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DETERMINANTS OF ENVIRONMENTAL EFFICIENCY: THE CASE OF THE CEFTA 2006 SIGNATORIES

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Abstract

This study analyzes 1) the environmental efficiency of CEFTA 2006 signatory countries using the DEA method and 2) the factors affecting environmental efficiency through a panel analysis for the period from 2010 to 2021. The balanced panel data used includes key variables such as the number of employees, energy consumption, production, and emissions of carbon dioxide (CO2) and sulfur dioxide (SO2). The DEA method enables the evaluation of the efficiency of different decision-making units (DMUs), taking into account both desirable and undesirable outcomes. The results show that Albania, Serbia, and Montenegro achieved the highest average environmental efficiency, while Bosnia and Herzegovina had the lowest. The data obtained with the DEA method were later used as the dependent variable of environmental efficiency in the panel analysis. The panel analysis shows that freight transport by road and rail has a positive influence on environmental efficiency, while passenger transport by road has a negative but statistically insignificant influence. The results indicate a positive impact of income per person and a negative impact of three variables (trade, industrial production, and renewable energy sources) on environmental efficiency. An examination of the impact of crisis periods, represented by binary variables for 2010 and 2020, indicates that the 2009 economic crisis had a positive effect on eco-efficiency. These results emphasize the importance of efficient transport, economic development, and careful policy planning to improve environmental efficiency.

Keywords: environmental efficiency, transport, emissions

DETERMINANTE EKOLOŠKE EFIKASNOSTI: SLUČAJ POTPISNICA CEFTA 2006

Apstrakt
Ova studija analizira 1) ekološku efikasnost potpisnica CEFTA 2006 korišćenjem DEA metodologije i 2) faktore koji utiču na ekološku efikasnost primenom panel analize za period od 2010. do 2021. godine. Korišćeni balansirani panel podaci obuhvataju ključne promenljive kao što su broj zaposlenih, potrošnja energenata, proizvodnja, i emisije ugljen-dioksida (CO2) i sumpor-dioksida (SO2). DEA metodologija omogućava ocenu efikasnosti različitih jedinica donošenja odluka (eng. decision making unit, DMU) uzimajući u obzir i poželjne i nepoželjne izlaze. Rezultati pokazuju da su Albanija, Srbija i Crna Gora ostvarile najvišu prosečnu ekološku efikasnost, dok Bosna i Hercegovina ima najnižu. Dobijeni podaci iz DEA metodologije su kasnije korišćeni kao zavisna promenljiva ekološke efikasnosti u panel analizi. Panel analiza otkriva da prevoz robe drumskim i železničkim saobraćajem pozitivno utiče na ekološku efikasnost, dok prevoz putnika drumskim saobraćajem ima negativan ali statistički neznačajan uticaj. Rezultati ukazuju na pozitivan uticaj dohotka po glavi stanovnika i negativan uticaj tri promenljive (trgovina, industrijska proizvodnja i obnovljivi izvori energije) na ekološku efikasnost. Analiza uticaja kriznih perioda, predstavljenih binarnim varijablama za 2010. i 2020. godinu, ukazuje na to da je ekonomska kriza iz 2009. godine imala pozitivan efekat na ekološku efikasnost. Ovi nalazi naglašavaju važnost efikasnog transporta, ekonomskog rasta i pažljivog planiranja politike za unapređenje ekološke efikasnosti.
Ključne reči: ekološka efikasnost, transport, emisije.

INTRODUCTION

The importance of environmental efficiency is growing in today's world, especially within regional trade agreements like CEFTA 2006 (Central European Free Trade Agreement). Environmental efficiency pertains to a country or region's capacity to reduce adverse environmental effects while maintaining an appropriate level of economic activity. Given the need for sustainable development and the alignment of environmental standards, environmental efficiency is vital within CEFTA 2006, which involves countries from Central Europe and the Balkans.

One of the most important sectors influencing environmental efficiency is transport. The transport sector, including passenger and freight transport by road, rail, and air, contributes significantly to greenhouse gas emissions and energy consumption. For this reason, it is essential to analyze the impact of transport on environmental efficiency in CEFTA countries. Bijelić et al. (2013) emphasize that the liberalization of interregional trade between the economies of the Western Balkans started in 2000 on the initiative of the EU and culminated in the signing of the agreement (CEFTA 2006). The agreement was signed by several European countries, as well as by the United Nations Mission in Kosovo (UNMIK), on behalf of the customs territory of Kosovo[1] **. With the signing of this document, interregional trade in goods has been

[1] **This designation is without prejudice to status and is in line with United Nations Security Council Resolution 1244 and the International Court of Justice's opinion on the Kosovo declaration of independence.

significantly liberalized, and a regional free trade area for goods, including agricultural products, has been created. Further liberalization of services and investments is planned for the future.
According to the IPCC, direct greenhouse gas emissions from the transport sector amounted to 8.7 GtCO2-eq in 2019 (compared to 5.0 GtCO2-eq in 1990) and accounted for 23% of global energy-related CO2 emissions (Jaramillo et al., 2023). Of these emissions, road transport accounted for 70, while rail, shipping, and air transport accounted for 1, 11, and 12, respectively. In addition to importing and exporting, international trade also encompasses foreign direct investment. Kastratović (2019) demonstrates that in developing countries, FDI inflows can lead to increased CO2 emissions. This conclusion can also be applied to the transport sector, as liberalization and increased investment in transport infrastructure can affect environmental efficiency in a similar way.
In this paper, dummy variables are used to assess the impact of two challenging periods: the global financial crisis and the COVID-19 pandemic. Global crises have a significant impact on trade and thus also on transportation, which is related to environmental efficiency. Bijelić et al. (2013) stated that the economic downturn slightly lagged in affecting the Western Balkan economies after it began in the US. This crisis transmission demonstrates the significant integration of Western Balkan countries into the global economy, primarily through imports and FDI inflows rather than exports to foreign markets. The economic openness of these economies was generally high, above 50%, except Albania, where it was around 40%. As a result, the decline in exports from the Western Balkans in 2008 was so significant that most regional economies had not even recovered by 2010. According to Popović-Petrović (2023), the global COVID-19 pandemic caused the deepest global recession since the Second World War, with a decline in global trade of almost 16% in the second quarter of 2020. This decline was greater than the impact of the global financial crisis. The pandemic had a strong impact on bilateral trade flows, especially for countries that were involved in regional trade agreements before the pandemic. The negative impact was particularly pronounced for exports from high-income countries. The pandemic caused a high level of general uncertainty, which was exacerbated by the speed of the outbreak of the crisis.

LITERATURE REVIEW

The impact of various modes of transportation is a significant concern due to their adverse effects on the environment. The use of energy should be aligned with environmental sustainability to promote economic efficiency, a resilient energy system, and improved societal well-being (Stošić & Mihajlović, 2018). It is important to maintain awareness of the environmental consequences associated with all decisions and actions undertaken (Aljković & Skenderović, 2020). Transportation activities directly affect the environment, making it essential to encourage transport companies to operate more responsibly (Bošković et al., 2020). The contribution of Industry 4.0 technologies to improving efficiency and reducing negative impacts aligns with EU regulations aimed at transitioning to zero-emission vehicles by 2035, further enhancing sustainability in transportation. This goal seeks to increase the number of electric vehicles on the roads (Ljajić et al., 2024). Andersson (2016) emphasizes the importance of cross-border collaborations to promote sustainable transport networks through joint projects focused on sustainable development. Regarding this, to reduce the negative impact of transportation on the environment, it is important to establish a unified policy that will enable achieving the best performance in the CEFTA region. Policy measures such as promoting intermodal transport and enforcing stricter emission standards can significantly reduce the negative influence of the transportation sector (Rodrigue, 2013). Furthermore, economic tools like carbon pricing and subsidies for environmentally friendly technologies are essential for motivating a transition to more sustainable transportation methods, as noted by Baranzini & Carattini (2017), Boyce (2018), and Gelb & Mukherjee (2019). Recent research has identified road transport as a major contributor to carbon emissions and local pollutants, as noted by Sohrab et al. (2022), Kończak et al. (2020), and Colvile et al. (2001), highlighting the need for stricter emission standards and increased use of electric vehicles. Madadi et al. (2017) further elaborate that road transport not only generates high levels of carbon emissions but also contributes to noise pollution and landscape fragmentation. Santos et al. (2010) point out that the apparent cost-effectiveness and flexibility of road transport often obscure its substantial long-term environmental costs, presenting challenges for reform in this sector. Ercan et al. (2022) suggest that the adoption of autonomous electric vehicles could cut transportation-related greenhouse gas emissions by up to 34% by 2050. Rail transport, particularly when utilizing renewable energy sources, is frequently considered a more sustainable alternative, with studies by Limin et al. (2020) supporting this view. Chang et al. (2019) have shown that modern rail systems can drastically lower carbon footprints relative to roads and airplanes, while Janić (2021) reports that high-speed rail systems are more energy-efficient and produce fewer carbon emissions per ton-kilometer than road vehicles. Air transport, essential for global connectivity, faces significant challenges in emission reduction, being the most carbon-intensive transport mode with significant impacts like contrails and cirrus cloud formation discussed by Peeters et al. (2009). Hileman et al. (2013) and Staples et al. (2018) argue that a 50% reduction in aviation-related emissions by 2050 will require the rapid adoption of innovative aircraft designs and widespread use of alternative fuels that have lower lifetime greenhouse gas emissions.

METHODOLOGY

This chapter describes the methodologies used for analyzing environmental efficiency using the Data Envelopment Analysis (DEA) methodology and panel data. The models include pooled OLS, fixed effects (FE), and random effects generalized least squares (REGLS) models. Approaches and models used to assess environmental efficiency and the impact of transport for the signatories of the CEFTA 2006 agreement for the period from 2010 to 2021 are presented in detail. The countries examined include Serbia, Bosnia and Herzegovina, Montenegro, North Macedonia, Albania, and Moldova.

DEA METHODOLOGY

The DEA methodology was employed to evaluate the environmental efficiency of the CEFTA 2006 signatories. This approach assesses the ability of decision-making units to maximize outputs while minimizing inputs. This study is based on the approach of Sueyoshi & Goto (2010, 2012a,b,c) and Song et al. (2016). Managerial disposability refers to a situation where a DMU, using advanced clean coal technologies and environmental management strategies, can reduce the amount of undesirable outputs. This approach allows DMUs to apply management strategies when facing changes in environmental regulations. The study shows that measuring and evaluating the performance of DMUs should encompass two key aspects. The first aspect relates to operational efficiencies, i.e., the ability to produce desirable outputs with given inputs or to reduce production costs with constant outputs. The second aspect is environmental efficiency, which relates to the ability to reduce undesirable outputs in accordance with environmental regulations. The non-radial DEA methodology under managerial disposability is used to measure the unique efficiency of DMUs, considering changes in environmental regulations and evaluating environmental performance alongside operational efficiencies.
The inputs used are in the categories of labor and energy. For labor, the variable used is the number of employees, obtained from the World Bank database, while for energy, the variable used is the total energy consumption in terajoules (TJ) obtained from the International Energy Agency (IEA). The outputs are classified as desirable and undesirable. The desirable output is production (expressed in constant 2015 US$), obtained from the World Bank database, while the undesirable outputs are carbon dioxide (CO2) emissions and sulfur dioxide (SO2) emissions, obtained from the Global Carbon Budget (2023) data sources.

PANEL ANALYSIS

This section describes the methodologies used to analyze the impact of passenger and freight transport on environmental efficiency. The analysis was conducted using panel data, and the models include pooled OLS, fixed effects (FE), and random effects generalized least squares (REGLS) models. Approaches and models used to assess environmental efficiency and the impact of transport are presented in detail below.

Starting equation (1):

$$y_{it} = \alpha + \beta X_{it} + \epsilon_{it}$$

where yit is the dependent variable (environmental efficiency), Xit is a vector of independent variables (such as freight transport by road, freight transport by rail, passenger transport by road, passenger transport by rail, passenger transport by air, freight transport by air, per capita income, industrial production, trade, renewable energy sources) for country i at time t.
Following the estimation of the OLS model, we proceeded to estimate both the fixed effects (FE) and random effects (REGLS) models. After conducting the Hausman test,

it was determined that the random effects (REGLS) models are more suitable. The random effects model is:

$$y_{it} = \alpha + \beta X_{it} + u_i + \epsilon_{it},$$

where u_i is the random effect specific to each country.

In the panel models, environmental efficiency is the dependent variable obtained using the DEA methodology. The data for independent variables, including passenger and freight transport by road, rail, and air, are obtained from the national statistical offices of each country. The independent variable GDP per capita (constant 2015 US$) is used as an approximation of the country's development, and the data are obtained from the World Bank database. Industrial production as a percentage of GDP is also sourced from the World Bank database. Trade, representing the total sum of imports and exports relative to GDP, is based on data from the World Bank database. Renewable energy sources, representing the share of renewables in final energy consumption, are obtained from the International Energy Agency database. The dummy variable for 2010 represents the economic crisis that began in the US in 2007-2008 and spread to the CEFTA region in 2010, while the dummy variable for 2020 approximates the impact of the COVID-19 crisis.

RESULTS AND DISCUSSION

DEA RESULTS

The data used in this analysis are balanced panel data for the signatories of the CEFTA 2006 agreement, specifically for Serbia, Bosnia and Herzegovina, Montenegro, North Macedonia, Albania, and Moldova, for the period from 2010 to 2021. This period was chosen to include the economic and environmental changes caused by the financial crisis that began in the world in 2007-2008 in the USA and spilled over into the CEFTA region in 2010, as well as the impacts of the COVID-19 pandemic, which was most pronounced in 2020, thereby allowing for a comprehensive assessment of environmental efficiency under different macroeconomic conditions.

To better understand the characteristics of the data used in this study, Table 1 presents descriptive statistics for the key input variables across different years. These statistics summarize the central tendency and dispersion of labor input (number of employees) and energy input (energy consumption), providing a foundational understanding of their variations over time and across countries. This overview serves as a crucial preliminary step before proceeding to the efficiency evaluation, as it highlights key trends and potential data heterogeneities that may influence the results.

Table 1
Descriptive statistics for relevant inputs by year

Year	Number of employees				Energy consumption			
	Mean	Standard deviation	Min	Max	Mean	Standard deviation	Min	Max
2010	1411840	950278.5	243784	3103533	63499.8	20515.43	30605.51	89848.73
2011	1432962	940646.2	244506	3091745	66828.31	21599.46	32112.76	93909.92
2012	1427001	945807.9	251895	3108558	62836.89	19732.05	28888.92	84782.7
2013	1418105	965114.3	252989	3157875	61252.88	18973.75	33661.87	87211.04
2014	1445784	967668.2	266788	3171544	59096.68	15448.32	33954.95	77958.22
2015	1446847	952302	272361	3135688	61343.6	19040.07	31903.42	87127.31
2016	1462009	982888.8	276767	3229602	63541.67	20613.63	32908.25	90686.09
2017	1457209	990451.5	277876	3256850	65314.08	20799.64	34541.1	93156.3
2018	1452893	995543.9	284888	3275646	67372.59	22651.5	34457.36	92109.6
2019	1465144	991024.7	292098	3272110	68216.93	21851.72	34206.16	92193.34
2020	1432125	979293	271119	3218733	66577.1	23841.85	31903.42	95961.46
2021	1481758	1042573	276234	3396557	70170.77	24394.54	33913.08	98641.01

Source: Authors' calculation

Table 2
Variables for the evaluation of environmental efficiency

Input/Output	Category	Variables
Input	Labor Input	Number of Employees
	Energy Input	Energy Consumption
Output	Desirable Outputs	Production
	Undesirable Outputs	Carbon Dioxide Emissions Sulfur Dioxide Emissions

Source: Authors

In accordance with the existing literature (Halkos & Tzeremes, 2009; Lv et al., 2012; Song et al., 2014; Song et al., 2016), the following two variables represent inputs: 1. the number of employees, and 2. energy consumption. The workforce and productivity are measured by the number of employees, while energy consumption is critical for understanding overall energy efficiency and its environmental impact. These inputs were chosen because they directly influence the production capacity and environmental footprint of the analyzed countries. As outputs, we used production as the desirable output and carbon dioxide (CO2) and sulfur dioxide (SO2) emissions as undesirable outputs. Production, expressed in constant 2015 US$, represents the economic output and measures the efficiency of economic activities. The environmental impact of industrial and energy activities can be assessed by measuring CO2 and SO2 emissions (Table 2). Reducing these emissions is essential for improving environmental efficiency and sustainable development. By using these specific variables, our analysis provides a comprehensive insight into the environmental efficiency of CEFTA region countries, allowing for the identification of successful strategies and policies that can be applied to improve environmental performance under different macroeconomic conditions.

Table 3

Evaluation of efficiency by year

Year	Country					
	Serbia	Bosnia and Herzegovina	Montenegro	North Macedonia	Albania	Moldova
2010	1	0.984	1	1	1	1
2011	1	1	1	1	1	0.975
2012	0.965	1	0.965	1	0.986	0.964
2013	0.993	1	0.993	0.947	0.960	1
2014	0.993	1	0.993	0.943	1	0.908
2015	1	0.971	1	0.895	0.960	0.901
2016	0.919	0.959	0.919	0.912	0.926	0.915
2017	0.907	0.942	0.907	0.928	1	0.980
2018	0.9845	0.929	0.9845	1	0.968	1

2019	0.971	0.927	0.971	1	0.964	1
2020	1	0.904	1	1	1	0.984
2021	0.918	0.857	0.918	1	0.988	1
Average	0.970	0.956	0.970	0.968	0.979	0.968
Rank	2	4	2	3	1	3

Source: Authors' calculation

The environmental efficiency scores presented in Table 3 were obtained using the Data Envelopment Analysis (DEA) method, applying an output-oriented approach to assess how effectively countries convert resources into economic output while minimizing environmental costs. The analysis was conducted separately for each year, allowing for a dynamic assessment of efficiency trends over time. The model incorporates both desirable and undesirable outputs, using a set of key input and output variables. Specifically, the inputs include the number of employees as a measure of labor input and energy consumption as a critical resource variable. The desirable output is production, expressed in constant 2015 US dollars, representing the economic benefits of resource utilization. In contrast, undesirable outputs include carbon dioxide (CO_2) and sulfur dioxide (SO_2) emissions, which capture the environmental externalities associated with energy use and industrial activity. These variables, summarized in Table 2, form the basis for evaluating the relative efficiency of each country in balancing economic productivity with environmental sustainability.

Table 3 shows the evaluation of environmental efficiency for CEFTA region countries from 2010 to 2021. Environmental efficiency is measured on a scale from 0 to 1, where 1 indicates maximum efficiency. The average values of environmental efficiency provide insight into the long-term performance of each country, while the ranking provides a comparison of the relative success in environmental efficiency between different countries. According to the presented data, Albania has the highest average environmental efficiency with a value of 0.979. Serbia and Montenegro share second place with an average value of 0.970, indicating similar levels of environmental efficiency. The third place is held by Moldova and North Macedonia, while the lowest average is recorded in Bosnia and Herzegovina. As shown in Table 3, countries maintained high environmental efficiency during the observed period, with intermittent declines due to particular challenges they faced. For instance, Bosnia and Herzegovina's efficiency decreased in recent years, and Moldova experienced declines but then regained high-efficiency levels. This information is crucial for understanding how different countries implement policies and technologies that impact environmental efficiency. They provide a basis for identifying successful strategies that can be applied in other countries to improve their environmental

performance. They also help in recognizing challenges that need to be addressed to achieve sustainable environmental efficiency at the regional level.
In 2010, environmental efficiency was high in most CEFTA region countries, which may be the result of measures taken in response to the 2007-2008 financial crisis that became evident in 2010 in the CEFTA 2006 region. These measures often included improvements in technologies and processes to reduce costs and increase efficiency, which had a positive impact on environmental efficiency. In 2020, environmental efficiency was also high in most countries, but there was a noticeable decline in some countries, which may be due to the spread of the virus. The pandemic resulted in a temporary decrease in gas emissions due to a decline in industrial production and logistics/transportation. However, the pandemic may lead to a decrease in investments in sustainable technologies, which could explain the decline in environmental efficiency in some countries.

PANEL ANALYSIS

In this chapter, we present the panel analysis results regarding the influence of transport (passenger and freight) on the level of eco-efficiency for the signatories of the CEFTA 2006 agreement. The models used include pooled OLS, fixed effects (FE), and random effects generalized least squares (REGLS). The analysis was conducted based on panel data covering relevant variables for the period from 2010 to 2021. Before conducting the panel analysis, descriptive statistics were performed for all key variables included in the analysis. This statistic provides a basic overview of the data and allows for insight into central tendencies, dispersion, and data distribution. Table 4 shows the basic descriptive statistics for the dependent variable, environmental efficiency, and independent variables such as passenger transport by road, freight transport by road, passenger transport by rail, freight transport by rail, passenger transport by air, freight transport by air, gross domestic product per capita (GDP per capita), industry, trade, and renewable energy sources.

Table 4

Descriptive statistics

Variable	Number of Observations	Mean	Standard deviation	Min	Max
Environmental efficiency	72	.969	.036	.857	1
Passenger transport by road	60	65611.15	87898.06	2697	273669
Freight transport by road	60	20556.93	20141.81	398	69395
Passenger transport by rail	72	5363.459	5097.042	76	13819
Freight transport by rail	72	1741.9	2004.346	18	7158
Passenger transport by air	66	989833.1	953913.1	385.1	3338147
Freight transport by air	66	2165.037	2052.856	.5	9850.269

Per capita	72	8.586	.295	7.798	9.155
Industry	72	3.064	.165	2.660	3.296
Trade	72	4.427	.195	3.959	4.870
Renewable energy sources	66	3.295	.341	2.649	3.898
Year 2010	72	.083	.278	0	1
Year 2020	72	.083	.278	0	1

Source: Authors' calculation

Equation (1) was initially evaluated in several forms: as a model with constant regression parameters using the pooled ordinary least squares (pooled OLS) method, as a fixed effects model (FE model), and as a random effects model using the generalized least squares method with random error components (REGLS). The variance inflation factor (VIF) for the model is 5.97. According to Hair et al. (2010), VIF values exceeding 10 indicate a potential multicollinearity problem. Since the calculated VIF is less than 10, we can conclude that there are no significant adverse effects of multicollinearity in the model. To test for the presence of heteroscedasticity in the model, White's test (1980) and the modified Wald test (Green, 2012) for groupwise heteroscedasticity were conducted. White's test results show a chi-square statistic of 55.00 with a p-value of 0.4365, which is considerably higher than conventional significance levels. Therefore, there is insufficient evidence to reject the null hypothesis of homoscedasticity, suggesting that the error variance is not statistically significantly heteroscedastic. Skewness and Kurtosis analyses further confirm the model's validity with p-values of 0.3507 and 0.1351. The modified Wald test for groupwise heteroscedasticity in the model indicates a chi-square statistic of 4.73 with a p-value below 0.05, suggesting insignificant differences in error variances among groups. The Baltagi-Li-Mak (ALM) test (Baltagi & Li, 1995) for serial correlation in the random effects model shows the following results: ALM (λ=0)= 2.23,Pr>χ2(1)= 0.1350. The null hypothesis (H0) of this test is that the autocorrelation coefficient λ is equal to zero. Since the p-value is higher than 0.05, we fail to reject the null hypothesis, indicating no serial correlation in the random effects model. The Pesaran test (Pesaran, 2015) for weak cross-sectional dependence examines the dependence between residuals obtained from the regression model. The test results are as follows: CD = 0.529, p-value = 0.597. The null hypothesis (H0) is that the errors are weakly cross-sectionally dependent. The errors are not significantly cross-sectionally dependent since the p-value is higher than 0.05. The combined results of these tests confirm that the proposed regression model satisfies the assumptions of homoscedasticity, normal error distribution, and lack of serial correlation in the model. The Pesaran test indicates no significant cross-sectional dependence, further confirming the model's validity.

We conducted the Hausman test (1978) to determine the appropriate model (fixed or random effects model). The Hausman test results showed a chi-square value of 1.47 with a p-value of 0.9617. Considering the p-value is greater than 0.05, the results suggest using a random effects model.

Table 5

Results of panel model evaluation

Dependent variable: Environmental efficiency			
Variables	Pooled OLS	FE	REGLS
Passenger transport by road	-1.04 (1.19)	-6.29 (4.88)	-1.04 (1.19)
Freight transport by road	**1.97***** **(6.56)**	**2.57***** **(8.47)**	**1.97***** **(6.56)**
Passenger transport by rail	3.08 (3.76)	2.56 (7.24)	3.08 (3.76)
Freight transport by rail	**3.79*** **(2.23)**	-2.88 6.93	**3.79*** **(2.23)**
Passenger transport by air	-1.46 (1.16)	-1.38 (1.70)	-1.46 (1.16)
Freight transport by air	2.39 (2.95)	3.30 (3.19)	2.39 (2.95)
Per capita	**0.10***** **(.02)**	.07 (.06)	**0.10***** **(.02)**
Industry	**-0.27***** **(.07)**	**-0.28**** **(.11)**	**-0.27***** **(.07)**
Trade	**-0.13***** **(.04)**	**-0.16***** **(.05)**	**-0.13***** **(.04)**
Renewable energy sources	**-0.05**** **(.02)**	-0.04 (.02)	**-0.05**** **(.02)**
Year 2010	**0.02*** **(.01)**	.02 (.01)	**0.02*** **(.01)**
Year 2020	-0.001 (.01)	-0.007 (.02)	-0.001 (.01)
Intercept	**1.64***** **(.34)**	**1.99***** **(.70)**	**1.64***** **(.34)**
Number of observations	55	55	55
Model significance	F (12, 42) = 4.04 p-value = 0.00	F(12,38) = 3.93 Prob > F = 0.00	Wald χ^2 (12) = 48.43 Prob > χ^2 = 0.00
Coefficient of determination	R^2 = 0.535 R^2_{adj} = 0.402	R^2_w = 0.553 R^2_b = 0.0093 R^2_o = 0.159	R^2_w = 0.527 R^2_b = 0.949 R^2_o = 0.535

Source: Authors' calculation

*Note: Standard errors are given in parentheses. Asterisks denote significance levels as follows: *** significance level of 1%, ** significance level of 5%, * significance level of 10%. R^2 represents the coefficient of determination, R^2adj the adjusted coefficient of determination, R^2w variations within groups over time, R^2b variations in averages between groups, and R^2o the total variability.*

Table 5 presents the results of evaluating environmental efficiency using three panel models. The REGLS model demonstrated a high level of statistical significance. The coefficient of determination within groups is 0.527, between groups is 0.949, and the overall coefficient of determination is 0.535. These results confirm the adequacy and reliability of the model in explaining the variability of environmental efficiency.

THE IMPACT OF FREIGHT TRANSPORT BY ROAD AND RAIL

Freight transport by road shows a positive and statistically significant effect on environmental efficiency in all three models (pooled OLS, FE, REGLS). This finding suggests that improving efficiency in road freight transport can significantly contribute to reducing emissions per unit of transported goods. Route optimization reduces fuel consumption and vehicle emissions, while using more modern vehicles with advanced engines and lower emissions, as well as better logistics, contributes to reducing the environmental footprint of road transport. Freight transport by rail also shows a positive and statistically significant effect in the pooled OLS and REGLS models. Rail transport is often more energy-efficient and produces fewer emissions per ton-kilometer compared to road transport. The higher energy efficiency of rail transport means that less energy is used per ton of transported goods, as trains can carry larger quantities of goods at once, reducing the number of trips needed and overall energy consumption. Rail transport tends to emit fewer harmful gases per unit of transported goods, especially when electric trains are used, which can be powered by renewable energy sources. Using rail transport reduces the pressure on road infrastructure and can alleviate traffic congestion, further decreasing emissions that occur during delays and congestion in road traffic.

THE IMPACT OF OTHER VARIABLES

The variable approximating a country's development, namely per capita income, has a positive and statistically significant effect on environmental efficiency. Higher per capita income often leads to greater investments in clean technologies, better environmental regulations, and increased awareness of environmental protection, which contribute to enhanced environmental efficiency. Industrial production, trade, and renewable energy sources negatively impact environmental efficiency. Industrial production is often associated with high levels of pollution and energy consumption, which reduce environmental efficiency. Trade can increase the environmental footprint due to the intensive energy and resource consumption related to the transportation of goods and services. The unexpected negative impact of renewable energy sources may result from high initial installation and integration costs, as well as potential technical challenges within the current energy mix. The dummy variable for the year 2010 is statistically significant and positively impacts environmental efficiency. This variable represents the economic crisis that began in 2007-2008 in the USA and subsequently spread to the CEFTA region during 2009 and 2010. During the crisis, the reduction in industrial activity and energy consumption may have temporarily improved environmental efficiency.

CONCLUSION

The analysis results show that freight transport by road and rail are key factors that positively impact environmental efficiency, highlighting the importance of efficient transport for improving environmental efficiency. Passenger transport by road and rail, as well as passenger and freight transport by air, are not statistically significant.
This study analyzed the environmental efficiency of the CEFTA 2006 signatories using DEA methodology and panel analysis for the period from 2010 to 2021. The data obtained using the DEA methodology were later applied as the dependent variable for environmental efficiency in the panel analysis. The DEA analysis results did not show significant differences in environmental efficiency among the countries, with Albania achieving the highest average environmental efficiency and Bosnia and Herzegovina having the lowest average value. The panel analysis results, conducted using fixed effects (FE) and random effects (REGLS) models, reveal key factors affecting environmental efficiency. In all models, road and rail freight transport have a positive impact on environmental efficiency, indicating that enhancing transport efficiency can reduce emissions per unit of transported goods. In contrast, passenger road, rail, and air transport have an insignificant influence. On the other hand, GDP per capita has a positive and statistically significant effect, which can be attributed to higher investments in clean technologies and better environmental regulations in more developed countries. Industrial production, trade, and renewable energy sources show a negative statistical impact on environmental efficiency. Industrial production is associated with high levels of pollution, while trade increases the environmental footprint due to the intensive energy consumption associated with transport. The negative impact of renewable energy sources may be due to high initial costs and technical challenges. The dummy variable for the year 2010, representing the economic crisis of 2007-2008, shows a positive impact on environmental efficiency, while the dummy variable for the year 2020, which represents the pandemic, is not statistically significant. The findings emphasize the crucial role of coordinated public policy aimed at improving eco-efficiency in this area.

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REZIME

Ova studija ima za cilj da pruži sveobuhvatnu analizu ekološke efikasnosti zemalja potpisnica sporazuma CEFTA 2006, kao i da identifikuje ključne determinante koje utiču na njen nivo u periodu od 2010. do 2021. godine. Istraživanje se zasniva na kombinaciji neparametarske i parametarske metodologije, čime se omogućava detaljno sagledavanje kako relativne efikasnosti pojedinačnih zemalja, tako i faktora koji tu efikasnost oblikuju u dinamičkom kontekstu. U prvom delu rada primenjena je Data Envelopment Analysis (DEA) metodologija radi procene ekološke efikasnosti zemalja kao jedinica donošenja odluka (DMU). Analiza se zasniva na balansiranom panel skupu podataka koji obuhvata ključne inpute, poput broja zaposlenih i potrošnje energenata, kao i poželjne i nepoželjne outpute, uključujući nivo proizvodnje i emisije zagađujućih gasova, konkretno ugljen-dioksida (CO_2) i sumpor-dioksida (SO_2). Primena DEA metodologije omogućava istovremeno razmatranje ekonomskih performansi i negativnih ekoloških eksternalija, čime se dobija realnija slika održivosti proizvodnih procesa. Rezultati DEA analize ukazuju na značajne razlike u nivou ekološke efikasnosti među posmatranim zemljama. Najviši prosečni nivoi ekološke efikasnosti zabeleženi su u Albaniji, Srbiji i Crnoj Gori, dok Bosna i Hercegovina ostvaruje najniže rezultate, što ukazuje na potrebu za dodatnim strukturnim i regulatornim reformama u oblasti zaštite životne sredine i energetske efikasnosti. Dobijeni indeksi ekološke efikasnosti zatim su korišćeni kao zavisna promenljiva u drugoj fazi istraživanja. U drugom delu rada primenjena je panel analiza kako bi se ispitali faktori koji utiču na ekološku efikasnost u posmatranim zemljama. Rezultati pokazuju da transport robe drumskim i železničkim saobraćajem ima statistički značajan i pozitivan uticaj na ekološku efikasnost, što može ukazivati na unapređenje logistike i racionalnije korišćenje transportnih kapaciteta. Nasuprot tome, transport putnika drumskim saobraćajem pokazuje negativan, ali statistički neznačajan efekat. Analiza dalje otkriva da rast dohotka po glavi stanovnika pozitivno utiče na ekološku efikasnost, što je u skladu sa pretpostavkama o većoj sposobnosti bogatijih ekonomija da ulažu u čistije tehnologije i ekološke standarde. Istovremeno, negativan uticaj trgovine, industrijske proizvodnje i obnovljivih izvora energije ukazuje na strukturne izazove i potencijalnu neefikasnost u njihovoj implementaciji i upravljanju. Poseban deo analize posvećen je uticaju kriznih perioda, modelovanih pomoću binarnih varijabli za 2010. i 2020. godinu. Rezultati sugerišu da je globalna ekonomska kriza iz 2009. godine imala pozitivan efekat na ekološku efikasnost, verovatno kao posledicu smanjenja industrijske aktivnosti i emisija zagađujućih materija. Zaključno, nalazi studije ukazuju na značaj efikasnog transportnog sistema, održivog ekonomskog rasta i pažljivo osmišljenih javnih politika u unapređenju ekološke efikasnosti zemalja CEFTA regiona. Rezultati mogu poslužiti kao relevantna osnova za kreatore politika u procesu usklađivanja ekonomskog razvoja sa ciljevima zaštite životne sredine i održivog razvoja.