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SUSTAINABLE DEVELOPMENT EFFICIENCY OF EUROPEAN COUNTRIES

Tijana Čobović[1] [0009-0001-0307-3825], *Gordana Savić*[2] [0000-0001-6233-1815], *Milica Jovanović*[3] [0000-0001-7618-6356]

Abstract

This paper assesses the efficiency of 44 European countries based on the values of indicators of the Sustainable Development Index (SDI). The objective of the research is to evaluate the success of European countries in implementing sustainable practices. Data Envelopment Analysis (DEA) is used to analyze sustainable development efficiency of the observed countries. DEA is a non-parametric technique based on linear programming that measures the relative performance of organizational units, particularly in comparisons with multiple inputs and outputs. DEA offers benchmark units, which is crucial for improving the practices of inefficient units. The analysis includes target values for inputs/outputs, indicating the extent to which inefficient units need to adjust their inputs/outputs to achieve efficiency. For this analysis, six indicators are divided into two inputs and four outputs, and model used input orientation. A comparative analysis was also conducted between the real values of the SDI and the efficiency indices provided by DEA, including a comparison of the rankings of countries. The results indicate that countries with lower input values tend to rank better, regardless of their output levels. Furthermore, it is recommended to set constraints on the maximum predicted output values.

Key words: *Sustainable Development, Efficiency, Data Envelopment Analysis, Sustainable Development Index*

1. Introduction

The future of planet Earth and civilization depends on the impact humans have on it. The importance of clean air, drinking water and healthy soil is becoming increasingly evident, as the rising number of diseases caused by pollution grows and the threat of their depletion looms. For all these reasons, a Sustainable Development

[1] University of Belgrade, Faculty of Organizational Sciences, Serbia, tijanacobovic@gmail.com
[2] University of Belgrade, Faculty of Organizational Sciences, Serbia, gordana.savic@fon.bg.ac.rs
[3] University of Belgrade, Faculty of Organizational Sciences, Serbia, milica.jovanovic@fon.bg.ac.rs

(SD) initiative has been launched, aiming to reduce the exploitation of non-renewable energy sources, protect the environment, decrease unemployment, improve living standards, reduce inequality among people and, in general, save the planet for the future generations.

Performance monitoring plays a crucial role in ensuring the timely implementation of both organizational and national strategies. Establishing and utilizing an effective performance evaluation system contributes to optimizing decision-making processes and enhancing the competitiveness of countries.

The objective of this study is to assess the efficiency of 44 European countries in implementing SD practices. To evaluate SD performance, the study will examine the Sustainable Development Index (SDI). Initially, the components that contribute to the assessment of the Index and its outcomes will be analyzed, followed by an evaluation of alternative methods for measuring performance. In this study, Data Envelopment Analysis (DEA) will be used to assess the efficiency index. DEA facilitates the comparison of entities (in this case, countries), identifies how inefficient some countries are, outlines ways to improve their efficiency and highlights which countries exhibit the best practices.

The aim of this paper is to address the following research questions: 1) How is SD measured? 2) Can DEA be used to measure SD, and which model is suitable for this purpose? 3) Are there any differences between the results obtained through the DEA method and the SDI, and if so, what are they?

The paper is structured into five chapters. Following the introduction, a literature review is provided, discussing previous work in the field of performance measurement and the application of the DEA method, highlighting the gaps for further research. The third chapter presents the DEA method, and the model used, along with the data and SD indicators. The fourth section focuses on the presentation of results and discussion. Finally, the conclusion is provided, along with suggestions for future research directions.

1.1 Literature review

There are no universally accepted sets of indicators for measuring SD due to varying terminology and differing interpretations of the concept of SD (Parris & Kates, 2003).

The United Nations Commission on SD developed a list of 134 indicators covering the economic, social, and institutional aspects of SD. This list was later reduced to 58 indicators, intended to be universal for all countries. However, it was subsequently announced that these indicators could be used by countries on a voluntary basis at the national level and could be adapted to their specific conditions (Parris & Kates, 2003).

Moran et al. (2008) argue that indicators must reflect changes in quality of life and demonstrate whether these changes are in line with the planet's ecological boundaries. They propose the Human Development Index (HDI) for measuring human development and the Ecological Footprint as an indicator of sustainable consumption for ecological sustainability. The HDI can range from 0 to 1, with a consensus agreeing that a value of 0.8 represents the threshold between medium and high human development. For citizens od countries that have reached this level of human development, any lower score does not indicate an adequate standard of living (Moran et al, 2008).

The Ecological Footprint measures how much human activity utilizes the regenerative capacities of the biosphere. By comparing the Ecological Footprint (national per capita) with the biocapacity (global per capita), an indicator is derived that measures the minimum number of planets equivalent to Earth that would be required to support the current population if the consumption level of a given country were universal. If the ratio of Earth-equivalents is greater than 1, it means that ecological resources are being consumed faster than they can regenerate. A ratio of ≤ 1 is the necessary minimum for sustainability (Moran et al, 2008).

Unfortunately, if constraints are set requiring that the HDI should be ≥ 0.8 and the Ecological Footprint to biocapacity ratio ≤ 1, no country would meet both criteria, even though these are the two minimum thresholds for sustainability. There are countries that fulfil one of these two conditions, but they are few in the world.

There are approaches that view sustainability through the goals to be achieved, which is more common, and those that take an opposite perspective, defining and measuring indicators to be avoided (e.g. overuse of marginal lands, landscape damage due to large projects, etc.).

The best example of this is the U.S. Central Intelligence Agency's (CIA) State Failure Task Force. From 127 indicators of state failure, they narrowed the list down to 75 indicators, covering social, economic, political and environmental aspects. The most effective model used indicators for infant mortality, trade openness and the level of democracy. States are at a higher risk of failure if their first parameter is above, and the second below, the median for given year, combined with partial democracy (Parris & Kates, 2003).

1.2 Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a non-parametric method that uses linear programming to assess the relative performance of organizational units with multiple inputs and outputs, making direct comparison difficult (Boussofiane et al., 1991). DEA is data-driven and does not require assumptions about the production function's form. It measures each unit's efficiency and offers insights to improve performance. Applications include identifying benchmarks, setting targets, monitoring efficiency changes, and resource allocation (Boussofiane et al., 1991).

DEA evaluates the relative efficiency of Decision-Making Units (DMUs), with an efficiency index of 1 indicating relative efficiency and values below 1 signalling inefficiency. A key challenge lies in determining appropriate weights for inputs and outputs, often allowing DMUs to assign their own weights to maximize efficiency, which introduces subjectivity (Boussofiane et al., 1991).

Initially applied to non-profit organizations, DEA now extends to profit-oriented sectors and comparisons within homogeneous groups like hospitals and schools (Bowlin, 1998). Examples include Smith's (1990) study of 47 pharmaceutical companies, Salinas-Jiménez and Smith's (1996) analysis of healthcare efficiency, and Miliotis' (1992) assessment of Greek power distribution. Markovits-Somogyi (2011) reviewed DEA in transportation, while Zhou et al. (2018) explored DEA applications in sustainability, highlighting three approaches: traditional models, models treating undesirable outputs as inputs, and models using weak disposability of technology. DEA's flexibility allows it to address diverse efficiency challenges, with room for further research at the international level.

The next section introduces the DEA model applied in this analysis.

1.1.1 DEA model with constant return to scale (CRS)

The model developed by the creators of the DEA method, Charnes, Cooper and Rhodes, known as the CCR ratio model, is a constant return to scale (CRS) model (Charnes et al., 1978). Under this assumption, changes in input scale cause proportional changes in outputs. This means that if inputs increase by a certain percentage, outputs will increase by the same percentage, and vice versa. The CCR ratio model calculates overall technical efficiency, which encompasses both pure technical and scale efficiency, accounting for the effects of operational size (Savić, 2016).

In the model, the objective is to maximize relative efficiency (hk), which is calculated as the ratio of the weighted sum of outputs to the weighted sum of inputs. The value of hk indicates whether the DMU is relatively efficient or not. If the value is equal to 1, the unit is relatively efficient. If the value of hk falls between 0 and 1, the DMU is relatively inefficient, and this value shows the percentage by which inputs need to be reduced to achieve efficiency.

For the analysis, input orientation was applied, meaning the goal is to minimize inputs while maintaining the same level of outputs.

2. Methodology

According to the SDI, the efficiency of 44 European countries was analyzed in this study. The data for SDI spans 11 years, from 2009 to 2019, and was sourced from the SDI website (SDG, n.d). The data for Serbia excludes information on Kosovo and Metohija. The structure of the Sustainable Development Index is shown on Figure 1. The details on methodology and calculations are described in the official report (SDI, n.d).

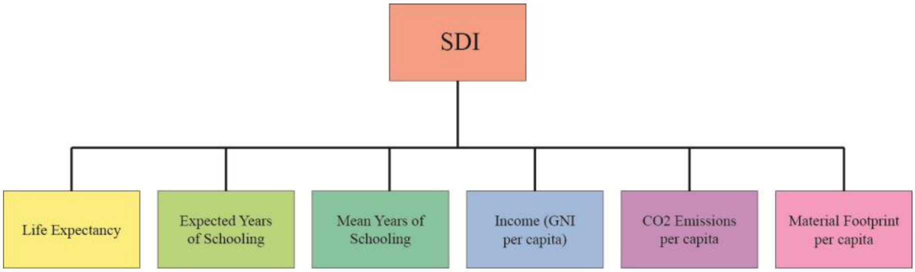

Figure 1: SDI Structure

The indicators used as inputs in the model were CO_2 emissions per capita and the Material Footprint per capita. The output indicators included: Life Expectancy, Expected Years of Schooling, Mean Years of Schooling and Income per capita.

Initially, a nonlinear model was developed and subsequently transformed into a linear model using Charnes-Cooper transformations. The key difference between the two models is that the linear model maximizes the weighted sum of outputs, while the weighted sum of inputs is constrained to equal 1. These represent two primal models. However, practical experience has demonstrated that the number of DMUs should be significantly greater than the total number of inputs and outputs, leading to the resolution of the dual CCR model. The mathematical model utilized for the analysis is given in Savić (2016, p. 24, model M3.3).

3. Results and Discussion

It is notable that year after year, the values of all indicators have been increasing. The minimum values for CO_2 emissions per capita have risen from 0.62 to 1.08, with a decrease in 2014 to the lowest recorded value of 0.18 tons. The minimum values for Material Footprint per capita range from 0.73 to 5.57 tons, with a slight decline in 2014. These values were achieved by Moldova. The maximum values for inputs range from 13.88 to 16.77 tons of CO_2 and from 34.82 to 38.08 tons of Material Footprint per capita. Interestingly, these values were recorded by the most environmentally conscious nations, Finland and Norway. Moldova had the lowest income per capita, while Switzerland had the highest, which is reflected in life expectancy, as Swiss citizen have the longest life expectancy.

Of the 44 countries, Moldova was the only one considered efficient during the first four years, and Kazakhstan was the least efficient country. In 2013, alongside Moldova, Russia also achieved efficiency, having previously been in 33rd place the year before, but with significant fluctuations in its positioning overall. Throughout the remaining years of the analyzed period, Serbia and Montenegro alternated as the least efficient countries. From 2014, Azerbaijan also achieved efficiency, and from 2015 Ireland joined the ranks of efficient countries. These four countries remained in these positions until the end of 2017. In the final year, Moldova, Ireland and Azerbaijan had the highest efficiency indices. Thus, throughout all 11 years, Moldova consistently held the top position, primarily due to its exceptionally low values for input indicators. The change in rankings is shown on Figure 2.

Efficiency indices were significantly lower during the first two years compared to the subsequent years. Excluding the efficient countries, the efficiency scores for 2009 ranged from 0.1162 for Kazakhstan to 0.3937 for Switzerland, while in the final year, the lowest score was 0.3408 for Serbia and the highest was 0.9596 for Malta. In the first year, CO_2 emissions and income per capita had the greatest impact on the efficiency scores. Over time, the impact of CO_2 emissions gradually decreased, while the significance of the material footprint increased and then diminished again. The results show a trend of increasing influence from expected years of schooling and a decreasing significance of income per capita. Life expectancy and the average number of years of schooling were almost entirely neglected and rarely influenced efficiency scores. Therefore, for future research, it would be advisable to introduce certain constraints for these factors.

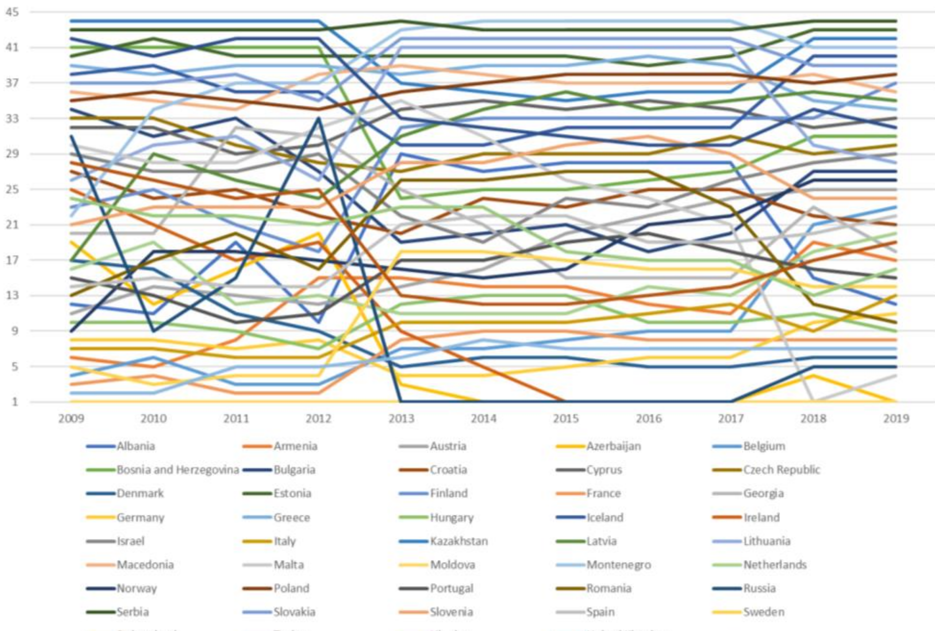

Figure 2: Change in rankings

It is evident that the efficiency indices according to the SDI are significantly lower than those produced by the CCR model in 2009. The range of the SDI values spand from 0.263 for Greece to 0.8 for Armenia, while in the constant returns to scale model (CCR), the lowest efficiency index was 0.1162 for Kazakhstan, and Moldova had an index of 1. The rankings for these countries were relatively consistent across both indices. According to the SDI, Moldova was ranked 11th. In Europe in 2009, Armenia had the highest SDI, while it was ranked 6th in the CCR model. However, there were also surprises and significant ranking discrepancies. For example, Ukraine ranked 7th according to the SDI but was 42nd according to the CCR model. Similarly, Switzerland, Sweden and Norway, which the CCR model ranked in the top 10, were among the lowest-ranked countries that year.

In the final year, Iceland recorded the lowest value in the SDI, which was also reflected in its ranking, placing it 40th in the model. Its index value was 0.178, the lowest real value in the observed period. The highest value was achieved by Georgia, with a score of 0.823, although it ranked 18th in the model. The largest discrepancy is observed with Ireland, which ranked first in the DEA model, but only 32nd according to the SDI. Comparison of SDI and CCR model for 2019 year is shown on Figure 3. From the previous analysis, it can be concluded that there are significant discrepancies between the results obtained using the DEA Solver software and the data from the official SDI website. The main reason for this discrepancy lies in the non-compensatory nature of the Index, due to the formula used for its calculation. The SDI does not allow negative results from one sub-index to be compensated by positive results from another.

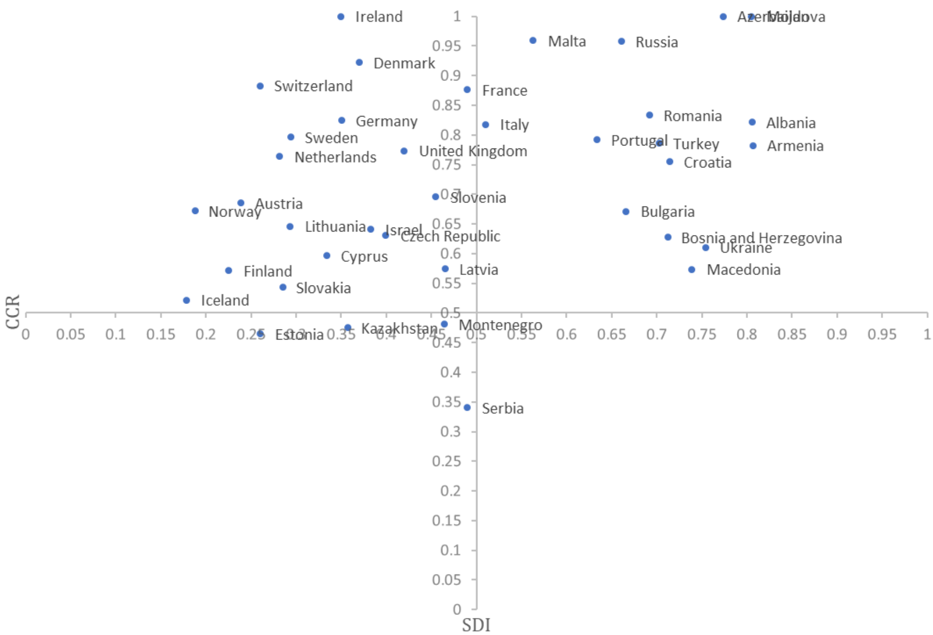

Figure 3: Comparison of SDI and CCR model – 2019

4. Conclusions

Performance measurement is an interesting and undoubtedly important area for all organizations, markets, regions, and countries, as well as the nonprofit sector. Based on achieved performance, it is possible to guide future efforts and, if necessary, adjust management policies to achieve desired goals.

In this paper, data from the Sustainable Development Index, spanning from 2009 to 2019, was used to evaluate European countries. Based on six factors, an efficiency index was calculated for each country, with Moldova standing out due to its undisputed efficiency, driven by the lowest input indicator values. A comparison with the actual SDI was made, where Switzerland and the Scandinavian countries showed the most significant differences in rankings, suggesting that further research into the environmental and social policies of these nations could be beneficial. The DEA model can be used for measuring sustainable development, but it is advisable to use original measurements rather than pre-constructed ratio indices.

It is assumed that updated data would provide a completely different picture of the observed countries. Additionally, the selection of factors greatly influences the obtained results. In future research, it is expected that introducing different indicators or altering the orientation of the same indicators would yield different outcomes, potentially leading to significantly varied insights on the same topic.

For future research in this field, it is recommended to use a constrained model, or a modification of this model, that allows for the setting of target values.

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