

Chapter 6

Efficiency and Performance of Sustainable Development of the Western Balkan Countries: Whether Membership in the European Union is Recipe for Sustainability?



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Abstract To evaluate the impact of economic growth over time, the concept of sustainable development stresses the need to balance the three pillars of sustainability: economic, social, and environmental factors. This study compares the countries of the Western Balkans with former socialist countries now in the EU by analyzing their efficiency and overall performance in terms of sustainable development. The analysis focuses on data from 2019, just before the onset of the COVID-19 pandemic. The study utilized Data Envelopment Analysis (DEA) with a Slacks-Based Measure (SBM) model. The input variables in this model included carbon dioxide (CO₂) emissions, the unemployment rate, and energy consumption, while the output variables were Gross Domestic Product (GDP) and life expectancy at birth. The main finding of the study was the identification of the average efficiency scores, showing that EU member states typically had the highest scores and demonstrated the best practices, with Bulgaria and, to a lesser extent, Slovakia as notable exceptions, along with Albania. In contrast, most of the other countries in the Western Balkans were found to be inefficient in their sustainable development policies. Additionally, developing countries, on average, performed the worst across the variables analyzed. For a more detailed assessment of efficiency, the study also calculated the harmonized efficiency of the observed countries. This was done by dividing individual efficiency results by the average efficiency within the Western Balkan countries group and the

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EU member states group. Composite efficiency was also considered, which represents the weighted sum of DEA efficiency and inverse DEA efficiency. To determine the sustainable development performance of the countries, the simple additive weighting (SAW) method was used, applying the weighting coefficients derived from the CRITIC method. The results of this analysis were consistent with those obtained from the SBM DEA method. EU member states, except for Bulgaria and Slovakia, generally had the highest index values and were ranked the best in terms of sustainable development performance. On the other hand, the Western Balkan countries ranked significantly lower in comparison.

Keywords Sustainable development · Efficiency · Performance · SBM DEA · CRITIC · SAW · Ranking

6.1 Introduction

Achieving consensus regarding economic growth, environmental sustainability, and human well-being is considered one of the greatest challenges facing society today (Lira and Cândido 2008). As the global population continues to grow, the pressure on natural resources intensifies, and the complexities of maintaining a balance between economic development, environmental protection, and social equity become increasingly difficult. This tri-dimensional challenge underscores the need for a more holistic approach to development, one that not only focuses on economic prosperity but also ensures the preservation of our ecosystems and the improvement of social conditions for current and future generations. Sustainable development is a dynamic and evolving concept that requires a deep integration of economic growth, environmental sustainability, and social well-being. Achieving this balance is one of the most significant challenges facing humanity today, but it is also an opportunity to reimagine how societies function and how we measure success. By prioritizing ecological integrity, social equity, and long-term prosperity, sustainable development offers a path toward a more just and resilient world. Sustainability consists of three pillars: social, economic, and environmental (Camioto and Pulita 2022). These pillars form the “triple bottom line” (TBL), whose goal is to meet the resource needs of current and future generations without compromising the environment (Khan et al. 2021). That is, sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Numerous studies (Santana et al. 2014; Camioto et al. 2016; Frugoli et al. 2015; Verma and Raghubanshi 2018; Zhou et al. 2019, etc.) have addressed the question of whether the observed growth model, environmental sustainability, and quality of life of the population are relevant variables. The concept of sustainable development, as a logical and consistent continuation of utopian theories of social well-being, social justice, and harmonious management of the environment and economic growth, establishes the closest relationship between socioeconomic development and sustainable development in its deepest form (Mukherjee and Chakraborti

2013; Kurniawan and Managi 2017). As things stand, the current model of economic growth completely collides with sustainable development, considering the literal depletion of many natural resources and the drastic degradation of environmental quality (Jorgenson and Dietz 2015). In this context, the concept of sustainable development is extremely important in developing countries to curb the unsustainable trend and direction of development in which modern society is moving. Therefore, it is crucial to analyze how these countries are developing to assess their performance in terms of sustainability and the quality of life for their populations.

The aim of this study is to compare the transition economies of the countries of the Western Balkans—Albania, Bosnia and Herzegovina, Montenegro, Northern Macedonia and Serbia—with the countries that were once part of the former Eastern bloc and are now members of the EU, i.e., Croatia, Hungary, Bulgaria, the Czech Republic, Slovakia, Romania, Slovenia, and Poland. The key result and contribution of the research are a ranking of the average efficiency of sustainable development, along with the averages of the relative disadvantages of each variable, showing the position of each country in relation to every variable used. These results allow an assessment of how each country performs in different areas of sustainable development, providing relevant information on which areas countries should focus on. For this purpose, the Data Envelopment Analysis (DEA) method was used, a non-parametric method for determining the so-called efficiency limits, based on linear programming. The DEA method will estimate the efficiency frontiers for a group of observed countries by analyzing multiple data sets and simultaneously solving multiple linear programming models. In line with the defined research focus and goals, this paper addresses the following research question:

RQ1: How does the average efficiency of sustainable development in the Western Balkan economies compare to that of former socialist states and current EU members in 2019?

RQ2: What is the overall sustainable development performance of the observed countries in 2019?

RQ3: What is the relationship between efficiency and overall sustainable development performance in the observed countries in 2019?

The paper is divided into four parts. The first part provides an introduction to the context of the research objective. The second part is a literature review related to the application of the *DEA* method to the topic of sustainable development. The third part briefly introduces the methods used in the study: *Slacks-Based Measure (SBM) DEA*, *Criteria Importance through Intercriteria Correlation (CRITIC)* and *simple additive weighting (SAW)* method. The fourth part refers to the clarification and structuring of the appropriate *SBM DEA* model to evaluate the efficiency of sustainable development and includes results and discussion that focus on the presentation of the results obtained in the study and their analysis.

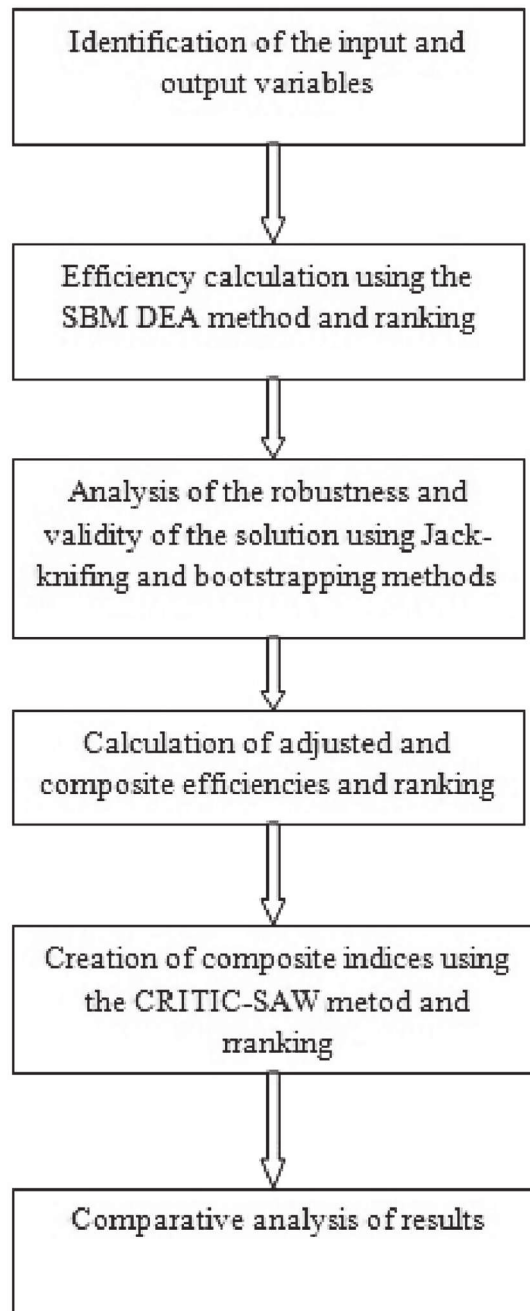
Finally, to measure the performance of sustainable development as a complex socioeconomic phenomenon, a composite measure was calculated using the method of simple additive weights, using the values obtained by the method *CRITIC* as weighting coefficients of the criteria, and the results and ranks were compared with

the results of the *DEA* model. Finally, there is a conclusion that concludes the study and shows how it can be used. Figure 6.1 shows all of the above.

6.2 Literature Review

The efficiency and effectiveness of sustainable development are frequently discussed in terms of observing, measuring, and analyzing the extent to which the Sustainable Development Goals (SDGs) are being achieved. These goals serve as a comprehensive framework for assessing global progress toward a more equitable, resilient, and environmentally sustainable future. The SDGs, consisting of 17 goals, were adopted by the United Nations in 2015 as part of the 2030 Agenda for Sustainable Development. This global initiative represents a call for international cooperation to eradicate poverty, safeguard the planet's ecosystems, and create the conditions for social well-being by 2030. These objectives encompass a wide range of issues, from economic development to environmental preservation and social equality. One of the key characteristics of the SDGs is their interconnected nature. Each goal is designed to support and enhance the others, recognizing that sustainable development cannot be achieved in isolation within one sector. For instance, efforts to combat climate change (Goal 13) are closely linked to the need for affordable and clean energy (Goal 7), which in turn impacts economic growth (Goal 8) and social inclusion (Goal 10). This interconnectedness highlights the complexity of measuring sustainable development as outcomes in one area inevitably influence others. As such, achieving balance across these domains is crucial, and the pursuit of progress in one goal must not come at the expense of another (Ganda and Ngwakwe 2014; Türkoglu and Kardogan 2017; Fankhauer and Jotzo 2018; Zakari et al. 2022), ecological and eco-industrial efficiency (Kurniati et al. 2010; Unruh and Ettenson 2010; Figge et al. 2014; Caiado et al. 2017; Zielinska-Chmielewska et al. 2021; Long 2021; Wang et al. 2019; Sharma et al. 2020; Khan et al. 2021; Zhou et al. 2021; Liu et al. 2022; Figge and Thorpe 2023), innovation efficiency (Nidumolu et al. 2009; Carfi and Schilirò 2012a, b; Cheng et al. 2014; Luqmani et al. 2017; Schiliro 2019; Krstic and Mimovic 2018, 2020; Krstić et al. 2021; Zhang et al. 2022), educational efficiency (Lupi et al. 2022; Alméstar et al. 2022; Casciati et al. 2022; Mylonas et al. 2023), land-use efficiency (Wei et al. 2023; Song et al. 2023; Wang et al. 2023), etc. When evaluating the efficiency and effectiveness of sustainable development, it is essential to adopt a multi-dimensional approach that considers the broad scope of the SDGs. These aspects are typically analyzed through a combination of quantitative and qualitative indicators that measure progress, identify challenges, and highlight areas for improvement. Energy efficiency, for example, plays a central role in assessing the effectiveness of environmental goals, particularly given its direct impact on reducing greenhouse gas emissions, enhancing resource use, and supporting sustainable production and consumption patterns. Indicators related to energy efficiency can help assess how well countries are meeting their climate targets while also contributing to economic growth

Fig. 6.1 Research framework of the work.
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and social well-being. Moreover, evaluating the efficiency of sustainable development involves looking beyond the achievement of individual goals to understand how they interact and contribute to overall sustainability. This involves considering trade-offs, synergies, and potential negative externalities that might arise when prioritizing certain goals over others. For example, while increasing industrial production may drive economic growth (Goal 8), it could also lead to greater environmental degradation if not paired with sustainable practices. Therefore, analyzing sustainable development performance requires a nuanced and integrated approach, ensuring that the strategies adopted are truly advancing long-term sustainability across all sectors. On the other hand, starting from the indicators of sustainable development, which are used to measure progress and achievements in various areas, and taking into account that these indicators integrate and balance three key dimensions of social development-economic, environmental, and social-a logical question arises as to whether it is possible to create a model that will adequately encompass all these dimensions in the process of measuring sustainable development performance. This question is important because sustainable development is not a one-dimensional concept, but rather encompasses a complex interaction between different aspects that must be balanced in order to achieve sustainability at the global level. Therefore, the need to find a model that will reflect all these aspects and measure them in the right way becomes crucial. In the literature dealing with this issue, a large number of studies focus on the selection and definition of appropriate indicators that will be useful for measuring sustainable development. These indicators should not only reflect the current state of affairs in each of the three dimensions, but also allow for the prediction of future trends, impacts and needs, which is necessary for planning and guiding policies that will contribute to long-term sustainability. The indicators must be selected in a way that will ensure that all critical areas of development are taken into account, from economic well-being, through environmental protection, to improving the quality of people's lives. Therefore, the process of structuring such a model requires the integration of different data and analyses that will be able to reflect the complexity and interdependence of these dimensions. This is a challenge, but at the same time a crucial step for the implementation of an effective system of assessment and monitoring of sustainable development (Santana et al. 2014; Rodriguez et al. 2018; Viglia et al. 2017; Biggeri and Mauro 2018; Mikayilov et al. 2018; Raza and Shah 2018; Cai et al. 2018; etc.). The number of indicators and their selection in the aforementioned studies varies depending on the objective and the chosen research method, and cannot be said to be predetermined. In this sense, the research results were not unambiguous and unconditionally generalized. A broader and good overview of studies in this context is provided by Camioto and Pulita (2022).

The DEA method has often been used in development performance analyses. A good overview of applications in this sense is given by Tsaples and Papathanasiou (2021) and Zhou et al. (2018). We will list some of them in order to illustrate the way and framework of using the DEA method and its extensions: Zhang et al. (2008) conducted an eco-efficiency analysis for regional industrial systems in China by developing Data Envelopment Analysis-based models. The results show that, provinces with higher level GDP per capita will have higher eco-efficiency

relatively; Tian et al. (2019), use the SBM DEA model to measure the sustainable efficiency of regional transport through a system of indicators that includes systemic, economic, social and environmental indicators and obtain quite realistic results; Lee et al. use a two-stage DEA model to evaluate the efficiency of industrial waste recycling treatment, and indicate three efficient recycling models; Wang et al. (2018) on the example of the Chinese thermal power industry proposed a DEA in the evaluation of the effectiveness of reducing the emission of harmful gases; Zhou et al. (2021) used the SBM DEA model, Malmquist index model of productivity, and Tobit regression model to measure and evaluate the industrial eco-efficiency. The results show that it is positively correlated with industrial development level, scientific and technological innovations, industrial structure, and environmental planning, whereas negatively correlated with the degree of opening up and industrial agglomeration; Long (2021) evaluated the eco-efficiency of 35 major Chinese cities from 2011 to 2015 using a Slacks-Based Measured DEA model. The findings reveal that the overall efficiency of these cities during the observed period is relatively low, with improvements in total-factor ecological productivity largely driven by technological advancements; Zurano-Cervelló et al. (2019) combined life cycle assessment, Data Envelopment Analysis, and advanced mathematical programming to compare and optimize electricity mixes based on sustainability criteria, applied to the 28 EU member states. The findings suggest that EU energy policies should focus on expanding hydropower, wind, and solar energy while gradually eliminating non-renewable sources and bioenergy; Toma et al. (2017) assessed the agricultural efficiency of EU countries using a bootstrap-DEA approach. The study concludes that policy planning and management decisions should not only focus on maximizing agricultural output but also on preventing the overexploitation of environmental resources. Mimović et al. (2019) applied DEA to assess the relative efficiency of research and development in nine Southern European countries from 2007 to 2016. Their findings suggest that being a member of the European Union is not always a requirement for the efficient utilization of research and development resources and capacities at the national level; Krstić et al. (2022a) used a combined approach of DEA Window analysis and the Malmquist productivity index to measure the macroeconomic efficiency of Balkan countries from 2006 to 2018, using macroeconomic indicators as model variables. The results showed that during the observed period, Albania and, to a larger extent, Montenegro had the highest average efficiency, effectively using available resources to achieve GDP growth. On the other hand, EU member states, particularly Greece and Croatia, saw the highest overall productivity growth, which was largely attributed to improvements in technical efficiency.

6.3 Methodology

Data Envelopment Analysis (DEA) is a method used to assess the relative efficiency of decision-making units (DMUs) by calculating the ratio of the weighted sum of outputs to the weighted sum of inputs required to produce them (Mello and Gomes

2004). In the DEA method, efficiency values always range between 0 and 1, with a DMU considered efficient if its value reaches a reference limit, which is set at 1 to represent full efficiency (Charnes and Cooper 1985). The Charnes, Cooper, and Rhodes DEA model (CCR) estimates the efficiency of a DMU_k by calculating the maximum value of the ratio between the weighted sum of output variables and the weighted sum of input variables. The weights reflect the relative importance of the input and output variables, and their optimal values are determined a posteriori, to ensure that the system of constraints is satisfied and that the objective function reaches its extreme value. The model applied in this paper is the *Slacks-Based Measured* (SBM) variant, which, as described by Tone (2001), seeks to minimize inputs while maximizing outputs simultaneously. This implies that reducing inputs does not necessarily lead to a decrease in outputs.

6.3.1 Slacks-Based Measure (SBM) DEA

Assume that there are n decision units, denoted as DMUs. Let DMU _{j} ($j = 1, 2, \dots, n$) consume m_1 variable input x_{i1j} ($i = 1, 2, \dots, m_1$) and m_2 fixed input x_{i2j} ($i = 1, 2, \dots, m_2$), to produce k_1 variable output y_{r1j} ($r_1 = 1, 2, \dots, k_1$) and k_2 fixed output y_{r2j} ($r_2 = 1, 2, \dots, k_2$). Then, according to Tone (2001), we can evaluate the performance of the observed DMU _{j} through the following SBM DEA model:

$$\min \theta = \frac{1 - \frac{1}{m_1} \sum_{i_1=1}^{m_1} \frac{s_{i_1}^-}{x_{i_1d}}}{1 + \frac{1}{k_1} \sum_{r_1=1}^{k_1} \frac{s_{r_1}^+}{y_{r_1d}}}. \quad (6.1)$$

Under restrictions:

$$\sum_{j=1}^n x_{i1j} \lambda_j + s_{i_1}^- = x_{i_1d}, \quad i_1 = 1, \dots, m_1, \quad (6.2)$$

$$\sum_{j=1}^n x_{i2j} \lambda_j = x_{i_2d}, \quad i_2 = 1, \dots, m_2 \quad (6.3)$$

$$\sum_{j=1}^n y_{r1j} \lambda_j - s_{r_1}^+ = y_{r_1d}, \quad r_1 = 1, \dots, k_1 \quad (6.4)$$

$$\sum_{j=1}^n y_{r2j} \lambda_j = y_{r_2d}, \quad r = 1, \dots, k_2 \quad (6.5)$$

$$x_{i_1d} - s_{i_1}^- \geq L_{i_1} x_{i_1d}, \quad \forall i_1, \quad (6.6)$$

$$y_{r_1d} + s_{r_1}^+ \leq U_{r_1} y_{r_1d}, \forall r_1, \quad (6.7)$$

$$\lambda_j \geq 0, \forall j.$$

The optimal solution of model (6.1) is denoted as $(\theta^*, \lambda_j^*, s_{i_1}^{+*}, s_{r_1}^{+*})$. Based on this solution, the performance of DMU_d can be improved by $x'_{i_{jd}} = x_{i_{jd}} - s_{i_1}^{+*}$ and $y'_{r_{jd}} = y_{r_{jd}} + s_{r_1}^{+*}$, wherein θ^* the efficiency of the d_{th} decision-making unit, λ_j^* contribution of the reference efficient decision-making unit in achieving the goal of the analyzed decision-making unit, and $(x'_{i_{jd}}, \forall i_1)$ and $(y'_{r_{jd}}, \forall r_1)$ optimally improved input and output variables, respectively. Constraints 2.5 and 2.6 limit the improved values of the variables within the corresponding range and affect the optimal solution. The model used seeks to minimize inputs while simultaneously maximizing outputs. This implies that reducing inputs does not necessarily result in a reduction of outputs.

6.3.2 CRITIC Method

The *CRITIC* method is a weighting approach used to determine objective weights for criteria in multi-criteria decision-making problems. Developed by Diakoulaki et al. (1995), this method takes into account contrast intensity and conflict within the decision problem's structure. *CRITIC* employs correlation analysis to identify contrasts between criteria (Yilmaz and Harmancıoğlu 2010). In this approach, the decision matrix is assessed, and the standard deviation of the normalized values for each criterion, along with the correlation coefficients between all pairs of criteria, is used to determine the contrast of each criterion, C_j . The method assigns greater weight to criteria that have a high standard deviation and low correlation with other criteria. Essentially, a higher value of C_j indicates that more information is derived from that criterion, making it more important for the decision problem.

6.3.3 Simple Additive Weighting

Simple additive weighting (SAW) is a method used in multi-attribute decision-making to select the most favorable alternative. The main idea behind the SAW method is to calculate the maximum sum of the weighted performance scores for each alternative across all attributes (Khairul and Siapun 2016). This method typically involves linearly normalizing the decision matrix, and the weight coefficients can be determined either through subjective or objective methods.

6.4 Structuring the Model and Results

In this study, the DEA method will be applied to analyze the efficiency of the observed countries in implementing sustainable development policies, focusing on achieving an optimal balance between economic growth, social well-being, and minimizing the negative environmental impact. The variables used in this research were selected for this purpose, particularly because they align with the three pillars of sustainable development, as indicated in the relevant studies, and due to the availability of data for all countries. The analysis covers the year 2019, which was just before the COVID-19 pandemic and the conflict in Ukraine, events that significantly impacted economic trends and, by extension, other areas of life such as energy consumption and employment. The assumptions underlying the DEA model are as follows: (1) The analysis covers the year 2019; (2) the input variables include: CO₂ emissions (in millions of tons per capita), energy consumption (in kilograms of oil equivalent per 1000 Euros of GDP), and unemployment rate (%). The output variables are: GDP growth rate (%), which is the most commonly used indicator of a country's overall economic activity, and life expectancy at birth (Table 6.1). Data for the selected input and output indicators were collected from the *World Bank data* and EUROSTAT databases.

In line with the principles of the SBM DEA method, the goal of our model is to reduce CO₂ emissions, unemployment rate, and energy consumption, while aiming to increase GDP and life expectancy at birth. DEA Solver was utilized to conduct this analysis (Table 6.2).

The results obtained by applying the SBM DEA model (efficiency of DMU_s and slacks of the variables), are shown in Table 6.5. It has been shown that the member countries of the European Union (Croatia, Hungary, Romania, Slovenia, and the Czech Republic) are efficient in terms of sustainable development and ranked first, with the exception of Bulgaria and Slovakia, which are 69% and 79% of the reference efficiency, respectively. The surprise is Albania, which also ranks at the level of best practice in terms of efficiency and is ranked first. Along with Poland, it is one of the only countries with efficiency above the average for the entire EU sample (0.92). For a more complete and comprehensive assessment of efficiency, the harmonized efficiency of the observed countries was calculated, by comparing the individual efficiency values of each country with the average efficiency within two different groups: the Western Balkans (0.64) and the EU Member States (0.92). This approach allows for a deeper understanding of how countries perform relative to each other within these regional categories. In addition, to explore the impact of external factors on the efficiency of sustainable development, an adjusted efficiency score was calculated. This adjustment was made by taking the ratio of each country's efficiency score to the average efficiency score of the corresponding groups (Western Balkans at 0.64 and EU Member States at 0.92). As illustrated in Table 6.11, after this adjustment, the efficiency of EU member states, with their efficiency measure value of 1, showed little or no change, highlighting that their performance was already close to the average for their group. In contrast, the efficiency scores for non-EU countries, especially in the Western Balkans, experienced a significant increase, with Albania

Table 6.1 Input and output variable for DEA

	Variable	Explanation	Source of data
Input variables	CO ₂ emissions	The carbon dioxide produced during the consumption of solid, liquid, and gaseous fuels, as well as the combustion of gas	https://data.worldbank.org/
	Energy consumption	The use of primary energy before it is converted into other fuels for final consumption	https://data.worldbank.org/ https://ec.europa.eu/eurostat
	Unemployment rate	The portion of the labor force that is unemployed but available to seek work	https://data.worldbank.org/
Output variables	GDP %	The sum of the gross value added of all resident producers in the economy, increased by taxes on products and decreased by all subsidies not included in the value of the product	https://data.worldbank.org/
	Life expectancy	Years of life if there were a trend of current mortality patterns throughout life	https://ec.europa.eu/eurostat

Source Authors

Table 6.2 Statistics on input/output data

Variable	CO ₂ emissions	Energy consumption	Unemployment rate	GDP %	Life expectancy
Max	9	458	17.3	4.9	82
Min	1.7	169.6	2	2.1	75
Average	5.3846	280	7.9692	3.6	77.538
S.D.	1.8425	98.624	5.1474	0.7805	1.7371

Source Authors

recording the most significant improvement its efficiency score rising from 1 to 1.56. This adjustment process revealed that the top-ranking countries generally showed both strong operational efficiency and high relative efficiency, especially those that are part of the EU, indicating a correlation between EU membership and better performance in sustainable development. On the other hand, some EU member states, such as Bulgaria and Slovakia, were inefficient, showing low operational efficiency and weak relative efficiency. This suggests that EU membership does not necessarily

guarantee optimal performance in terms of sustainable development. Interestingly, Albania, a non-EU country, emerged as an exception to the pattern. Despite not being an EU member, Albania showed a relatively high efficiency score, especially compared to its Western Balkan counterparts. This anomaly highlights the complexity of efficiency dynamics and suggests that factors outside EU membership, such as the quality of governance or strategic national policies, can significantly influence a country's efficiency in sustainable development. This adjusted efficiency analysis not only highlights the different levels of performance between countries within these two groups, but also highlights the importance of considering both operational and relative efficiency when assessing sustainable development outcomes. The results suggest that regional context, as well as external factors, plays a key role in shaping countries' efficiency in the domain of sustainable development. Moreover, looking at Albania's performance challenges the assumption that EU membership is a definitive factor in achieving high efficiency, pointing to the need for a more nuanced understanding of what drives success in sustainable development in different regions. Changes on the side of the output variables are limited to the GDP growth rate, namely in Bosnia and Herzegovina where in 2019 a growth rate of 3.95% was necessary, instead of the achieved 2.8%, and in Slovakia, 4% instead of the achieved 2.5%. At the same time, in Bosnia and Herzegovina it was necessary to reduce CO₂ emissions by 38.89%, energy consumption by 54.56%, and unemployment by 74.8%, in order for sustainable development to be at the level of the best practices of efficient countries. Slovakia needed to reduce CO₂ emissions by 31.57%, energy consumption by 0.187% and unemployment by 30.9% in order to achieve effective sustainable development in 2019, while, for example, Serbia had to emit 36.97% less carbon dioxide, to reduce energy consumption by 52.50% and unemployment from 10.4 to 3.7%, which is a reduction of 64.4%, so that in 2019 the efficiency of its sustainable development would be at the level of best practice. In the other observed countries, the necessary changes were exclusively on the side of input variables. On average, at the level of the entire group of observed countries, it was necessary to reduce CO₂ emissions by 13.75%, energy consumption by 17.33%, unemployment by 25.44% and at the same time increase the average GDP growth rate from 3.53 to 3.8%, so that the efficiency of sustainable development would be equal1. It is clear that, to the greatest extent, the necessary changes in input variables were limited to non-EU countries, along with Bulgaria and Slovakia (Table 6.3). Average values original and optimal value of input and output variables are shown in Table 6.4.

It is interesting that the comparative analysis of the efficiency of sustainable development in 2019 and 2021 showed that the deviations in the values and ranking of countries are insignificant (Fig. 6.2). In doing so, it was assumed that life expectancy in a short period remained at the level of 2019, while some values of the selected variables, primarily the countries of the Western Balkans, for which data in 2021 are not available, were corrected for the average change at the global level compared to the previous year. For example, it is known that the average level of energy consumption growth in 2021 at the global level was higher by about 5% compared to 2020, in which the level was lower by about 4% compared to 2019. With the conditional acceptance of the aforementioned assumptions, the analysis showed that in 2021, the EU

Table 6.3 Original and optimal value of input and output variables

	CO ₂ emissions			Energy consumption			Unemployment rate			GDP %			Life expectancy		
DMU	Data	Project	Diff%	Data	Project	Diff %	Data	Project	Diff%	Data	Project	Diff%	Data	Project	Diff %
Albania	1.7	1.7	0	224.6	224.6	0	11.5	11.5	0	2.1	2.1	0	79	79	0
Bosnia and H	6.3	3.85	−38.88	458	208.1	−54.56	15.7	3.95	−74.8	2.8	3.95	41.1	77	77	0
Bulgaria	5.6	3.88	−30.60	424.4	206.4	−51.35	4.2	3.77	−10.1	4	4	0	75	75	0
Croatia	4.1	4.1	0	185.9	185.9	0	6.6	6.6	0	3.4	3.4	0	78	78	0
Hungary	4.7	4.7	0	230.1	230.1	0	3.4	3.4	0	4.9	4.9	0	76	76	0
Montenegro	4.2	3.98	−5.1	281.5	211.7	−24.76	15.1	3.87	−74.3	4.1	4.1	0	77	77	0
Romania	3.8	3.8	0	205.4	205.4	0	3.9	3.9	0	3.9	3.9	0	76	76	0
N.Mac	4	3.79	−5.2	334	208.3	−37.60	17.3	4.14	−76.0	3.9	3.9	0	77	77	0
Slovenia	6.5	6.5	0	169.6	169.6	0	4.4	4.4	0	3.5	3.5	0	82	82	0
Serbia	6.6	4.16	−36.97	453.3	215.2	−52.50	10.4	3.7	−64.4	4.3	4.3	0	76	76	0
Czech	9	9	0	238.5	238.5	0	2	2	0	3	3	0	79	79	0
Slovakia	5.7	3.9	−31.6	211.2	210.8	−0.187	5.8	4.00	−30.9	2.5	4.0	60.1	78	78	0
Poland	7.8	5.42	−30.39	231.6	230.5	−0.439	3.3	3.3	0	4.4	4.4	0	78	78	0

Source Authors

Table 6.4 Average values original and optimal value of input and output variables

	CO ₂ emissions			Energy consumption			Unemployment rate			GDP %			Life expectancy		
	Data	Project	Diff%	Data	Project	Diff %	Data	Project	Diff%	Data	Project	Diff%	Data	Project	Diff%
Aver.	5.38	4.5	−13.75	280.6	211.1	−17.03	7.96	4.50	−25.44	3.6	3.8	7.78	77.5	77.5	0
Max	9	9	0	458	238.5	0	17.3	11.5	0	4.9	4.9	60.1	82	82	0
Min	1.7	1.7	−38.88	169.6	169.6	−54.56	2	2	−76.03	2.1	2.1	0	75	75	0
St dev	1.91	1.7	16.66	102.6	18.5	23.50	5.35	2.32	33.79	0.8	0.6	19.4	1.80	1.80	0

Source Authors

Table 6.5 Efficiency and slack variables

			Slack	Slack	Slack	Slack	Slack
DMU	Eff	Rank	CO ₂ emissions	Energy consumption	Unemployment rate	GDP %	Life expectancy
Albania	1	1	0	0	0	0	0
Bosnia and H	0.439	13	2.45	249.897	11.749	1.151	0
Bulgaria	0.692	9	1.714	217.965	0.427	0	0
Croatia	1	1	0	0	0	0	0
Hungary	1	1	0	0	0	0	0
Montenegro	0.652	10	0.216	69.725	11.223	0	0
Romania	1	1	0	0	0	0	0
N.Mac	0.603	11	0.209	125.606	13.153	0	0
Slovenia	1	1	0	0	0	0	0
Serbia	0.487	12	2.44	238.02	6.7	0	0
Czech	1	1	0	0	0	0	0
Slovakia	0.790	8	1.8	0.395	1.797	1.503	0
Poland	0.897	7	2.371	1.017	0	0	0

Source Authors

member states were at the level of the efficiency limit in terms of sustainable development and, with the exception of the Slovak Republic, maintained their rank, while the countries of the Western Balkans were more or less also at their level of efficiency immediately before the corona virus pandemic. Albania also showed the resilience of its economy, and thanks to the relatively proportional, mutually balancing changes in the values of the selected variables, in the period 2019–2021, it remained at the level of the efficiency limit, maintaining a high rank of 1. It should also be noted that the overall average efficiency is at the level of the observed group, in 2021 amounted to 87.6% of reference efficiency, which is above 81.2% in 2019, which confirms the thesis about the sustainability of the observed economies despite the initial shock caused by the corona virus pandemic. However, it seems that according to the available data on the movement of the values of the selected variables in 2022, it seems that the situation was not rosy (Tables 6.5 and 6.6).

Analysis of the Robustness and Validity of the Solution

The reliability and robustness of the position of the best-performing units can be tested in several ways. One of them is *Jack-knifing* analysis. In this analysis, one efficient DMU is alternately eliminated from the set of DMUs in order to establish a possible difference in efficiencies (Charles et al. 2012). From the results obtained by applying *Jack-knifing* analysis, by alternating elimination of efficient DMUs, it can be concluded that there are no significant changes in the position of efficient DMUs, and that they remain effective despite the mentioned changes in the set

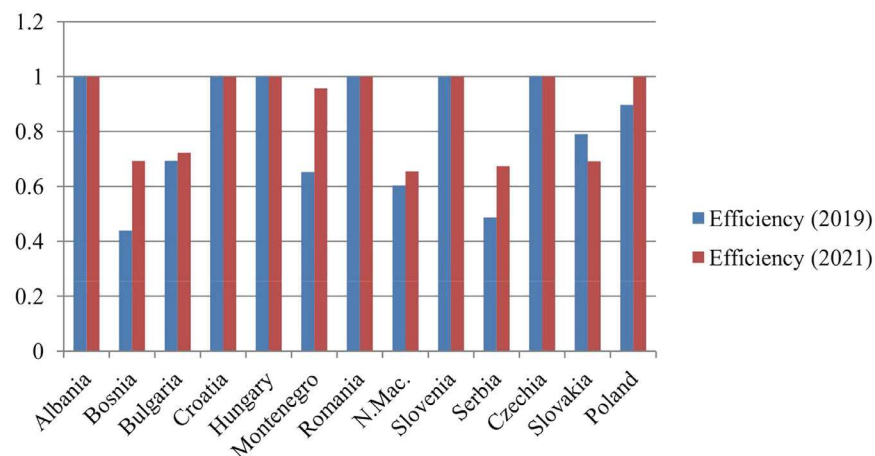


Fig. 6.2 Comparative presentation of efficiency of sustainable development of the observed countries in 2019 and 2021. *Source* Authors

Table 6.6 Average values of slack variables

	Score	Rank	CO ₂ emissions	Energy consumption	Unemployment rate	GDP %	Life expectancy
Average	0.8126	5.8462	0.8615	69.4327	3.4653	0.2042	0
Max	1	13	2.45	249.897	13.153	1.503	0
Min	0.4391	1	0	0	0	0	0
St Dev	0.2136	4.9134	1.0877	101.89	5.2376	0.5035	0

Source Authors

of DMUs, which confirms the robustness of the original results obtained. One of the challenges associated with DEA is that the efficiency estimates obtained can be sensitive to the sample size and the specific data points used. This sensitivity can lead to biased estimates, especially in cases where the sample is small or not fully representative of the wider population. Biases in DEA efficiency results can arise from various factors, such as the influence of outliers, data dimensionality, and measurement errors, which can distort the true efficiency levels of the DMUs being estimated. To address these issues and improve the accuracy of efficiency estimates, the Bootstrap method can be used, which involves resampling the original data with replacement to generate multiple new samples (called “bootstrap samples”) that mimic the characteristics of the original data set. This process allows for the creation of a sampling distribution for the DEA efficiency results, which can then be used to assess the variability and bias of the original estimates. These adjusted estimates take into account sampling variability and provide a more robust estimate of the performance of the DMU. In addition to reducing bias, the bootstrap method also improves the interpretability of the DEA results. Although DEA can provide point

estimates of efficiency, these estimates alone may not convey the full uncertainty associated with the evaluation. The bootstrap approach allows for the calculation of confidence intervals, which provide a range of possible values for efficiency rather than a single point estimate. This additional layer of information allows decision makers to assess the reliability of the DEA results and make better-informed decisions based on the degree of uncertainty inherent in the data (Krstić et al. 2021, 2022b; Rejman-Petrović et al. 2022; Jakšić et al. 2023, etc.).

The bias value is calculated as the difference between the bootstrap value and the calculated parameter value, i.e.,

$$\text{Bias}(\theta_k) = E(\theta_k) - \theta_k,$$

where $E(\theta_k)$ represents the bootstrap value of the parameter, in this case, the average efficiency, and θ_k is the measured average efficiency. The model efficiency, corrected for bias estimation, is calculated as the difference¹:

$$\theta_k^{\text{corr}} = 2 \times \theta_k - E(\theta_k).$$

For $n = 1000$ pseudo samples, with a confidence level of 0.05 the corrected average efficiency was calculated:

$$\theta_k^{\text{corr}} = 2 \times 0.8126 - 0.796 = 0.829$$

which is slightly higher than the calculated average DEA efficiency, which also confirms the validity and accuracy of the obtained DEA results.

Composite Efficiency and Overall Performance of Sustainable Development

To allow for greater discrimination in terms of efficiency across countries or decision-making units (DMUs), the so-called inverse efficiency frontier method is often used (Entani et al. 2002; Angulo-Meza et al. 2005; Soares de Mello et al. 2008; Camiato and Pulita 2022). This method provides a more nuanced and detailed analysis of efficiency by addressing one of the inherent limitations of traditional DEA models, which tend to group DMUs with different levels of inefficiency into a single efficiency frontier. While conventional DEA focuses on constructing a frontier based on the best-performing units, the inverse efficiency frontier method seeks to identify inefficiency by constructing a frontier composed of the units that exhibit the worst management practices, often referred to as the inefficiency frontier. Essentially, the inverse efficiency frontier method works by reversing the standard DEA approach. Instead of focusing primarily on the best-performing units to establish efficiency measures, it identifies those units with the least efficient management practices. These inefficient units are used to construct a frontier that represents the worst-case performance scenario. The inefficiency frontier provides a reference point that allows for a clearer distinction between more efficient and less efficient units within the sample. In

¹ Song et al. (2013, p. 52).

addition, the inverse efficiency frontier method is particularly useful when the focus is on identifying “best practice” inefficiencies, which can inform policy decisions and guide improvements in management strategies. By analyzing the inefficiency frontier, policymakers and practitioners can identify key factors contributing to poor performance and target areas for intervention. This allows for more focused and effective strategies aimed at reducing inefficiencies and improving overall performance in specific sectors or countries. The inverse efficiency frontier method is also useful for distinguishing between countries or organizations that, while performing adequately, may still be far from optimal in terms of resource allocation, production processes, or management practices. This helps to uncover inefficiencies that might otherwise remain hidden when more traditional methods are used, leading to more accurate estimates of performance across a range of dimensions. To calculate the inefficiency limit, the inputs are replaced with the outputs of the original DEA model, and the inverse efficiency values are shown in Table 6.7.

With the results of the inverse limit, a composite index (*CI*) was calculated, as:

$$CI = \alpha \times \text{Eff} + (1 - \alpha) \times (1 - \text{InvEff}),$$

where α is the confidence index, whereby for different values of α , different values of the composite index of efficiency can be obtained. So, for the values $\alpha = (0.3, 0.5, \text{ and } 0.7)$, respectively, the value of the composite index is shown in Table 6.8.

For $\alpha = 0.5$, the average value of the composite index of all observed countries is 0.47, while the average *CI* value of the countries of the Western Balkans and EU members is 0.35 and 0.55, respectively. As expected, the EU member states have the highest *CI* value, with the exception of Slovakia and Bulgaria, whose *CI* values are

Table 6.7 Inverse efficiency

DMU	Score	Rank
Albania	0.845	5
Bosnia and Herzegovina	1	1
Bulgaria	0.8	7
Croatia	0.528	11
Hungary	0.509	12
Montenegro	0.809	6
Romania	0.465	13
North Macedonia	1	1
Slovenia	0.705	10
Serbia	1	1
Czech	1	1
Slovakia	0.789	8
Poland	0.758	9

Source Authors

Table 6.8 Composite efficiency of observed countries

DMU	CI^a	CI^b	CI^c
Albania	0.409	0.578	0.747
Bosnia and Herzegovina	0.130	0.220	0.307
Bulgaria	0.348	0.445	0.544
Croatia	0.630	0.736	0.842
Hungary	0.640	0.746	0.847
Montenegro	0.329	0.421	0.513
Romania	0.670	0.500	0.860
North Macedonia	0.181	0.300	0.422
Slovenia	0.794	0.650	0.788
Serbia	0.146	0.244	0.341
Czech Republic	0.300	0.500	0.700
Slovak Republic	0.385	0.246	0.616
Poland	0.438	0.570	0.700

Note ^a $-(\alpha = 0.3)$; ^b $-(\alpha = 0.5)$; ^c $-(\alpha = 0.7)$

Source Authors

below the average not only for the group of EU member states, but also below the average of all countries. Also, with the countries of the Western Balkans, there are no unexpected results, except for Albania, whose CI value is even above the average at the level of the observed EU member states (Table 6.9).

The overall performance (OP) of sustainable development in the observed countries was determined using the simple additive weighting method, with the weights for the criteria derived from the *CRITIC* method. When assigning weights to the criteria, both the standard deviation and the correlation between the criteria are taken into account. In this context, the weight of the j th criterion (w_j) is calculated as follows:

$$w_j = \frac{C_j}{\sum_{j=1}^n C_j}, \quad (6.8)$$

Table 6.9 Weight coefficients of sustainable development factors calculated using the *CRITIC* method

Variable	w_j
CO ₂ emissions	0.190
Energy consumption	0.182
Unemployment rate	0.213
GDP	0.238
Life expectancy	0.176

Source Authors

where C_j is the amount of information contained in the j th criterion and is calculated as:

$$C_j = \sigma_j \sum_{j'}^n (1 - r_{jj'}), \quad (6.9)$$

where σ_j is the standard deviation of the j th criterion and $r_{jj'}$ is the correlation coefficient between the two criteria, the normalized decision matrix. The decision matrix is normalized using the following equation:

$$x_{ij}^* = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \quad i = 1, 2, \dots, m; \quad j = 1, 2, \dots, n \quad (6.10)$$

for the benefit criteria, and

$$x_{ij}^* = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})} \quad i = 1, 2, \dots, m; \quad j = 1, 2, \dots, n \quad (6.11)$$

for the non-benefit criteria,

wherein x_{ij}^* is the normalized value of the performance of the alternative i on the criterion j , and x_{ij} is the value of the performance of the alternative i on the criterion j , where it should be noted that the normalization does not take into account the type of criterion.

The weight coefficients of the selected variables, calculated using the CRITIC method, are shown in Table 6.9.

In that case, the sustainable development performance of the observed countries, using the *CRITIC-SAW* method, is calculated as follows:

$$I_i^* = \sum_{j=1}^5 x_{ij} w_j \quad i = 1, \dots, 13,$$

where

I_i^* is the sustainable development index, x_{ij} is the realized and normalized value of the i th country according to the j th dimension of sustainable development expressed through the corresponding variable, and w_j is the weighting coefficient of the j variable calculated using the CRITIC method. The values of the overall performance of sustainable development are shown in Table 6.11. It can be seen that the best performance, as expected, is achieved by the member states of the European Union, Slovenia (0.722), Hungary (0.712), Romania (0.659), Poland (0.638), Croatia (0.634), and Czech Republic (0.528). Those same countries, with slight deviations in the ranking, also have the highest efficiency in terms of sustainable development. It is also striking that Bulgaria, as a member of the EU, ranks quite poorly according to the realized values of the index of efficiency and performance of

sustainable development, in ninth and tenth places, while Slovakia is in eighth place according to all observed parameters. As expected, the countries of the Western Balkans are ranked significantly worse according to the achieved composite indicators of sustainable development, with the exception of Albania, whose efficiency of sustainable development is equal to the best practice (1), while according to the sustainable development index, it is in a high seventh place. Albania's high position can be explained by relatively low values of input variables and relatively high values of output variables of sustainable development (Table 6.10). Mann–Whitney U-test of statistical significance of the difference between the SBM DEA efficiency values and the matched efficiency values shows that the z -score is -2.0708 and the p -value is 0.03837 , which means that the result is significant at $p < 0.05$, that is H_0 (there is difference) is rejected. A similar conclusion (the z -score is 3.1992 and the p -value is 0.001378) is also valid in the case of testing the statistical significance of the differences in SBM DEA efficiency and composite efficiency, which indicates a high influence of the observed countries' membership in the European Union on their efficiency in terms of sustainable development. On the other hand, correlation analysis (H_0 5%) shows a high degree of correlation between the performance of sustainable development and the sustainable development of the observed countries in terms of efficiency, except with adjusted efficiency (Table 6.11).

Table 6.10 Comparative overview of efficiency, composite efficiency, and sustainable development performance of observed countries (2019)

DMU	Efficiency	Rank	Adjusted efficiency	Rank	CI ($\alpha = 0.5$)	Rank	Sustainable Development Index	Rank
Albania	1	1	1.56	1	0.578	4↓	0.518	7↓
Bosnia and Herzegovina	0.439	13	0.69	13	0.220	13	0.176	13
Bulgaria	0.693	9	0.75	12↓	0.445	8↑	0.452	10↓
Croatia	1	1	1.09	2↓	0.736	2	0.634	5↓
Hungary	1	1	1.09	2↓	0.746	1↑	0.712	2↓
Montenegro	0.653	10	1.02	7↑	0.421	9↓	0.487	9
Romania	1	1	1.09	2↓	0.500	6↓	0.659	3↑
North Macedonia	0.604	11	0.94	9↑	0.300	10↓	0.411	11↓
Slovenia	1	1	1.09	2↓	0.650	3↓	0.722	1↑
Serbia	0.487	12	0.76	11↑	0.244	12↓	0.392	12
Czech Republic	1	1	1.09	2↓	0.500	6↓	0.528	6
Slovak Republic	0.791	8	0.86	10↓	0.246	11↓	0.512	8↑
Poland	0.897	7	0.98	8↓	0.570	5↑	0.638	4↑

Source Authors

Table 6.11 Means, standard deviations, and correlation coefficients of sustainable development performance and sustainable development efficiency (2019)

	Mean	S.D	1	2	3	4
SBM DEA efficiency	0.8126	0.2135	–	0.743	0.829	0.868
Adjusted efficiency	1.0008	0.2225		–	0.628	0.577
Composite efficiency	0.4735	0.1822			–	0.880
Sustainable Development Performance	0.5262	0.1516				–

Note $p < 0.05$

Source Authors

6.5 Conclusion

The necessity to align social development policymakers with the three pillars of sustainability (economic, social, and environmental) arises from the goal of achieving economic growth without causing environmental harm and ensuring an optimal level of well-being for the population. A particular challenge for underdeveloped and developing countries is to achieve these goals simultaneously. Therefore, the main objective of the work was to compare, within the framework of sustainable development, the more developed countries, the former members of the so-called Eastern Bloc, and current members of the EU, with the countries of the Western Balkans, in order to identify and analyze the comparative advantages of membership in the EU for sustainable development policies. Analyzing the achieved efficiency of sustainable development in 2019, it can be noted that the top five countries (Croatia, Hungary, Romania, Slovenia, and the Czech Republic) are part of the European Union both in terms of efficiency and composite efficiency, as well as in terms of sustainable development performance. However, it can also be noted that the remaining two EU members, Bulgaria and Slovakia, are ineffective in both directions studied, which shows that these countries need to improve their practices by investing more in sustainable development policies. On the other hand, among the Western Balkan countries that are not members of the EU, Albania stands out, having effectively implemented sustainability policies in 2019 in the context of the analyzed variables, with a relatively good sustainable development performance, while among the remaining countries, Serbia is an unpleasant surprise, occupying a convincing penultimate place according to all observed parameters. In the partial analysis of the achieved values of the variables in 2019, one can see the good results of the EU member states, with the exception of Bulgaria, and the poor results of the countries of the Western Balkans, with the exception of Albania. As for CO₂ emissions, the highest CO₂ emissions in 2019 were achieved by the Czech Republic and the lowest by Albania. Bosnia and Herzegovina had the highest energy consumption in 2019, while Slovenia had the lowest. Northern Macedonia had the highest unemployment rate in 2019, while the Czech Republic had the lowest. Hungary had the highest growth rate in 2019, while Albania had the lowest. Finally, Slovenia had the longest life expectancy at birth in 2019 and Bulgaria the shortest. Thus, it can be seen that at

least one EU Member State ranked first or second in all variables. With the exception of Albania, all the countries of the Western Balkans, assuming effective sustainable development policies in 2019, the time frame of the analysis, showed a relatively significant decrease in the value of the input variables in the first place, while relatively good results were obtained in the values of the output variables. Among the EU member states, Bulgaria showed by far the worst performance in the achieved values of the input variables, which affected not only efficiency but also the performance of sustainable development. Therefore, if we compare the countries of the Western Balkans with the former members of the Eastern Bloc that are now members of the EU, we can see that the latter, with the exception of Bulgaria, were outstanding in terms of sustainability in 2019, which shows that they are skillful in taking advantage of EU membership and have policies that reveal a strong social awareness of sustainable development. It should also be said that the synergistic effect of simultaneous changes in the values of the observed variables of sustainable development in the period 2019–2021 was such that the observed countries coped relatively well and quickly recovered from the consequences of the corona virus pandemic, maintaining a high level of efficiency of sustainable development in a relative sense, while for some deeper and more specific conclusions, an analysis over a longer time horizon is necessary, as well as a comparison with developed countries, primarily of the European Union. In summary, the efficiency and effectiveness of sustainable development cannot be fully captured through isolated measures. Instead, they must be viewed through a comprehensive lens that takes into account the multidimensional nature of the SDGs and the ways in which progress in one area can either support or undermine objectives in others. By using a combination of robust indicators, including those for energy efficiency, we can better understand the degree of progress toward a more sustainable and equitable global society.

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Data-Policy Interaction

The research starts from the three dimensions on which sustainable development rests, economic, ecological, and social, which represent key points of reference in the sustainable development agenda of the United Nations from 2015 and have been accepted by the European Union. In accordance with the European Union's response to the United Nations 2030 agenda, which envisages a strategic approach to the implementation of sustainable development goals both at the level of the member states and at the level of all other interested parties, the focus of the analysis was the countries that gravitate to the Western Balkans and Eastern Europe, the latter of which have since become members of the European Union. The idea is to place the space for the implementation of sustainable development goals in the context of the need for further enlargement of the EU, which helps its sustainability in the long term, from which, implicitly, its members will also benefit. All the more so, as the countries of the Western Balkans, both geographically and politically and economically, form an inseparable part of the European space. The analysis unequivocally established the key link between membership in the European Union and the performance of sustainable development in terms of the efficiency of the realization of the goals of sustainable development and indicated the need to continue the process of association with the aim of general sustainability.

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