicator of environmental pressures and economic growth from base year 0 to year t is defined by D^t and this equation is as follows (Sun, 1999).

For the decoupling analysis, for periods t and t-1, let the change in resources be $\Delta Y = \frac{(Yt-Y0)}{Y0}$ and the economic change be $\Delta G = \frac{(Gt-G0)}{G0}$. Accordingly, the decoupling index for year t:

$$D^t = \frac{\%\Delta Y}{\%\Delta G} = \frac{\frac{Yt-Y0}{Y0}}{\frac{Gt-G0}{G0}} \qquad (3)$$

The Tapio classification used in the evaluation of the elasticity results obtained is taken into account and this classification is explained in detail in Table 4.

Table 4. Decoupling states according to Tapio classification

Categorization	Focus on Decoupling	Δ Y	Δ G	D
	Absolute decoupling	<0	>0	$D^t < 0$
Decoupling	Relative decoupling	>0	>0	$0 \leq D^t < 0.8$
	Recessive decoupling	<0	<0	$D^t > 1.2$
	Strong neg. decoupling	>0	<0	$D^t < 0$
Negative decoupling	Weak neg. decoupling	<0	<0	$0 \leq D^t < 0.8$
	Expansive neg. decoupling	>0	>0	$D^t > 1.2$
Coupling	Expansive coupling	>0	>0	$0.8 \leq D^t < 1.2$
	Recessive coupling	<0	<0	$0.8 \leq D^t < 1.2$

Absolute decoupling (strong decoupling– $D^t < 0$) and relative decoupling ($0 < D^t < 1$) are the most expected situations for sustainable development (Bodur, 2021).

3.4. Productivity analysis: The malmquist productivity index

With DEA analysis efficiency scores are calculated only for a certain period. It is an important issue to analyze the time-dependent changes in efficiency and to reveal the source of these changes (Malmquist, 1953). For this reason, the Malmquist index created by Caves et al. can be used (Caves, 1982). According to Färe et al. the input-oriented Malmquist productivity index is defined as follows (Färe, 1992).

Malmquist index formulation*:*

$$M^{t+1}(y^{t+1}, x^{t+1}, y^t, x^t) = \left[\frac{D^t(y^{t+1},\ x^{t+1})}{D^t(y^t,\ x^t)} * \frac{D^{t+1}(y^{t+1},\ x^{t+1})}{D^{t+1}(y^t,\ x^t)}\right]^{½} \quad (4)$$

In equation (4), y represents outputs and x represents inputs. D represents the distances of the input functions. The equation in question denotes the Malmquist index for period t. Here, period t and t+1 are expressed as comparison.

According to the technology of period t, the input-oriented Malmquist productivity index is as follows:

$$M^t = \frac{D^t(y^{t+1},\ x^{t+1})}{D^t(y^t,\ x^t)} \quad (5)$$

Equation (7) below shows the Malmquist index for time period t + 1. Here, productivity change (according to technology level) from period t to period t+1 is expressed. Accordingly, the Malmquist productivity index according to the technology of period t + 1 is shown as follows:

$$M^{t+1} = \frac{D^{t+1}(y^{t+1},\ x^{t+1})}{D^{t+1}(y^t,\ x^t)} \quad (6)$$

The Malmquist productivity index is as follows (Multiplicative result of EFFCH and TECHCH):

$$M^{t+1}(y^{t+1}, x^{t+1}, y^t, x^t) = \frac{D^{t+1}(y^{t+1},\ x^{t+1})}{D^t(y^t,\ x^t)} * \left[\frac{D^t(y^{t+1},\ x^{t+1})}{D^{t+1}(y^{t+1},\ x^{t+1})} * \frac{D^t(y^t,\ x^t)}{D^{t+1}(y^t,\ x^t)}\right]^{½} \quad (7)$$

or

$$M^{t+1}(y^{t+1}, x^{t+1}, y^t, x^t) = \text{EFFC} * \text{TECHC} \quad (8)$$

In Equation (8), the Malmquist total factor productivity index is the product of a change in productivity in the identical period (EFFCH) and a measure of technical progress measured in periods t + 1 and t (TECHCH).

4. Applications and Results

In this study, the performance of EU countries and Türkiye for the period 2010-2022 is assessed using the variables of GDP, GHG, MF and TCL. For this purpose, Decoupling Analysis and Malmquist Total Factor Productivity Index (MTFPI) were applied.

According to the Malmquist Total Factor Productivity Index, the productivity status of the countries and the source of the changes in this situation were determined.

In addition, the most fundamental variable in measuring environmental performance is economic growth and its consequences. Therefore, the Decoupling Method was used to measure whether there is any connection between economic growth and environmental problems. Table 5 shows the decoupling results obtained for countries.

Table 5. Decoupling elasticities results for countries in the period 2010-2022

	Period	(GHG)	(MF)	(TCL)
Austria	2010-2022	-0,21178	25,5883	0,855924
Belgium	2010-2022	-0,4114	23,31004	-0,64659
Bulgaria	2010-2022	-0,06029	0,236012	0,096677
Croatia	2010-2022	-0,18983	-0,14014	1,724439
Cyprus	2010-2022	-0,31225	-1,50961	1,280886
Czech	2010-2022	-0,34385	0,08705	6,821212
Denmark	2010-2022	-0,44542	0,138135	-0,06102
Estonia	2010-2022	-0,2814	-0,58807	0,815656
Finland	2010-2022	-1,37158	0,014224	2,506488
France	2010-2022	-0,48418	-0,02824	0,02934
Germany	2010-2022	-0,39535	-0,23138	1,953912
Greece	2010-2022	15,15728	13,55978	23,44575
Hungary	2010-2022	-0,02316	8,167101	0,316895
Ireland	2010-2022	-0,00865	0,037526	0,140039
Italy	2010-2022	-1,04615	33,43296	10,42798
Latvia	2010-2022	-0,06792	0,399935	0,301742
Lithuania	2010-2022	-0,01473	0,742887	0,307561
Luxembourg	2010-2022	-0,52295	1,823842	-0,03509
Malta	2010-2022	-0,29136	0,221732	-0,34782
Netherlands	2010-2022	-0,57532	0,151334	0,031079
Poland	2010-2022	-0,01642	0,052691	13,98931
Portugal	2010-2022	-0,10571	-0,14391	0,881355
Romania	2010-2022	-0,24916	-2,44268	0,442788
Slovakia	2010-2022	-0,17023	16,31241	0,496693
Slovenia	2010-2022	-0,88712	-4,3481	145,0955
Spain	2010-2022	-0,32218	-0,31762	29,64961
Sweden	2010-2022	-0,53252	0,553826	0,924428
Türkiye	2010-2022	0,04143	0,017821	0,076413

In the period 2010-2022, the decoupling elasticity indices of GHG and MF for Türkiye and Greece are positive. For Türkiye, relative decoupling ($0 < D^t < 1$) occurs, this implies that the growth of MF consumption and GHG emissions is less than economic growth. For these countries, a positive elasticity is also recorded in the case of the decomposition index of the Loss of Tree Covered Area from GDP (Table 5).

For the countries of Croatia, Cyprus, Estonia, France, Germany, Portugal and Spain, the decoupling index of GHG emissions and MF from GDP for the period 2010-2022 is negatively elastic. Absolute decoupling ($D^t < 0$) is realized, which means that GHGs and MFs decrease while economic growth continues.

In terms of the decoupling index of tree cover loss from GDP, Germany shows an elasticity greater than one in the period 2010-2022. No decoupling occurs ($D^t > 1$), which means that the rate of increase of the loss of tree cover is considerably more than economic growth.

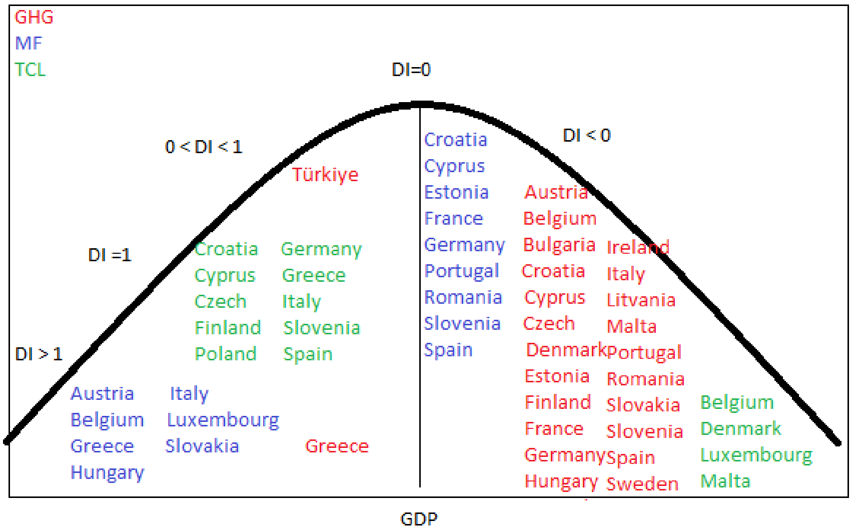

Figure 1. Indices and countries at different economic levels

As the Kuznets curve in Figure 1 shows, a relationship has been established between the performance of countries in decoupling indices economic levels. If we look at the decoupling indices at different levels of economic growth, we can determine the direction of the relationship between economic growth and environmental indicators.

For example, according to the Kuznets Curve obtained, it is seen that while economic growth continues in Belgium, Denmark and Malta, greenhouse gas emissions and tree cover loss areas decrease at the same time. In summary, absolute decoupling has not occurred for these countries (DI<0). When we look at Austria, Belgium, Greece, Hungary, Italy, Luxembourg and Slovakia, the increase rate in Material Flows is more than economic growth. In other words, decoupling has not occurred for these countries (DI >1).

In this study, the change scores of EU countries according to different types of efficiency calculated with the Data Envelopment Analysis Program (DEAP).

When interpreting the results of the analysis, a tfpch value equal to 1 means that there is no progress or regression; a TFPCH value greater than 1 means that total factor productivity is progressing; and a value less than 1 means that total factor productivity is regressing. Table 6 shows the results obtained for the countries.

This table of results showing the change over the years is an important part of the study. Because it is a priority for decision makers to follow the change over the years and to determine in which years there is an increase and in which years there is a decrease.

Table 6 shows the change in average total factor productivity by years. According to the results obtained, the overall average was calculated as 0.871 in the period under consideration. This implies that there is no increase for TFPCH. There is no increase in total factor productivity in the period 2010-2022. The results of the Malmquist Index analysis are interpreted especially through TECHCH values.

According to the results, there is an increase in the change in technical efficiency in the 2016-2017 and 2018-2019 periods. In addition, an increase in efficiency changes was observed in the periods 2011-2012, 2012-2013, 2014-2015, 2017-2018 and 2020-2021.

Table 6. Changes in Malmquist index and country results by years

Period	Efficiency Change (EFFCH)	Technical Efficiency Change (TECHCH)	Change in Pure Technical Efficiency (PECH)	Scale Efficiency Change (SECH)	Total Factor Productivity (TFPCH)
2010-2011	0.811	0.792	1.000	0.811	0.642
2011-2012	1.049	0.783	1.000	1.049	0.821
2012-2013	1.090	0.710	1.000	1.090	0.774
2013-2014	0.931	0.946	1.000	0.931	0.881
2014-2015	1.079	0.810	1.000	1.079	0.874
2015-2016	0.939	0.919	1.000	0.039	0.863
2016-2017	0.958	1.019	1.000	0.958	0.976
2017-2018	1.155	0.818	1.000	1.155	0.945
2018-2019	0.893	1.112	1.000	0.893	0.993
2019-2020	0.932	0.944	1.000	0.932	0.880
2020-2021	1.218	0.783	1.000	1.218	0.954
2021-2022	0.935	0.977	1.000	0.935	0.914
Mean	0.993	0.877	1.000	0.993	0.871

Table 7. Changes in the efficiency of economic systems by country in the period 2010-2022

Countries	EFFCH	TECHCH	PECH	SECH	TFPCH
Austria	1.008	0.804	1.000	1.008	0.811
Belgium	1.041	0.805	1.000	1.041	0.838
Bulgaria	1.013	1.012	1.000	1.013	1.024
Croatia	0.930	1.011	1.000	0.930	0.941
Cyprus	1.006	0.821	1.000	1.006	0.826
Czech	0.955	0.829	1.000	0.955	0.791
Denmark	0.891	0.971	1.000	0.891	0.865
Estonia	0.968	0.884	1.000	0.968	0.855
Finland	0.996	0.821	1.000	0.996	0.818
France	1.077	0.854	1.000	1.077	0.920
Germany	0.998	0.800	1.000	0.998	0.798
Greece	1.012	0.908	1.000	1.012	0.919
Hungary	0.956	1.037	1.000	0.956	0.992
Ireland	0.993	0.814	1.000	0.993	0.808
Italy	0.959	0.843	1.000	0.959	0.809
Latvia	0.967	0.975	1.000	0.967	0.943
Lithuania	1.000	0.921	1.000	1.000	0.921
Luxembourg	1.026	0.919	1.000	1.026	0.942
Malta	0.994	0.884	1.000	0.994	0.878
Netherlands	1.024	0.811	1.000	1.024	0.831
Poland	0.980	0.822	1.000	0.980	0.806
Portugal	1.008	0.846	1.000	1.008	0.853
Romania	1.002	0.884	1.000	1.002	0.885
Slovakia	1.000	0.896	1.000	1.000	0.896
Slovenia	1.006	0.829	1.000	1.006	0.834
Spain	1.006	0.850	1.000	1.006	0.855
Sweden	1.000	0.869	1.000	1.000	0.869
Türkiye	1.000	0.916	1.000	1.000	0.916
Mean	0.993	0.877	1.000	0.993	0.871

If productivity change (EFFCH) > (TECHCH), productivity growth is due to the positive trend in productivity. If productivity change (EFFCH) < (TECHCH), productivity growth is due to positive trend in technology.

$$EFFCH = PECH \times SECH \tag{9}$$

An increase in pure technical efficiency, one of the components of efficiency change, indicates managerial success between periods t and t+1. An improvement in scale efficiency is represented in economic terms as an improvement towards scale size (Fung, 2008).

If the (PECH) value obtained is higher than the (SECH) value, the change in efficiency is the result of the improvement in the (PECH) score. If the (PECH) value obtained is less than the (SECH) value, the change in efficiency is the result of the improvement in the (SECH) score (Bampatsou, 2017).

According to Table 7, in the period 2010-2022, no productivity change was observed in Lithuania, Slovakia, Sweden and Türkiye, while half of the other countries experienced an increase and the other half a decrease. In addition, the best improvement in technological development was observed in Hungary with 3.7 percent.

5. Conclusions and Discussion

In this study, DEA, Malmquist Index and Decoupling Analysis are used together to make a comprehensive analysis of the countries. In this way, the effectiveness of countries' environmental indicators on certain indicators and the pressure of economic growth on the environment were revealed.

The Malmquist index allows units to be compared and their changes over time to be tracked. In this way, countries will be able to use the results obtained as a basis for target and policy formulation. For example, in general, the vast majority of countries have experienced a decline in productivity. Accordingly, the results obtained from the study will be the basic data when determining environmental policies.

The EU has two main targets: to reduce greenhouse gas emissions by at least 55% compared to 1990 emission levels by 2030 and to be climate neutral by 2050, that is, to reach a point where greenhouse gas emissions are balanced by emissions absorbed from the atmosphere. To achieve these goals, the EU implements various policies and measures. Some of these are those:

• European Green Deal: It is a road map that will enable the EU to achieve its goal of climate neutrality by 2050.

• Fit for 55 Package: It is a document containing new laws and regulations to increase the 2030 emission reduction target to 55%.

• European Emissions Trading System (ETS): A market-based mechanism to limit and price greenhouse gas emissions.

• Renewable Energy Directive: It is a directive that encourages member countries to increase the use of renewable energy resources.

• Energy Efficiency Directive: It is a directive that aims to increase energy efficiency in buildings.

The achievement of these goals is measured with the help of indices. For these purposes, the purpose of this paper is to calculate the index of change in factor productivity of countries and at the same time to determine the driving forces for these countries.

In order to identify the sources of changes in the index, TFPCH index efficiency change (EFFCH), technical change (TECHCH), pure efficiency change (PECH) and scale efficiency index (SECH) were calculated.

Changes in economic growth, global problems and diminishing natural resources are decoupled from economic growth by calculating the DI decoupling index. If we look at the activity change Table 8 in general;

Table 8. Efficiency change table

	EFFCH	TECHCH	PECH	SECH	TFPCH
< 1	12	25	0	12	27
= 1	4	0	28	4	0
>1	12	3	0	12	1

In the period 2010-2022, Lithuania, Slovakia, Sweden and Türkiye did not experience any efficiency change, while 12 countries experienced an increase, and 12 countries experienced a decrease in efficiency change.

Total factor productivity is obtained by multiplying efficiency change and technological change (technical efficiency change). In the period 2010-2022, while 1 country experienced an increase in total factor productivity, 27 countries experienced a decrease. The country with the highest increase in technical efficiency change, in other words technological development, is Hungary with 3.7 per cent.

According to 2022 Climate Change Performance Index (CCPI) data, Sweden, Denmark, Germany and France increased compared to previous years. Latvia and Croatia showed a decrease. However, when looking at the results obtained in the study, it was found that Sweden, for example, did not show any change for the entire 13-year period. The reason for this is thought to be the effectiveness of the studies carried out within the scope of adaptation to climate change, especially in recent years. Considering Türkiye, although its environmental performance is behind according to the index, the fact that it has not shown any change in efficiency in the 2010-2022 period is attributed to the energy investments in recent years.

Additionally, results from analyzes may differ depending on the variables used and the decision-making units analyzed. It is difficult to include all environmental factors in evaluating environmental performance. However, as a suggestion for future studies, various variables that will represent environmental performance can be added to the model.

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