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The Non-Parameter Evaluation of the Quality of Education in European Countries Based on Panel Data

Abstract

Objective: The aim of this paper is to evaluate the performance of sustainable development in the education sector through a relative comparison of thirty-five European countries in the period of 2013–2021. Sustainable Development Goal number 4, namely the quality of education, was taken as a benchmark for evaluation.

Research Design & Methods: The performance of the countries was evaluated using the combined Slack Based Measure DEA Window model, which has a higher discriminating power than the standard DEA model and a dynamic dimension of observation. Finally, the robustness and sensitivity of the results was tested using bootstrapping methods.

Findings: The results showed that the performance of the quality of education, measured in terms of the DEA concept of efficiency, in the period 2013–2021, was at a relatively low but stable level overall. It was shown that, above all, the observed countries that are not members of the EU achieved a far worse level of the quality of education in the observed period, including the United Kingdom.

Contribution / Value Added: The obtained results are important in terms of benchmarking public policies related to sustainable development, especially in terms of contributing to discussions regarding the evaluation of countries' performance, especially in the field of education, as one of the key goals of sustainable development. Also, the results refer to the sources of the inefficiency of educational policies, primarily in countries that are not members of the European Union, but also in some of the member countries.

Keywords: sustainability development goals, quality of education, performance, efficiency, data envelopment analysis

Article classification: research article

JEL classification: C61, H52, I25

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Introduction

The concept of sustainable development is not new, and it is defined as a concept based on ecological integrity and balance between economic, environmental, and social dimensions. Sustainability consists of three pillars: social, economic, and environmental (UN, 2012a; Stevens & Kanie, 2016; Boyer et al., 2016; Purvis et al., 2019; Olawmi & Chan, 2018). That is, sustainable development is development that meets the current needs of society without compromising the ability of future generations to meet their own needs (Brundtland Report, 1987). According to this model, sustainable development should equally try to reach ecological, economic, and social goals (Wichaisri & Sopadang, 2017, Diaz-Sarachaga et al., 2018). Sustainable development goals are mutually integrated, expressing the awareness that action in one area will affect results in others, and that development must find a balance between social, economic, and environmental sustainability. In this sense, when talking about the efficiency of sustainable development and its performance, in the scientific and professional literature it is viewed as multidimensional, through the prism of its goals, i.e. indicators.

Considering the accelerated depletion of many natural resources and the drastic degradation of the quality of the environment, it was necessary to redefine the model of economic growth and harmonise it with sustainable development (Jorgenson & Dietz, 2015). In 2015, the United Nations General Assembly adopted the Sustainable Development Agenda with 17 Sustainable Development Goals (SDG) and 169 related sub-goals, which can be grouped into three categories: basic needs (SDG 2, 6, 7, 14, and 15), objectives (SDG 1, 3–5, 8, 10, and 16), and governance (SDG 9, 11–13 and 17). Although this classification has been widely used in SDG studies, the combinations of different SDGs are relatively conceptual and based on expert knowledge. These goals reflect different dimensions of sustainable development, with different levels of achievement, which results in different national performances of sustainable development.

Sustainable development is a core principle of the Treaty on European Union and a priority objective for the EU's internal and external policies. The Sustainable Development Goals represent the core of European policy and are firmly rooted in the European Treaties as well as included in key projects, sectoral policies, and initiatives of the European Commission (2022). Hence the constant monitoring of the progress of EU members towards the proclaimed goals, for the purpose of which a set of appropriate indicators has been developed. Indicator trends are evaluated based on their average annual growth rate over the past five years. For twenty-two indicators with quantitative EU targets, progress towards those targets is assessed. These goals mainly exist in the areas of climate change, biodiversity, the European Pillar of Social Rights, energy consumption, and education. All other indicators are evaluated according to the direction and speed of change. The report of the Eurostat, the statistical office of the European Union, based on simple monitoring of statistical trends of selected indicators, shows that the EU has made progress towards most goals over the last five years, in line with the Commission's priorities in key policy areas such as the European Green Deal, the 8th Environment Action Programme, and the European Pillar of Social Rights Action Plan. The data shows that the EU has progressed strongly towards many socioeconomic goals, while more progress is expected in the environmental domain as the Member States implement the ambitious targets of the European Green Deal. The report shows that, over the last five years, the EU has made significant progress towards three SDGs (SDG 1, SDG 5, and SDG 8) and moderate progress towards most others. The smallest progress was achieved towards SDG 13, SDG 15, and SDG 17.

The quality of education as one of the goals of sustainable development, promoted in the UN agenda as SDG 4, is defined as the requirement to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (*Sustainable Development Goals*). This goal represents one of the vital components of sustainable development (Agbedahin, 2019; Leicht et al., 2018), its key driver, but also its condition *sine qua non*, because the ability to understand the importance of establishing a stable balance between the need for progress embodied in socioeconomic development and the controlled consumption of limited natural but also social, material, and spiritual resources depends on the level of individual awareness and the level of social responsibility. The main purpose of the SDG 4, is to encourage the principles and practices of sustainable development to create societies with exceptional opportunities in all fields of education (Franco et al., 2020). According to the UN, the world is falling far behind achieving quality education. It is estimated that by 2030, as many as 84 million children and young people will be out of the education system, 300 million students will fall behind in primary education, while only one out of six states will achieve the universal secondary school completion target (UN, 2012a, 2012b). Achieving the goals set within SDG 4 is of great importance for the achievement of other sustainable development goals. In addition to the fact that they provide literacy and access to basic education, higher education institutions are also considered very influential in achieving sustainable development, with the social responsibility to create an environment that fosters sustainable development among their students and communities (Ferguson &Roofe, 2020). Also, trade activities are directly related to education. The lack of educational opportunities in a certain region, i.e. the lack of professional and personal skills of people living in that region, significantly affects the creation of a business environment and new business areas in the region, as well as the degradation of the level of entrepreneurial and investment activities. That is why investing in the education of the population is of fundamental importance for faster economic development (Hanushek & Woessmann, 2008; Johnes et al., 2017; Cervello-Roio et al., 2020).

In this context, **the aim** of this paper, on the one hand, is to evaluate the achieved SDG 4 performance through a relative comparison of the observed countries, so that the indicators of the SDG 4 goal, as defined by the European Commission, will be considered as output variables of the Data Envelopment Analysis model, while their mutual influences are also taken into account. On the other hand, the relative comparison was made over a period of nine years, which is slightly longer than the EU standard (5 years), but in addition to the temporal dimension, it is also comparative. In this paper, Slack Based Measure Data Envelopment Analysis was used to calculate the results, which – compared to the standard DEA model – has a higher discriminating power and, therefore, provides a better and more harmonised efficiency calculation. The dynamic dimension of the model is provided by the coordinated application of DEA Window analysis.

In accordance with the determined research subject and objective, the following **research questions** are raised in the paper:

RQ1: Which countries achieved the best practice, i.e. the highest level of achievement of SDG 4 – the quality of education – in the observed period?

RQ2: What is the trend of relative technical efficiency of education policy, i.e. of the achieved level of education, from the point of view of the observed indicators of the observed countries in the period 2013–2021?

RQ3: What is the performance of the EU Member States in relation to the observed SDG 4 in the period 2013–2021?

The paper contains five parts. The first part presents an introduction to the research subject with a brief review of reference aspects of the problem. The second part provides a brief overview of the literature that refers to the topic of education as one of the goals of sustainable development. The methodology used is described in the third part of the paper. The fourth part structures the appropriate SBM DEA window models for evaluating and benchmarking the efficiency of the observed countries. The obtained results of the model, the robustness of the chosen methodology, and the validity of the obtained results are presented and discussed in the fifth part of the paper. The research framework of the paper is shown in Figure 1.

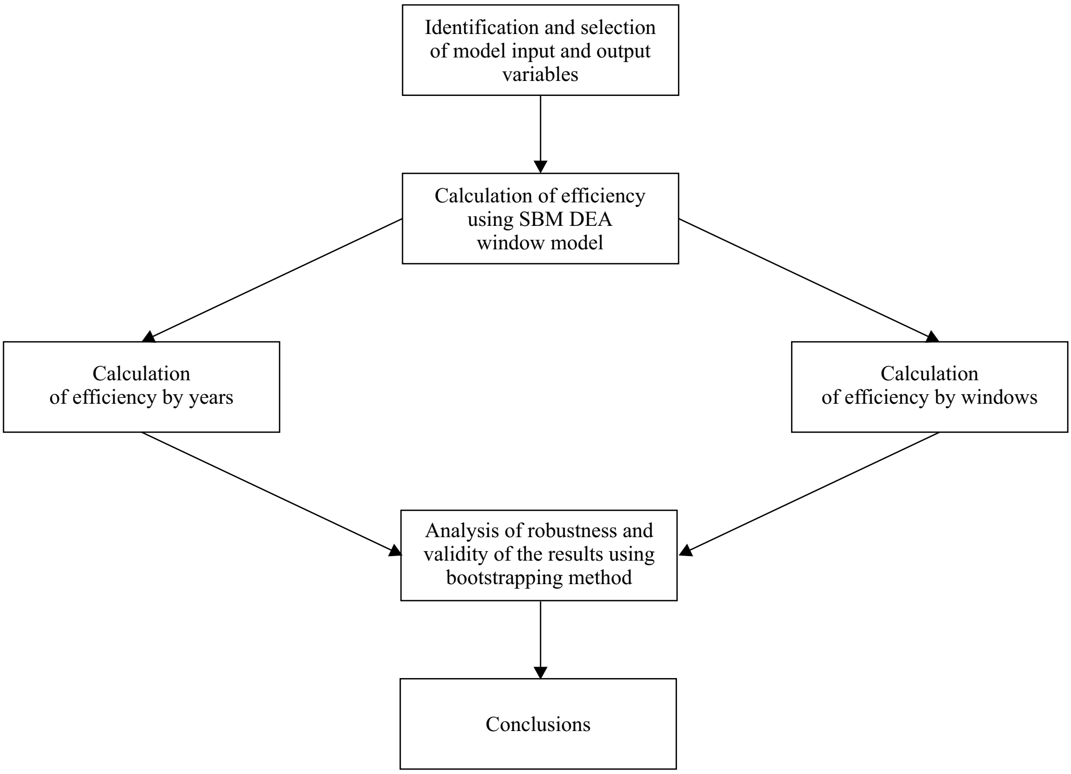

Figure 1. The research framework

Source: Authors' own work.

Theoretical background

There is no single definition of the quality of education, nor is there a universal consensus on what the appropriate strategy for ensuring and managing the quality of education is (Becket & Brookes, 2006), which has led to different interpretations and concepts associated with the quality of education (Shah, 2012). Quality in education is a multidimensional concept with different components (Sallis, 2002). The UNESCO (2021b) provided a quality framework for stakeholders that comprises five dimensions of quality education, namely (1) student characteristics; (2) the economic, social, cultural, and national context; (3) input-enabling intent; (4) the containment of different pedagogical dimensions; and (5) outcome.

Problems related to the quality of education are discussed both at the level of a specific educational institution, at the national level, and at the international level. These problems include measuring the quality of education, improving the quality of education, establishing quality standards, etc., and are multidimensional in nature (Ahmad, 2015). The literature devoted to the problem of the quality of education mainly focuses on certain levels of the educational hierarchy – primary, secondary, or higher education – or on different aspects of observation (Elsheaer, 2012; Brooks, 2021). Ko (2017) provides an overview of studies that identify the most significant factors affecting the quality of education in secondary schools, which concern both the educational infrastructure and the social context. Scheerens and colleagues (2011) use input-process-output-context for the selection and categorisation of quality indicators at all levels of the educational hierarchy, defining different perspectives of the quality of education: productivity, effectiveness, efficiency, fairness, responsiveness, and a more eclectic use of quality indicators the input, process, outcome, and context of education. Rodriguez and colleagues (2022) propose a multidimensional indicator for measuring the quality of education in public secondary schools. The results of the conducted study show the relevance of extrinsic factors, mainly the social context. Camilleri and Camilleri (2020) look at the quality of education in the broader context of sustainable development. The results show that quality education can have implications for job creation, competitiveness, and greater social cohesion, and that striving for continuous improvements in education quality and social inclusion could improve the cycle of productivity, economic growth, and prosperity results. The connection between the quality of education and sustainable development is also investigated by Grobler (2022), who proposes two interpretations of quality education – first, as a highly desirable goal, i.e. SDG 4 in the 2030 Agenda; and, second, as formal education (structured education system) of high quality and as a means to promote sustainability. Krstić Srejović and colleagues (2024) apply a multi-criteria approach to monitoring progress in terms of sustainable development indicators and identifying measures for improvement. They analyse the equality of educational opportunities, after which, using the ELECTRE III method, they rank European countries and, using benchmarking, give recommendations for national policies in order to improve them. Also, Saini and colleagues (2022) consider a case study to understand the relationship between the observed SDG 4 indicators. For this purpose, exploratory data analysis and the mining of numerical association rules in combination with genetic algorithm approaches were applied. The results reveal the presence of a significant degree of connection between these parameters, indicating the fact that understanding the impact of one (or more) indicator(s) on other related indicators is crucial for achieving the goals (or factors) of SDG 4.

Bearing in mind everything that has been said so far, in order to understand the broader picture of the state and progress of states in achieving the target level of education quality, it is necessary to apply a methodology of at least the same level of complexity as the quality of education itself as a goal of sustainable development.

Research methodology

Slack Based Measuring (SBM) DEA

Data envelopment analysis (*DEA*) is a method used for the comparative evaluation of the efficiency of decision-making units (DMUs), which are the relative performance variables of a production system. The calculation of the relative efficiency of the DMU is done by the ratio of the weighted sum of the outputs and the weighted sum of the inputs required for their generation. The efficiency value in the *DEA* method always ranges between 0 and 1. The DMU will be efficient if it is above the reference limit, which contains a value of 1 as efficiency.

The Charnes, Cooper, and Rhodes DEA model, also known as the CCR (or CRS) ratio model (Charnes and colleagues, 1978), measures the efficiency of the *j-th* DMU as the maximum value of the quotient of the weighted sum of outputs and the weighted sum of inputs, where the weights are weighting coefficients of input and output variables, whose optimal values should be determined so as to satisfy the system of limiting conditions and ensure the extreme value of the objective function. With the Charnes–Cooper transformation, the output-oriented CCR model proposed by Charnes and colleagues (1978) can be formulated as below using linear programming:

$$\max \theta_k = \Sigma_{r=1}^{s} u_r y_{rk} \tag{1}$$
$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0 (j = 1, \ldots, n)$$
$$\sum_{i=1}^{m} v_i x_{ik} = 1$$
$$u_r \geq \varepsilon, r = 1, \ldots, s$$
$$v_i \geq \varepsilon, i = 1, \ldots, m$$

where θ_k is relative efficiency of the k-th DMU, n is number of DMUs to be compared, m is number of input variables, s is number of output variables, u_r is weight coefficient for output r, v_i is weight coefficient for input i, and ε is small positive value. In the literature, it is most often suggested that $\varepsilon = 10^{-6}$. The optimal objective value θ_k is called the ratio efficiency of the DMU. Potentially, if they exist, the optimal solution reveals the existence of excesses in inputs and shortfalls in outputs called "slacks". A DMU with the full ratio efficiency, θ_k =1, and with no slacks in any optimal solution is called CCR-efficient.

Assume that there are n decision units, denoted as DMUs. Let DMUj (j = 1,2,…,n) consume m_1 variable input $x_{i_{1j}}$ (i = 1,2,…,m_1) and m_2 fixed input $x_{i_{2j}}$ (i = 1,2,…,m_2), to produce k_1 variable output $y_{r_{1j}}$ (r_1 = 1,2,…,k_1) and k_2 fixed output $y_{r_{2j}}$ (r_2 = 1,2,…,k_2). Then, according to Tone (2001), one can evaluate the performance of the observed DMU0 through the following Slack Based Measure (SBM) DEA model (1):

$$\min \theta_0 = \frac{1 - \frac{1}{m} \Sigma_{i=1}^{m} \frac{s_i^-}{x_{i0}}}{1 + \frac{1}{s} \Sigma_{r=1}^{s} \frac{s_r^+}{y_{r0}}} \tag{2}$$
$$x_{i0} = \sum_{j=1}^{n} \lambda_j \times x_{ij} + s_i^{(-)}$$
$$y_{r0} = \sum_{j=1}^{n} \lambda_j \times y_{rj} - s_r^{(+)}$$
$$s^- \geq 0, s^+ \geq 0$$

The optimal solution of model (1) is denoted as $(\theta, \lambda_j^*, s_i^{*(-)}, s_r^{*(+)})$. In model (2) the performance of DMU_0 can be improved by $x_{i0}' = x_{i0} - s_i^{*(-)}$ – and = $y_{r0}' = y_{r0} - s_r^{*(+)}$, wherein θ^* the efficiency of the j_{th} decision-making unit, λ_j^* contribution of the reference efficient decision-making unit in achieving the goal of the analysed decision-making unit, and $(x_{i0}', \forall i)$ i $(y_{r0}', \forall r)$ (optimally improved input and output variables, respectively.

The DEA Window analysis

In order to determine the performance and monitor the performance trends of the decision-making units over a specific time period, it is possible to use an extended DEA. In the literature, this analysis is known as the Window DEA method and represents a variant of a traditional DEA approach that can be described as a moving-moving technique and establishes efficiency measures by observing the DMU at different time periods as a separate unit (Wang and colleagues, 2013). At the beginning of the analysis, the length and number of windows in which the time periods overlap. Each unit is treated as a different DMU in a different time period, while the performance of the observed DMU is compared with its performances over other periods of time and with the performance of all other units encompassed by a single window (Yang & Chang, 2009). In the general case, the observed set consists of $n \times k$ entities and one entity in the period t. A window that starts at the moment l, $1 \leq l \leq k$ and has a length w, $w = k — p+1$, and consists of $n \times w \times p$ observations, where p is length of window and $p < k$ (Cooper and colleagues, 2007).

The corresponding SBM-DEA window model for is:

$$\min \theta_0^k = \frac{1 - \frac{1}{m_k}\sum_{i=1}^{m^k} \frac{s_i^{(-,k)}}{x_{i0}^k}}{1 + \frac{1}{s_k}\sum_{r_{k=1}}^{s^k} \frac{s_r^{(+,k)}}{y_{r0}^k}} \tag{3}$$

$$x_{i0}^k = \sum_{j=1}^{n} \lambda_j^k \times x_{ij}^k + s_i^{(-,k)}$$

$$y_{r0}^k = \sum_{j=1}^{n} \lambda_j^k \times x_{rj}^k - s_r^{(+,k)}$$

$$s_i^{(-,k)}, s_r^{(+,k)} \geq 0$$

By means of Charnes – Cooper transformations, it can be transformed into a suitable linear programming model, through which the efficiency is calculated for each window (Muhammad and colleagues, 2018).

Bootstrapping analysis

Bootstrapping analysis can be defined as a method by which a large number of new samples, of the same size as the original sample, are created based on available data from a sample, by random selection with return from the set of available data. The main goal of this method is to estimate population parameters. Based on its obtained values, confidence intervals are calculated for the parameter one is evaluating, and it can be used to test statistical hypotheses (Toma and colleagues, 2017). The number of bootstrap iterations can be from 1,000 to 5,000, although it is considered that the number of 2,000 is optimal for ensuring the proper range of the confidence interval for bootstrap efficiency estimation (Kang et al., 2024). Also, bias is often assessed in this analysis as well as a bias-corrected estimator (Simar& Wilson, 1998, 2000; Staat, 2006; Ropero and colleagues, 2018). Recently, however, a number of efficiency bootstrapping applications have emerged (Odeck, 2009; Song and colleagues, 2013; Toma and colleagues, 2017; Savović & Mimović, 2021; Savović and colleagues, 2021; Krstić Srejović and colleagues, 2022; Kang and colleagues, 2024).

Calculating efficiency using the DEA method can lead to biased estimates due to the lack of sample. Using a Bootstrap method to get the sampling distribution can simulate the distribution of the original sample estimator and correct biased estimates of the efficiency value (Song and colleagues, 2013). The bias value is calculated as the difference between the bootstrap value and the calculated parameter value, i.e.:

$$Bias_k = \theta_k^* - \theta_k \tag{4}$$

…where θ_k^* is the bootstrap value of the parameter, in this case the average efficiency both by window and by year in the period 2013–2021, for each observed DMU, i.e. state, while θ_k is the measured average efficiency, respectively. Then, the model efficiency corrected for bias estimation is equal to the difference (Song and colleagues, 2013):

$$\theta_k^{'} = 2 \times \theta_k - \theta_k^* (5) \tag{5}$$

…where $\theta_k^{'}$ is bias corrected efficiency, and

$$(\theta_{k,lowerbound}^{'}, \theta_{k,upperbound}^{'}) = (\theta_k^{'*(\alpha)}, \theta_k^{'*(1-\alpha)})$$

confidence interval for $\theta_k^{'}$.

The structuring of the model

The Data Envelopment Analysis has often been used, in different variants, in the measurement and analysis of sustainable development performance (Zhang and colleagues, 2008; Tian and colleagues, 2019; Li and colleagues, 2019; Wang and colleagues, 2018; Long, 2021; Zurano-Cervello and colleagues, 2019; Toma and colleagues, 2017; Grochová & Litzman, 2021; Jakšić and colleagues, 2024). Starting from the subject and goal of the research, and the principles underlying the application of the DEA method, as well as the fact that the focus is on maximising output, the components of the appropriate CCR-output-oriented model are defined as follows:

1. A group consisting of thirty-five countries for which there is available data is observed, mostly EU members.
2. The available data was collected from the Eurostat database for the period 2013–2021. As the focus is on the outputs in order to measure the achieved level of education quality, the input of each individual country is reduced to one (Lee and colleagues, 2022), while the outputs are indicators of the goal of SDG 4 – the quality of education in the EU (Table 1).
3. The corresponding SBM-DEA-Window model with one input and three outputs is formed.

The selected output variables SDGs 4–10, according to their characteristics, belong to the category of so-called undesired variables, for which it is characteristic that it is better if they have a lower value (Tone, 2021). This is in contrast to efficiency measurement in the DEA sense, for which the general rule is that an increase in the value of output variables has a positive effect on efficiency. To ensure this, a multiplicative inversion of the SDGs 4–10 output value was used: $f(0) = \frac{1}{0}$ (Krstić Srejović and colleagues, 2022). Thus, the following model (3) is formed:

$$\min \theta_0^k = \frac{1}{\frac{1}{1+\frac{1}{s_k}} \sum_{rk=1}^{s^k} \frac{s_r^{(+,k)}}{y_{r0}^k}} \tag{6}$$

$$y_{r0}^k = \sum_{j=1}^{n} \lambda_j^k \times y_{rj}^k - s_r^{(+,k)},\ s_r^{(+,k)} \geq 0$$

4. The selected window length is 4, in accordance with the recommendations of Cooper and colleagues (2007), who proposed that a window length of three or four time periods tends to yield the best balance of the informativeness and stability of the efficiency measure.

Based on the performed DEA window analysis with 6 windows[1] (p) each $w = 4$ in width, thirty-five observed decision units (n) and time period of 9 years (T), the total number of observations is $n \times w \times p = 840$ (Cooper and colleagues, 2007).

Table 1. Output variables for DEA

	Variable	Operationalisation	Source of data
Output variables	Early leavers from education and training by sex (D) (SDGs 4–10)	The indicator measures the share of the population aged 18 to 24 with at most lower secondary education who were not involved in any education or training during the four weeks preceding the survey.	https://ec.europa.eu/eurostat
	Tertiary educational attainment by sex (S) (SDGs 4–20)	The indicator measures the share of the population aged 25–34 who have successfully completed tertiary studies (e.g. university, higher technical institution, etc.)	https://ec.europa.eu/eurostat
	Participation in early childhood education by sex (S) (SDGs 4–31)	The indicator measures the share of the children between the age of three and the starting age of compulsory primary education who participated in early childhood education and care (ECEC), which can be classified as ISCED level 0 according to the International Standard Classification for Education (ISCED, 2011).	https://ec.europa.eu/eurostat
	Adult participation in learning in the past four weeks by sex (SDGs 4–60)	The indicator measures the share of people aged 25 to 64 who stated that they received formal or non-formal education and training in the four weeks preceding the survey (numerator). The denominator consists of the total population of the same age group, excluding those who did not answer the question 'participation in education and training'.	https://ec.europa.eu/eurostat

Source: Authors' own work.

Table 2. The descriptive statistics of model variables

Variable	SDG4-10	*SDG4 –20*	*SDG4-31*	SDG4-60
Max	0.0261	21.5	29.7	0.9
Min	0.4545	62.3	100	34.7
Average	0.1293	40.7	83.5	11.5
S.D.	0.0656	8.867	17.186	8.458

Source: Authors' own work.

Results and discussion

The results of the SBM DEA Window model

The obtained results indicate a relatively low efficiency of the sustainable development policy of the observed countries in relation to SDG 4 – the quality of education. Observed by years (Table 3), a stable trend of relatively low efficiency is present in most countries. It is noticeable

[1] $p = T - w + 1$ (Cooper et al., 2007).

that the COVID-19 pandemic did not have a significant impact on efficiency (2020–2021), which indicates the fact that European countries generally consistently implemented the goals of the sustainable development policy in this domain. The best practice (100%), with the maximum realisation of output in the period 2013–2021, in each observed year, was achieved only by France, while Switzerland had an average of 98.1%, Ireland – an average of 96.1%, Sweden – 93.7%, Lithuania – 92.4%, Luxembourg – 91.7%, and Denmark – 90.4%, these being the only countries whose efficiency is over 90% of the reference. The lowest efficiency was achieved, above all, by the Balkan countries that are not members of the EU, with the exception of Montenegro, whose average efficiency in the observed period was 84.4%, but, which is perhaps not surprising, with regard to the EU members whose geographical location is also the Balkans, Romania had an average of only 15.8% of the reference efficiency and Bulgaria – an average of 19.7%. Perhaps the biggest surprise is the United Kingdom's result of 56.6% and Germany, whose average efficiency was only 47.6% of best practice. The average efficiency of all the observed countries in the period 2013–2021 was 60.4% of the best practice; at the EU level, it was 61.9%, and at the level of non-EU countries, the average efficiency was 55.2% of the best practice. All eleven EU member states have an average efficiency above the EU average efficiency. In fact, it can be said that individually, in the observed period, a relatively or very low efficiency of sustainable development policy was achieved (with most countries below 60% or 50%), but that at the EU level, the trend of average efficiency is significantly above the average efficiency of countries that are not members of the EU (Figure 2), which only shows that, despite all the problems in that period, the EU remained firmly committed to the persistent implementation of the outlined policy of sustainable development in the field of education – somewhere with more and somewhere with less success. When the changes in efficiency are observed by certain time periods – windows (Figure 3) – it can be concluded that the results are somewhat better, but that the states mostly kept their ranks (Table 4). France is also the only country that was efficient in all windows and whose average efficiency is 100%, followed by Switzerland with 99.3%, Lithuania with 95.7%, Ireland with 95%, Croatia with 94.9%, Cyprus with 93.6%, and Montenegro with 93.1% as well as Sweden with 90.9%. These are also the only countries whose average efficiency per window in the observed period was over 90% of the best practice. The lowest efficiency in the observed period by windows was achieved by Romania with 13.3%, Bulgaria with 20%, North Macedonia with 22.7%, Turkey with 24.3%, and Slovakia with 29.8% (Figure 3). The average efficiency at the level of EU member states, according to the windows in the observed period, was 61.5%; for non-EU members, it was 55.5%; and for all countries – 60.2% of best practice (Figure 4), which only confirms the thesis of the relatively consistent and relatively efficient implementation of the set goals of sustainable development in the field of quality education, primarily at the EU level.

The analysis of the obtained results unequivocally confirms the thesis that membership in the European Union is a comparative advantage of member states in relation to non-member states when it comes to the effectiveness of national sustainable development policies. Specifically, when it comes to the goal formulated as SDG 4 – the quality of education – this advantage is especially emphasised in times of prosperity and stability. The very illustrative Figure 2 shows a clear noticeable difference in the measure of efficiency in the periods immediately after the world financial crisis (2013–2014) and immediately before the crisis caused by the epidemic of COVID-19 (2016–2019). With the already mentioned exceptions (Bulgaria, Slovakia, etc.), on the other hand, the greater resistance of non-member states to the crises itself is striking, so that in 2015 and 2020, the average efficiency of both states is almost equal. However, as

Table 3. Average efficiency by years in the period 2013–2021

	2013	2014	2015	2016	2017	2018	2019	2020	2021
Belgium	0.568	0.620	0.526	0.559	0.631	0.602	0.565	0.593	0.726
Bulgaria	0.202	0.207	0.194	0.203	0.210	0.219	0.181	0.172	0.188
the Czech Republic	0.619	0.589	0.536	0.531	0.551	0.514	0.485	0.414	0.405
Denmark	1.000	1.000	1.000	0.906	0.813	1.000	0.736	0.715	0.965
Germany	0.508	0.495	0.481	0.475	0.466	0.454	0.450	0.463	0.491
Estonia	0.648	0.577	0.534	0.598	0.591	0.600	0.610	0.649	0.609
Ireland	1.000	1.000	0.830	0.823	1.000	1.000	1.000	1.000	1.000
Greece	0.300	0.293	0.295	0.338	0.366	0.357	0.375	0.403	0.438
Spain	0.454	0.450	0.444	0.434	0.436	0.451	0.447	0.471	1.000
France	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Croatia	0.392	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.389
Italy	0.395	0.431	0.404	0.420	0.402	0.397	0.401	0.401	1.000
Cyprus	0.868	1.000	1.000	1.000	1.000	1.000	1.000	0.481	0.621
Latvia	0.491	0.438	0.421	0.469	0.482	0.451	0.466	0.487	0.560
Lithuania	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.635	0.685
Luxembourg	1.000	1.000	0.810	0.905	0.777	0.851	0.911	1.000	1.000
Hungary	0.292	0.291	0.440	0.393	0.380	0.369	0.363	0.357	0.421
Malta	0.573	0.425	0.418	0.415	0.469	0.476	0.487	0.496	0.555
the Netherlands	0.774	0.761	0.758	0.739	0.753	0.731	0.726	0.756	0.870
Austria	0.643	0.709	0.684	0.685	0.673	0.656	0.633	0.593	0.763
Poland	0.397	0.378	0.332	0.340	0.358	0.449	0.392	0.360	0.409
Portugal	0.450	0.455	0.482	0.464	0.470	0.483	0.503	0.548	0.766
Romania	0.193	0.151	0.132	0.121	0.113	0.095	0.126	0.115	0.379
Slovenia	1.000	0.802	0.704	0.674	0.728	0.708	0.647	0.613	0.562
Slovakia	0.297	0.289	0.284	0.265	0.286	0.321	0.297	0.279	0.477
Finland	0.785	0.766	0.748	0.776	0.747	0.742	0.781	0.749	0.885
Sweden	1.000	1.000	0.905	0.865	0.832	0.832	1.000	1.000	1.000
Iceland	0.581	0.601	0.608	0.551	0.573	0.476	0.523	0.542	0.837
Norway	0.674	0.703	0.671	0.599	0.588	0.576	0.581	0.557	0.529
Switzerland	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.832
the United Kingdom	0.622	0.598	0.578	0.537	0.529	0.525	0.520	0.525	0.661
Montenegro	0.290	0.309	1.000	1.000	1.000	1.000	1.000	1.000	1.000
North Macedonia	0.270	0.242	0.215	0.238	0.204	0.213	0.236	0.240	0.236
Serbia	0.324	0.345	0.364	0.374	0.347	0.326	0.332	0.336	0.412
Türkiye	0.224	0.232	0.237	0.240	0.240	0.250	0.250	0.258	0.246
Average	0.595	0.604	0.601	0.598	0.601	0.604	0.601	0.577	0.655

Source: Authors' own work.

shown in Figure 4, viewed from the so-called windows, the difference in average efficiency is significantly more pronounced, especially in periods of crisis, without tangent points. Additional analysis of the impact of explanatory variables can include and emphasise the broader context of the problem – pointing to key sources of inefficiency in national strategies for the development of education in order to raise its quality – as a strategic resource of a nation.

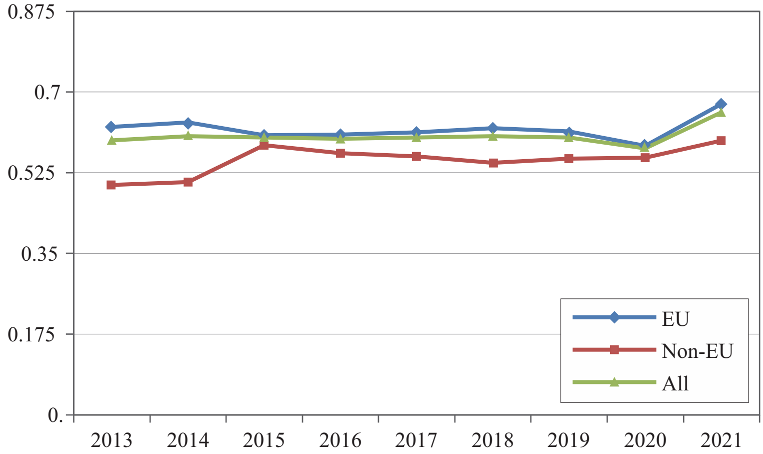

Figure 2. Average efficiency by years – EU countries vs. non-EU countries

Source: Authors' own work.

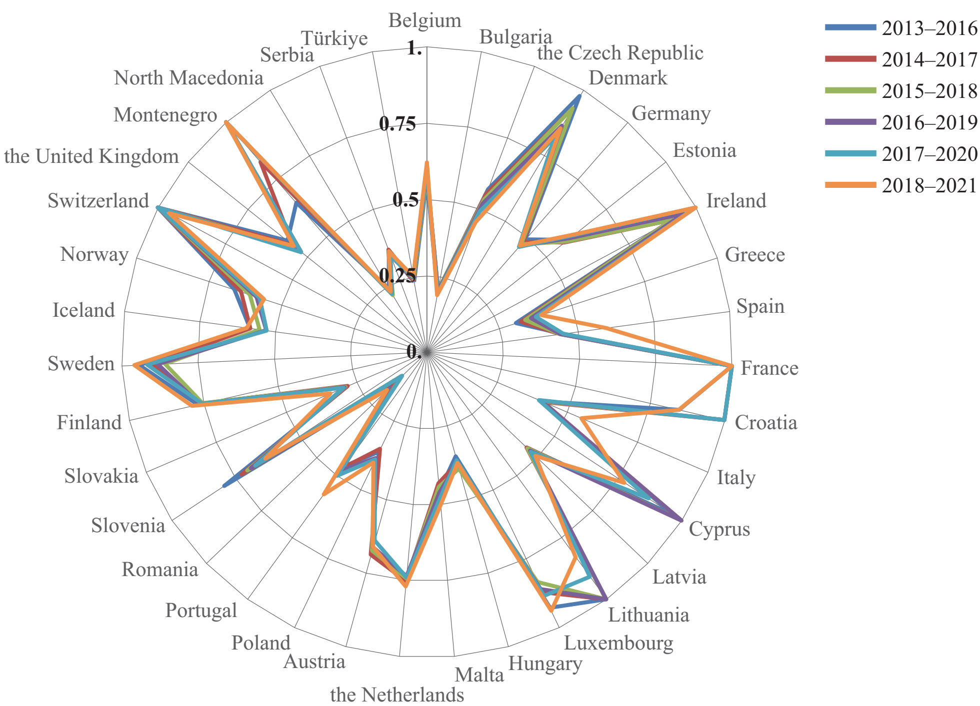

Figure 3. Average efficiency by windows in the period 2013–2021

Source: Authors' own work.

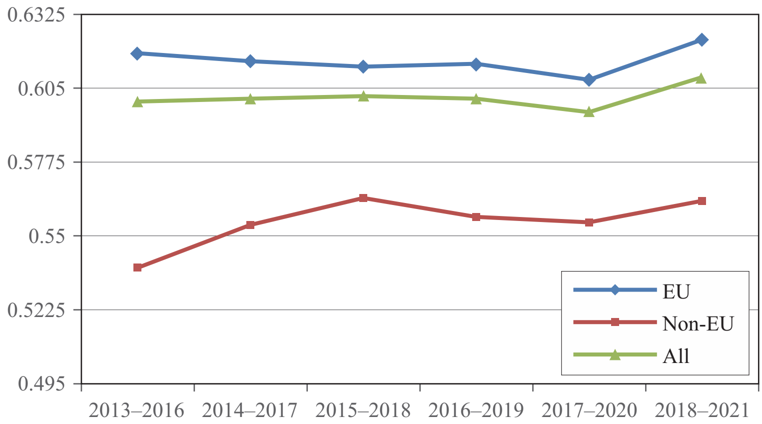

Figure 4. Average efficiency by windows – EU countries vs. non-EU countries

Source: Authors' own work.

The analysis of the robustness and validity of the results

For $n = 2000$ pseudo samples, corrected average efficiencies per model are calculated, with a confidence level of 0.05. The results of the bootstrapping analysis show that there were no significant deviations of the bootstrapped values from the original values and that they range within the allowed confidence intervals. A similar conclusion can be made regarding the average efficiencies per window. This is supported by the fact that almost all countries maintained their rank and that there were no significant deviations in the rank, except in the case of Croatia, whose rank according to the measured average efficiency per window was 10, and according to the bootstrapped value it was ranked in the fifth place (Table 4). Rank one according to the bootstrapped average efficiency of 100% by years and windows was achieved by France and Switzerland, rank three was retained by Ireland (by years), etc. Generally speaking, in most cases, the measured efficiency is underestimated (and in a small number of cases – overestimated), but this deviation is insignificant, which indicates the validity and accuracy of DEA results and the absence of bias in the assessment.

Table 4. Measured efficiencies, bias-corrected efficiencies, and ranking of observed countries in the period 2013–2021

	θ_k *by years*	Rank	$\theta_k^{'}$	Rank	θ_k *by windows*	Rank	$\theta_k^{'}$	Rank
Belgium	0.599	17	0.591	18	0.590	17	0.558	18
Bulgaria	0.197	34	0.196	34	0.200	34	0.198	34
the Czech Republic	0.516	20	0.525	22	0.520	20	0.501	21
Denmark	0.904	7	0.938	5	0.895	9	0.909	7
Germany	0.476	24	0.476	25	0.470	22	0.469	25
Estonia	0.602	16	0.607	17	0.596	16	0.606	16
Ireland	0.961	3	0.999	3	0.950	4	0.949	4
Greece	0.352	29	0.341	30	0.349	29	0.349	29

Table 4 – contineud

	θ_k *by years*	Rank	$\theta_k^{'}$	Rank	θ_k *by windows*	Rank	$\theta_k^{'}$	Rank
Spain	0.510	22	0.567	20	0.469	23	0.493	22
France	1.000	1	1.000	1	1.000	1	1.000	1
Croatia	0.864	9	0.864	10	0.949	5	0.949	3
Italy	0.472	26	0.475	26	0.431	26	0.407	26
Cyprus	0.886	8	0.900	9	0.936	6	0.957	3
Latvia	0.474	25	0.484	24	0.466	24	0.471	24
Lithuania	0.924	5	0.930	6	0.957	3	0.943	6
Luxembourg	0.917	6	0.906	8	0.888	10	0.880	10
Hungary	0.367	28	0.368	28	0.374	28	0.378	27
Malta	0.479	23	0.486	23	0.463	25	0.479	23
the Netherlands	0.763	12	0.764	11	0.751	12	0.753	12
Austria	0.671	14	0.669	14	0.668	14	0.655	14
Poland	0.379	27	0.383	27	0.381	27	0.377	28
Portugal	0.514	21	0.541	21	0.494	21	0.511	20
Romania	0.158	35	0.190	35	0.133	35	0.128	35
Slovenia	0.715	13	0.742	13	0.706	13	0.697	13
Slovakia	0.310	31	0.314	31	0.298	31	0.298	31
Finland	0.776	11	0.754	12	0.765	11	0.768	11
Sweden	0.937	4	0.960	4	0.909	8	0.907	8
Iceland	0.588	18	0.625	16	0.563	18	0.568	17
Norway	0.609	15	0.639	15	0.606	15	0.624	15
Switzerland	0.981	2	1.000	1	0.993	2	1.000	1
the United Kingdom	0.566	19	0.578	19	0.550	19	0.551	19
Montenegro	0.844	10	0.921	7	0.913	7	0.895	9
North Macedonia	0.233	33	0.233	33	0.227	33	0.226	33
Serbia	0.351	30	0.347	29	0.349	29	0.349	30
Türkiye	0.242	32	0.234	32	0.243	32	0.244	32

Source: Authors' own work.

Conclusions

The obtained results, based on the integrated application of Slack Based Measure DEA and DEA Window analysis of the efficiency of thirty-five European countries in the period 2013–2021, show a relatively stable trend and a relatively low efficiency of the implementation of the sustainable development policy in terms of achieving the goals proclaimed by the European Commission, specifically the quality of education. The effectiveness of the achievement is targeted by the requirement to minimise the reciprocal value of the weighted sum of the outputs, whereby the outputs are identified as indicators of SDG 4 – the quality of education – and measured using the non-parametric DEA method. Generally speaking, the efficiency in realising the goals of the education policy by year in EU member states in the observed period was at a significantly higher level than the efficiency of non-EU states, while the average efficiency was also at a slightly higher level (61.9%: 55.2%). However, this is not in line with the optimistic conclusions based on the simple monitoring of statistical trends in Eurostat reports. The worst educational performances, in addition to the traditionally and expectedly poorly performing Balkan countries that are not EU members, were achieved by Romania, whose average efficiency was only 15.8%, and Bulgaria – with 19.7% of the reference efficiency. A bigger surprise is the weak result of Germany (47.6%) and the United Kingdom (56.6%), as well as the excellent performance of Montenegro (84.4%). The best performances were achieved by EU members – France, Ireland, Sweden, as well as by Switzerland as a non-member. At the same time, only seven countries, six of which are members of the EU, achieved an average efficiency of over 90% by year, while by periods (windows) an average efficiency of over 90% was achieved by eight countries, two of which, Switzerland and Montenegro, are no members of the EU. As many as ten EU members in the observed period were not even at 50% of the reference average efficiency. The dynamic analysis of efficiency, which included the time component, showed that there were no significant changes in the average efficiency and that there were no significant deviations in the relative achieved performances, so there were no deviations in the rank order either. A more detailed look at the results by year shows significant deviations between the achieved and target values of the observed indicators, where the most pronounced deviations observed by country were in the SDGs 4–10 indicators and especially in SDGs 4–60, and slightly smaller in the remaining two indicators, but for deeper indications and conclusions, a more detailed analysis should be carried out in order to understand the causes of these deviations, on the basis of which measures can be taken to improve the quality of education, both at the basic level and at all stages of life, including the development and improvement of digital skills. In the end, the analysis of the robustness of the obtained average efficiency values, using the bootstrap method, shows that the measured efficiency values, except the case of Montenegro, are relatively slightly underestimated and overestimated, and that this did not affect the achieved rankings of the countries, which indicates the validity and accuracy of the obtained results.

The obtained results are important in terms of benchmarking public policies related to sustainable development in the field of education, especially in terms of contributing to discussions regarding the evaluation of countries' performance, especially countries that are not members of the European Union. The analysis also helps to identify countries with the best educational policies and practices, as a benchmarking and model of how to build an effective education system, taking into account the importance and broader social implications of education and its impact on other sustainable development goals.

The inclusion in the analysis of several factors, which is both a limitation and a potential of the conducted research, would certainly contribute to a more credible assessment of the current situation, which is a fundamental assumption for identifying the key sources of the inefficiency of the educational system and, implicitly, the limiting factors of the quality of education. Also, additional analysis of the impact of explanatory variables can include and emphasise the broader context of the problem, pointing to key sources of inefficiency in national strategies for the development of education in order to raise its quality, as a strategic resource of a nation. In this sense, considering the application of DEA methodology and efficiency interval values (0–1), *Tobit* (censored) linear regression can provide a deeper insight into the key determinants of the effectiveness of national education policies.

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Conflicts of Interest

The authors declare no conflict of interest.

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All data will be available and shared upon request.