ENVIRONMENTAL EFFICIENCY OF THE EU COUNTRIES BASED ON A DEA APPROACH

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Abstract: Measuring environmental efficiency is a key tool for monitoring the progress of EU countries in achieving common environmental policy goals. The presented study deals with this issue on a sample of 27 EU countries in the period 2000-2020 using the DEA method. The results point to persistent differences between member countries, with new member states achieving better values compared to old member states. Despite the significant reductions in greenhouse gases, sulphur oxides and nitrogen oxides that have been recorded for all EU countries, there is no improvement in environmental efficiency over time for countries with average and low efficiency, which represent eight Member States. The study also confirmed that it is possible to achieve high environmental efficiency even while achieving economic development.

Keywords: *Environmental policy, efficiency, EU countries, DEA.*

1 Introduction

The concept of sustainable development makes more sense today than ever before. Increased concerns about the global impacts of environmental pollution in countries such as China have made environmental efficiency analysis a central topic of much research. At the level of European Union (EU) countries, environmental efficiency represents the ability of Member States to produce goods and services while minimizing the negative impact on the environment. The EU actively works to promote environmental efficiency through various policies and regulations, including the EU's commitment to reduce greenhouse gas emissions, increase the use of renewable energy and promote resource efficiency (Duľová Spišáková et al. 2020; Beltrán-Esteve & Picazo-Tadeo, 2017).

However, the EU's environmental policy faces a serious problem, which stems from significant differences in the ability of countries to apply these principles and goals at the national level, from the fear that the country will not be able to achieve sufficient economic development. An example is Poland, which, as the largest producer of hard coal in the EU, prioritizes the national interests of economic development (Marcinkiewicz & Tosun, 2015). Many EU member states changed their decision-making priorities after the economic crisis of 2008, during which their concerns about economic development were much greater (Slominski, 2016). The reason was also increasing public spending on environmental policy (Zhu et al. 2022). Thus countries promote a concept whereby environmental efficiency grows while increasing economic performance (Mardani et al. 2017). Current studies also point to a different level of environmental efficiency between the old and new member states. The results of some research concluded that old members have higher environmental efficiency (Beltrán-Esteve et al., 2019; Matsumoto et al., 2020; Sanz-Díaz et al., 2017; Zhu et al., 2022), while some studies claim the opposite, namely that new Member States have score higher in environmental efficiency (Duman & Kasman, 2018). The question remains whether states can increase their environmental efficiency at the same time as achieving economic development in the country and whether there are significant differences in environmental efficiency between new and old Member States. The answers to these research questions will be the subject of the present study.

2 Environmental efficiency in the EU countries

In recent years, many research papers on environmental efficiency have appeared, with long-term greenhouse gas emissions at the centre of interest. Some studies focus on solving the problem at the micro level (Dirik et al., 2019; Park et al., 2018), but significantly more studies focus on the macroeconomic level of countries, regions and economies (Chen et al., 2019; Iram et al., 2020; Mardani et al., 2017). At the national level, these are studies focused on environmental efficiency, primarily in China and the USA (Li et al., 2021; Chen et al., 2019), at the transnational level, they are groupings of EU or OECD countries (Halkos & Petrou, 2019; Czýzewski et al., 2020; Hermoso-Orzáez et al., 2020; Puertas et al., 2022; Zhu et al., 2022). Scholars have examined the environmental efficiency of the EU from different perspectives. For example, Sanz-Díaz et al. (2017) used the DEA and Malmquist method to measure environmental efficiency in 28 EU countries and compared the results of Spain with other EU members as a priority.

Beltrán-Esteve and Picazo-Tadeo (2017) integrated Luenberger productivity indicators, DEA, and the directional distance function (DDF) to assess the environmental performance of the EU and compared the environmental efficiency of members in different periods. They found that the environmental performance of all member states improved and there were differences in the environmental performance of older and newer members over the period under review.

Moutinho et al. (2017) evaluated the environmental performance of 26 EU countries in two steps. In the first step, the DEA method is used to measure each country's efficiency. In the second step, the quantile regression technique was used to explain the different efficiency scores through the selected variables. Duman and Kasman (2018) used parametric hyperbolic distance functions to analyse the environmental efficiency of EU member and candidate countries in the period 1990–2011. They concluded that the EU-15 countries, in contrast to the new members and candidate countries, have a greater potential for reducing CO2 emissions while simultaneously increasing GDP and reducing energy consumption.

Hermoso-Orzáez et al. (2020) monitored a sample of 28 EU countries in the period 2005-2012 using two selected variants of the DEA method. The authors' results show that there are 14 out of 28 countries that have high relative environmental efficiency. Among the countries with very low environmental efficiency were the last acceding countries, where environmental policies are not yet implemented effectively with positive results. Puertas et al. (2022) on the analysis of 20 European countries in the period 2014-2018 confirmed that countries with low environmental efficiency are concentrated in the East of Europe. For this purpose, they used the DEA method and the Malmquist Index (MI). Zhu et al. (2022) applied the DEA method to investigate three different objectives of environmental policy in EU countries in the period 2013-2019. He confirmed that there are significant differences between states. where countries that joined the EU earlier have higher efficiency values. Czýzewski et al.'s (2020) study came up with interesting results, which examined EU countries from 2005-2016. The authors concluded that the highest efficiency of environmental spending in the context of "deadweight loss" was recorded in the countries of Central and Eastern Europe, the Scandinavian countries and Spain.

3 Methodology

The presented study's main goal is to measure EU countries' environmental efficiency. The essence of the research is the verification of the following two hypotheses, the determination of which is based on theoretical foundations:

H1: Old Member States have higher environmental efficiency compared to new Member States.
H2: Member States with high GDP per capita achieve higher levels of environmental efficiency.

The subject of the study is 27 EU Member States in the period 2000-2020. The Data envelopment analysis (DEA) method implemented in R studio was chosen to measure efficiency, which is among the most used methods for evaluating environmental efficiency (Wei et al., 2021; Tian et al. 2020). Its use in the given area can be confirmed by several studies, see for example Moutinho et al. (2017), Park et al. (2018), Wegener and Amin (2019), Matsumoto et al. (2020) or Zhu et al. (2022) etc. DEA is a mathematical programming approach that evaluates the performance of decision-making units (DMUs). In this evaluation, the inputs that were invested in the process are compared with its achieved results (outputs) (Charles et al. 2018). In the area of environmental efficiency, the division of outputs into desirable and undesirable is added (Goto et al., 2014). In the context of environmental efficiency, DMUs can be countries, regions, organizations or firms, and inputs and outputs can be environmental indicators such as greenhouse gas emissions, water consumption, energy consumption or waste generation. DEA has been widely accepted in the scientific community due to its great flexibility in defining the problem: it accepts different measurement units for inputs and outputs and allows direct comparison of some DMUs with others as well as with their combination (Lotfi et al., 2020). Based on previous studies, the inputs and outputs were defined, which formed the basic data sample for the DEA analysis. It is recommended that the total number of inputs and outputs does not exceed 1/3 of the number of examined DMUs.

Table 1 Variables for DEA analysis

	Indicator	Unit	Database	Source
Inputs				
X_1	Total public expenditure	% GDP	Eurostat	Czýewsky et al. (2020), Melledu and Pulina (2018)
X_2	Public expenditures for environmental protection	% GDP	Eurostat	
X_3	Total labour force per capita	Thousand inhabit.	OECD	Halkos and Petrou (2019), Mavi et al. (2019)
X_4	Primary energy consumption	Tonnes per GDP	Eurostat	Jiandong et al., (2015), Mavi et al. (2019)
X_5	Income from environmental taxes	% GDP	Eurostat	Štreimikienė et al. (2022)
Undesirable outputs				
X_6	Sulphur oxides (SOx)	Tones per GDP	Eurostat	Halkos and Petrou (2019), Yang et al. (2014)
X_7	Greenhouse gases (CO2) per capita	Tonnes per HDP	Eurostat	Zhu et al. (2022)
X_8	Nitrogen oxides (NO2)	Tonnes per HDP	Eurostat	Halkos and Petrou (2019)
Desirable outputs				
X_9	GDP per capita	EUR	Eurostat	Puertas et al. (2022), Apergis and Garcia (2019)

Source: own processing.

Input variables X_3 to X_8 were subsequently adjusted and expressed as a ratio indicator concerning GDP per capita in constant prices or as a % of GDP in the case of environmental taxes. The robustness of the DEA model is affected by the degree of correlation between the variables. Before creating the correlation matrix, a normality test is performed using the Jarque-Bera and D'Agostino tests. A value of 0.8 is a high degree of correlation and testing takes place at a significance level of 0.01; 0.05; 0.1. Based on the study by Hermoso-Orzáez (2020), an evaluation scale of environmental efficiency was compiled for the median values of EU countries as "• excellent environmental efficiency" (0.99-1), "• good environmental efficiency" (0.8-0.99), "• average environmental efficiency" (0.5-0.79), " • low environmental efficiency" (0-0.49).

We applied a model based on Seiford and Zhu (2002). Let DMU_j denotes n independent decision units ($j = 1,2,\dots,n$), each DMU_j needs m inputs x_{ij}, ($i = 1,2,\dots,m$) to produce s_1 desirable outputs $y^g_{\bar{r}j}$ ($\bar{r} = 1, 2, ..., s_1$) and s_2 undesirable outputs $\bar{y}^b_{\bar{\bar{r}}j}$, ($\bar{\bar{r}} = 1, 2, ...,s_2$). Model is given by the following expressions:

$$
\begin{aligned}
&Max\ ß_p\\
&\sum_{j=1}^{n} \lambda_j x_{ij} \le x_{ip}, \quad i = 1,2 \dots,m,;\\
&\sum_{j=1}^{n} \lambda_j y^g_{\bar{r}j} \ge ß_p y^g_{\bar{r}p}, \quad \bar{r}=1,2,\dots s_1,\\
&\sum_{j=1}^{n} \lambda_j \bar{y}^b_{\bar{\bar{r}}j} \ge ß_p \bar{y}^b_{\bar{\bar{r}}p}, \quad \bar{\bar{r}}=1,2,\dots,s_2,\\
&\sum_{j=1}^{n} \lambda_j = 1, \lambda_j \ge 0, \ j = 1,2\dots n\\
&where\ \bar{y}^b_{\bar{\bar{r}}j} = -\bar{y}^b_{\bar{\bar{r}}j} + w_{\bar{\bar{r}}} > 0
\end{aligned}
\tag{1}
$$

3 Results

Based on the results of the Jarque-Bera and D'Agostino tests in our R study, the hypothesis of the normality of the set was rejected, leading to the use of non-parametric correlation tests such as Kendall's and Spearman's correlation coefficient, which are robust to outliers and do not assume data normality. The results of the correlation matrix are presented in Table 2.

Table 2 Correlation matrix

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9
X_1	1	-0.02	-0.07	**-0.35** ***	**0.23** ***	**-0.44** ***	**-0.45** ***	**-0.38** ***	**0.41** ***
X_2	-0.01	1	**-0.27** ***	-0.10 **	-0.03	-0.02	0.08*	-0.08	0
X_3	-0.04	-0.19 ***	1	-0.23 ***	-0.02	**-0.32** ***	-0.25 ***	-0.25 ***	**0.35** ***
X_4	**-0.25** ***	-0.06 **	-0.16 ***	1	0	**0.82** ***	**0.78** ***	**0.74** ***	**-0.87** ***
X_5	0.15 ***	-0.03	-0.02	0	1	-0.01	0.07 *	0.13 ***	0.016
X_6	**-0.23** ***	-0.01	-0.22 ***	**0.64** ***	-0.006	1	**0.86** ***	**0.82** ***	**-0.79** ***
X_7	**-0.32** ***	0.06*	-0.17 ***	**0.61** ***	0.05 *	**0.67** ***	1	**0.74** ***	**-0.75** ***
X_8	-0.26 ***	-0.06 **	-0.17 ***	**0.58** ***	0.09 **	**0.66** ***	**0.57** ***	1	**-0.74** ***
X_9	**0.29** ***	0.01	0.25 ***	**-0.68** ***	0.02	**-0.61** ***	**-0.56** ***	**-0.57** ***	1

Source: own processing.

Based on the correlation matrix, variables X_1 and X_4 were selected as inputs to the model. Variables X_2 and X_3 and X_5 were discarded due to low values of correlation coefficients with the considered outputs. Indicators X_7, X_8 and X_9 were selected as outputs for the DEA model. Indicator X_6 was excluded due to the high correlation coefficient with indicators X_7 and X_8. By excluding the variables, the conditions for DEA analysis, which requires a low correlation between selected inputs and a high correlation between inputs and outputs, were met.

In the case of variables X_7 and X_8, a deeper analysis and comparison of countries over time was carried out, which is illustrated in Figure 1 and Figure 2.

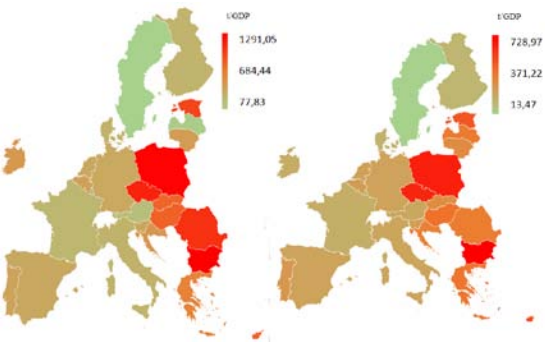


Figure 1 Greenhouse gases (CO2) of EU countries (tones of GDP) - comparison of 2000 (right map) and 2020 (left map)
Source: own calculation.

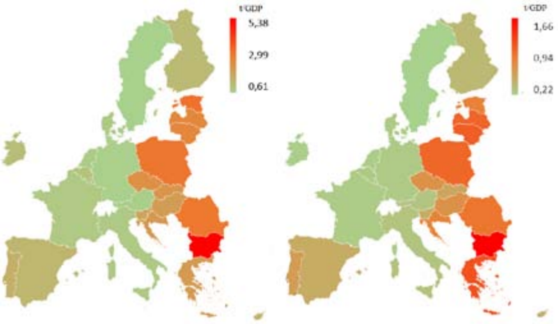


Figure 2 Nitrogen oxides (NO2) of EU countries (tones of GDP) - comparison of 2000 (right map) and 2020 (left map)
Source: own calculation.

The results illustrated in Figure 1 and Figure 2 show a significant improvement in both monitored variables over the 20-year period, which is visible in significantly lower emission rating scales in 2020 compared to 2000. However, differences remain between countries, with emission growth moving from the west to the east.

The complete results of the DEA analysis for the years 2000-2020 are presented in Table 3.

Table 3 Results from DEA

	SE	ES	SI	SK	RO	PT	PL	NL	MT	LU	LT	LV	IT	IE	HU	EL	DE	FR	FI	EE	DK	CZ	CY	HR	BG	BE	AT
2000	1.00	0.93	0.85	0.74	0.65	0.89	0.63	1.00	0.90	1.00	0.83	1.00	0.99	1.00	0.79	0.78	1.00	0.97	0.92	0.64	1.00	0.74	0.93	0.78	0.32	0.95	1.00
2001	1.00	0.95	0.84	0.75	0.64	0.89	0.63	1.00	0.90	1.00	0.80	1.00	1.00	1.00	0.79	0.77	1.00	0.97	0.92	0.64	1.00	0.73	0.92	0.79	0.31	0.95	1.00
2002	1.00	0.96	0.86	0.78	0.66	0.89	0.66	1.00	0.91	1.00	0.81	1.00	1.00	1.00	0.81	0.78	1.00	0.97	0.92	0.66	1.00	0.75	0.92	0.78	0.32	0.95	1.00
2003	1.00	0.96	0.88	0.82	0.66	0.88	0.67	1.00	0.90	1.00	0.85	1.00	1.00	1.00	0.81	0.70	1.00	0.97	0.91	0.70	1.00	0.74	0.91	0.79	0.30	0.95	1.00
2004	1.00	0.95	0.88	0.82	0.68	0.87	0.66	1.00	0.89	1.00	0.85	1.00	1.00	1.00	0.81	0.77	1.00	0.97	0.91	0.76	1.00	0.75	0.92	0.80	0.33	0.95	0.99
2005	1.00	0.94	0.87	0.81	0.70	0.85	0.63	1.00	0.87	1.00	0.82	1.00	0.99	1.00	0.81	0.75	1.00	0.96	0.94	0.75	1.00	0.76	0.91	0.80	0.35	0.94	0.97
2006	1.00	0.94	0.87	0.82	0.66	0.86	0.58	1.00	0.85	1.00	0.83	1.00	0.99	1.00	0.79	0.75	1.00	0.96	0.91	1.00	1.00	0.74	0.91	0.79	0.37	0.94	0.97
2007	1.00	0.92	0.89	0.85	0.69	0.87	0.58	1.00	0.85	1.00	0.84	1.00	0.99	1.00	0.77	0.72	1.00	0.96	0.91	1.00	1.00	0.74	0.91	0.77	0.33	0.94	0.97
2008	1.00	0.94	0.86	1.00	0.76	0.87	0.59	1.00	0.85	1.00	0.83	1.00	0.99	1.00	0.77	0.70	1.00	0.97	0.92	0.69	1.00	0.77	0.96	0.77	0.42	0.94	0.98
2009	1.00	0.94	0.85	0.85	0.78	0.84	0.62	1.00	1.00	1.00	0.85	0.99	0.99	1.00	0.77	0.67	1.00	0.97	0.91	0.65	1.00	0.77	0.98	0.75	0.40	0.95	0.97
2010	1.00	0.93	0.82	0.88	0.68	0.83	0.57	1.00	1.00	1.00	0.94	0.77	1.00	1.00	0.76	0.69	1.00	0.97	0.88	0.64	1.00	0.76	0.97	0.75	0.42	0.95	0.97
2011	1.00	0.92	0.83	0.93	0.70	0.86	0.64	0.99	0.91	1.00	0.94	0.88	0.99	1.00	0.79	0.71	1.00	0.97	0.91	0.96	1.00	0.80	0.91	0.76	0.40	0.96	0.97
2012	1.00	0.88	0.84	0.92	0.66	0.85	0.59	0.99	0.87	1.00	1.00	0.96	0.98	1.00	0.76	0.67	1.00	0.97	0.91	0.72	1.00	0.73	0.86	0.77	0.41	0.96	0.97
2013	1.00	0.90	0.79	0.87	0.69	0.83	0.57	1.00	0.92	1.00	1.00	0.91	0.98	1.00	0.74	0.64	1.00	0.96	0.88	0.66	1.00	0.73	0.89	0.77	0.40	0.95	0.95
2014	1.00	0.90	0.80	0.87	0.76	0.82	0.63	1.00	0.92	1.00	1.00	0.79	0.98	1.00	0.76	0.65	0.99	0.97	0.90	0.62	1.00	0.74	0.83	0.77	0.31	0.96	0.95
2015	1.00	0.87	0.82	0.84	0.78	0.81	0.62	0.98	0.94	1.00	0.90	0.79	0.97	1.00	0.75	0.68	0.97	0.96	0.91	0.64	1.00	0.73	0.87	0.76	0.29	0.95	0.94
2016	1.00	0.89	0.82	0.85	0.78	0.81	0.60	0.99	0.98	1.00	0.88	0.84	0.97	1.00	0.76	0.66	0.97	0.97	0.90	0.62	1.00	0.74	0.88	0.75	0.32	0.96	0.94
2017	1.00	0.89	0.81	0.84	0.79	0.79	0.55	0.99	0.97	1.00	0.87	0.87	0.97	1.00	0.73	0.67	0.97	0.96	0.91	0.59	1.00	0.73	0.88	0.76	0.32	0.96	0.94
2018	1.00	0.88	0.82	0.84	0.76	0.82	0.57	0.98	0.96	1.00	0.86	0.78	0.96	1.00	0.74	0.66	0.97	0.97	0.89	0.59	1.00	0.73	0.87	0.75	0.31	0.96	0.95
2019	1.00	0.87	0.84	0.83	0.74	0.83	0.59	0.98	0.94	1.00	0.82	0.82	0.95	1.00	0.74	0.66	0.97	0.97	0.88	0.65	1.00	0.73	0.84	0.74	0.31	0.96	0.95
2020	1.00	0.84	0.85	0.83	0.70	0.79	0.59	0.96	0.92	1.00	0.75	0.68	0.95	1.00	0.74	0.63	0.97	0.97	0.90	0.68	0.96	0.74	0.87	0.68	0.32	0.97	0.95

Source: own processing.

The results in Table 3 show a significant difference in the environmental efficiency of the EU countries. During the entire observed period, Bulgaria was among the countries with the lowest environmental efficiency, whose values did not change even after joining the EU. On the opposite side are countries like Denmark, Germany, Ireland, Luxembourg, Sweden, and the Netherlands. For better interpretability of the results, median values were calculated from the values for the period 2000-2020, which more accurately depict the position of the countries compared to the average values reported, for example, by Zhu et al (2022).

For comparability with other studies, the median values were also calculated for the period 2005-2012, which corresponds to the monitored period of the Hermoso-Orzáes (2020) study and are listed in Table 4.

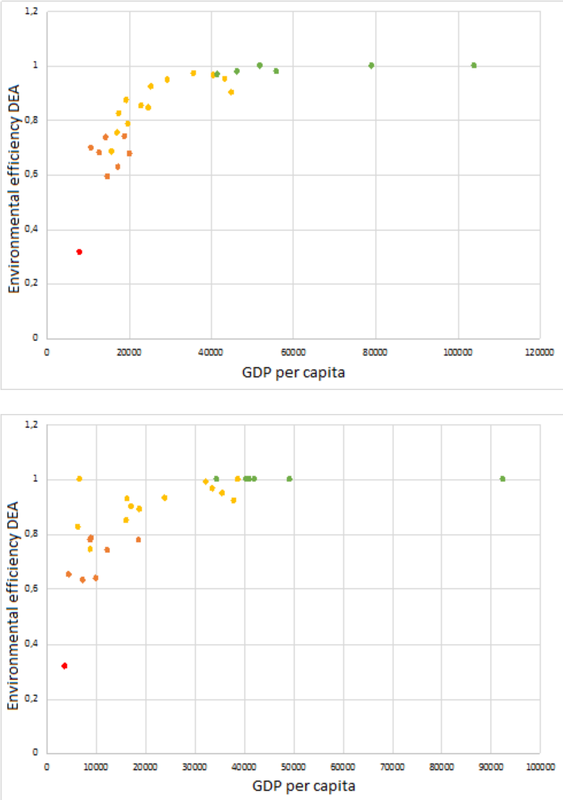
Table 4 Results from DEA and their comparison

Hermoso-Orzáes et al. (2020)		**Own results**		**Own results**		**Own results**	
Median 2005-2012		Median 2005-2012		Median 2013-2020		Median 2000-2020	
DK	1.00	DK	1.00	DK	1	DK	1.00
DE	1.00	DE	1.00	IE	1	DE	1.00
IE	1.00	IE	1.00	LU	1	IE	1.00
LU	1.00	LU	1.00	SE	1	LU	1.00
NL	1.00	NL	1.00	NL	0.98	NL	1.00
SE	1.00	SE	1.00	DE	0.97	SE	1.00
AT	1.00	IT	0,99	IT	0.97	AT	0.97
FR	1.00	LT	0,98	FR	0.97	FR	0.97
IT	1.00	AT	0,97	BE	0.96	IT	0.97
LT	1.00	FR	0.97	AT	0.95	BE	0.95
MT	1.00	BE	0.95	MT	0.94	ES	0.92
PL	1.00	ES	0.93	FI	0.90	CY	0.91
CY	1.00	CY	0.91	LT	0.88	LT	0.91
BE	0,96	FI	0.91	ES	0.88	FI	0.91
LV	0.95	MT	0.87	CY	0.87	MT	0.91
EL	0.94	SK	0.86	SK	0.84	PT	0.85
PT	0.91	SI	0.85	SI	0.82	LV	0.85
ES	0,87	PT	0.85	PT	0.82	SK	0.84
HR	0.72	LV	0.85	LV	0.81	SI	0.84
EE	0.69	HR	0.77	HR	0.76	CR	0.77
SI	0.69	HU	0.77	RO	0.76	HU	0.77
FI	0.69	EL	0.76	HU	0.74	RO	0.76
SK	0.51	CZ	0.76	CZ	0.74	CZ	0.74
RO	0.43	RO	0.74	EL	0.66	EL	0.69
HU	0.40	EE	0.74	EE	0.63	EE	0.66
BG	0.35	PL	0.59	PL	0.59	PL	0.60
CZ	0.33	BG	0.41	BG	0,31	BG	0.32

Notes: • excellent • good • average • low environmental efficiency
Source: own processing, Hermoso-Orzáes (2020).

The results in Table 4 show excellent environmental efficiency for Denmark, Germany, Ireland, Sweden, and Luxembourg both in the results of the present study and the results of the study by Hermoso-Orzáes (2020). According to the 2000-2020 results, good environmental efficiency was achieved in 13 countries, e.g. in Austria, France, Italy, but also Slovakia and Slovenia. Seven countries, among them most of the new Member States such as Hungary, Czechia, Estonia, and Poland, achieved average environmental efficiency, and the lowest values were recorded by Bulgaria. Compared to the Hermoso-Orzáes (2020) study, there is a decrease in countries with excellent environmental efficiency and an increase in countries with good environmental efficiency. In the context of the division of countries into old and new Member States, where we consider the new Member States to be the countries joining the EU after 2004, it is visible that the old Member States achieve better results in environmental efficiency in the long term. This result is confirmed by the results from Table 3 and Table 4, which makes it possible to confirm H1: Old Member States have higher environmental efficiency compared to new Member States. This is consistent with the results of studies such as Beltrán-Esteve et al. (2019), Matsumoto et al. (2020), Sanz-Díaz et al. (2017), and Zhu et al. (2022).

However, it is important to note that all EU countries have significantly reduced the shares of greenhouse gases, sulphur oxides and nitrogen oxides in % of GDP. However, it had no impact on the ranking that year. The result of the study by Puertas et al (2022) was also confirmed, which says that Eastern European countries, which form a buffer zone against non-member countries that do not have such strict environmental policy goals as the EU, achieve less efficiency. Many Member States are concerned that the expenses associated with achieving the EU's environmental goals will hurt their economic growth or that high environmental efficiency cannot be associated with high GDP per capita. Figures 1 illustrate the state of environmental efficiency according to DEA as well as the size of GDP per capita in EU countries for the years 2000 and 2020.



Notes: • excellent, • good • average • low environmental efficiency

Figure 3 GDP per capita and environmental efficiency according to the DEA method for 2000 (up) and 2020 (down)
Source: own processing.

Figure 3 points out that the EU Member States that achieved a high level of environmental efficiency in the monitored periods are among the states with the highest GDP per capita. Conversely, states with low environmental efficiency are at the bottom of the GDP per capita ranking. A simple illustration of the results thus confirms H2: States with high GDP per capita achieve a higher level of environmental efficiency, which is in line with Duman and Kasman (2018). The results need to be seen in a wider context. The old Member States have been working for a long time to achieve the EU's environmental goals by increasing the use of renewable resources, a high rate of recycling or transitioning to a circular economy.

4 Discussion and conclusion

The concept of sustainable development makes more sense today than ever before. Increased concerns about environmental pollution problems in countries such as China have made eco-efficiency analysis a central issue of much research. The countries of the European Union have also set strategic goals that support a sustainable environmental framework.

The presented study aimed to measure the environmental efficiency of EU countries using the DEA method, which is often used in this issue. With the help of the R program, efficiency was measured in each of the years 2000-2020, and then the median from the periods 2005-2012, 2013-2020 and 2000-2020 was calculated. The results showed a significant difference in environmental efficiency across EU countries, with the old Member States performing better than the new Member States, thus confirming H1. Countries such as Latvia, Lithuania, Slovakia, and Slovenia come closest to the old Member States. Countries such as Poland, Czechia, Romania, and Bulgaria lag significantly behind. The results largely agree with other studies in this area even when using different inputs and outputs in DEA analysis.

Comparing the results of DEA and GDP per capita also led to the acceptance of H2: States with high GDP per capita achieve a higher level of environmental efficiency. The finding that countries with higher GDP per capita produce fewer emissions that significantly affect environmental efficiency is a consequence of the introduction of more effective environmental policies that support technological progress, improved energy efficiency and the use of cleaner energy sources. Examples include countries such as Sweden, Luxembourg, and Ireland, which are actively taking steps to reduce greenhouse gas emissions and achieve their climate goals. They introduced instruments such as the climate law, the carbon tax, financial support for renewable energy sources and free public transport by buses, trams, and trains or the "polluter pays" rule. Overall, these countries are making significant efforts to transition to a low-carbon economy and reduce their environmental impact, using environmental policy principles and a combination of normative and economic instruments. The results of the DEA analysis confirmed the low position of Bulgaria, which covers 20% of the total energy consumption with renewable sources. However, it still lags behind the standards set in the directive on municipal wastewater treatment and air pollution. The conviction that economic growth should take precedence over changes in environmental protection has persisted in Poland for a long time. The results of the study proved that this is a false assumption. Fossil fuels accounted for 70% of Poland's energy sources in 2020, and coal is expected to remain the country's main energy source until 2049. Problems are also emerging in waste management. For countries such as Estonia, Hungary, Poland and the Czech Republic, the EU's goals of environmental neutrality in 2050 seemed too ambitious, leading to the blocking of the "Green Deal".

The presented study confirmed that significant differences between EU Member States persist for a long time. Despite the demonstrable fact that countries with high environmental efficiency can produce high economic growth, many countries are reluctant to gradually reorient at least part of their industry to sectors with smaller negative impacts on the environment. If countries were to adopt this change, its effect would only be demonstrated after a few years, and it would have to gain high and consistent political support. The main problem uncovered by this study is the fact that, even though all EU Member States are making significant progress in achieving environmental goals when measuring efficiency, the groups with average and low efficiency are still the same countries. Without major national reforms and commitment from the EU, for example in the form of a different system of allocation of funds for this area, it will not be possible to achieve a reduction of the gap that exists between EU Member States in this area even in the horizon of a decade.

For a more in-depth examination of the issue, it would be appropriate to supplement the monitored variables in the DEA analysis with, for example, technological progress, or to monitor the dynamics of changes in environmental efficiency. Likewise, to examine the existence of the influence of the type of environmental expenses on efficiency. It seems interesting to examine the geographical interconnectedness of countries given the worse results of the eastern countries of the EU and the impact of non-member states on the environmental efficiency of neighbouring EU Member States.

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