Full research paper

RANKING OF EUROPEAN UNIVERSITIES BY DEA-BASED SUSTAINABILITY INDICATOR

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ABSTRACT

The paper introduces a novel approach to university rankings that considers a university's contribution to sustainable development. It addresses the usual controversies surrounding the construction of rankings using composite indicators. The conventional approach typically involves normalizing sub-indicators and applying subjective weights for aggregation, which raises concerns about the reliability of the rankings. In response to this issue, we propose an alternative method based on Data Envelopment Analysis (DEA) that utilizes flexible weights. Our approach is applied to the data from the UI-GreenMetric World University Ranking. We initially employ a general Benefit of the Doubt DEA model and subsequently enhance its discrimination power by computing super-efficiency. In the third model, we impose weight restrictions on sub-indicators. The results of our analysis offer valuable insights for all stakeholders, as illustrated by the implications derived for Czech universities included in the sample. Furthermore, we compare the results of universities in various European countries, establishing a connection between rankings and the fulfillment of Sustainable Development Goals (SDG) within individual countries. This research contributes to a more comprehensive understanding of the relationship between university performance, sustainability, and the associated implications for policy and benchmarking.

KEYWORDS

Composite index, Data Envelopment Analysis, sustainability goals, university ranking

HOW TO CITE

Matulová M. (2023) 'Ranking of European Universities by DEA-Based Sustainability Indicator', *Journal on Efficiency and Responsibility in Education and Science*, vol. 16, no. 4, pp. 287-298. http://dx.doi.org/10.7160/eriesj.2023.160403

Article history

Received

May 1, 2023

Received in revised form

September 24, 2023

Accepted

October 31, 2023

Available on-line

December 31, 2023

Highlights

- *The paper presents an alternative to the UI-GreenMetric World University Ranking with lower sensitivity to sub-indicator weighting.*
- *Moreover, the methodology used in our study allows for identifying areas with potential for improvement and peer units for benchmarking purposes.*
- *The analysis results demonstrate positive correlations between university rankings and the fulfillment of sustainable development goals in their respective countries.*

INTRODUCTION

As a reaction to global challenges our planet faces, the United Nations General Assembly established the global Sustainable Development Goals (SDGs) for 2015–2030 (United Nations, 2014). Governments, civil societies, private companies, and other organizations are supposed to conduct their activities in accordance with these goals, see Table 1. Countries are assessed using the so-called SDG Index (Sachs et al., 2022) to measure how far they are on the road towards development, balancing social, economic, and environmental sustainability. The level of SDG attainment in the European countries ranges from 70.41% (Turkey) to 86.51% (Finland); the values are depicted in the map in Figure 1. Over the years 2015-2020, the EU has generally made progress toward achieving most sustainable development goals, with varying advancement rates across different goals. SDG 16, which focuses on peace, justice, and strong institutions, notably saw significant improvements. Reductions in poverty and enhancements in the EU's health situation (SDG 1 and SDG 3) also showed positive trends, although these assessments predate the COVID-19 pandemic. The pandemic has had a noticeable impact on the economy, labor market, education, gender equality, inequality, and global partnerships (SDG 8, SDG 4, SDG 5, SDG 10, and SDG 17), resulting in interruptions and deteriorations in these areas. Moderate progress has been observed in sustainable cities, consumption and production, sustainable agriculture, and R&D and innovation (SDG 11, SDG 12, SDG 2, and SDG 9). However, the assessments are based on data predating the pandemic. SDG 13, climate action, has seen neutral progress, influenced by both positive trends in climate mitigation and negative impacts of climate change. SDG 7 and SDG 15, however, show slight deviations from sustainable development objectives, primarily due to increased energy consumption and ongoing pressure on ecosystems and biodiversity, respectively (Sachs et al., 2022).

Goal	Description
SDG1	End poverty in all its forms everywhere
SDG2	End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
SDG3	Ensure healthy lives and promote well-being for all at all ages
SDG4	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
SDG5	Achieve gender equality and empower all women and girls
SDG6	Ensure availability and sustainable management of water and sanitation for all
SDG7	Ensure access to affordable, reliable, sustainable and modern energy for all
SDG8	Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all
SDG9	Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation
SDG10	Reduce inequality within and among countries
SDG11	Make cities and human settlements inclusive, safe, resilient, and sustainable
SDG12	Ensure sustainable consumption and production patterns
SDG13	Take urgent action to combat climate change and its impacts
SDG14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
SDG15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
SDG16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels
SDG17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

Table 1: The goals of the UN's 2030 Agenda for Sustainable Development (Source: United Nations. Sustainable Development, https://sustainabledevelopment.un.org/)

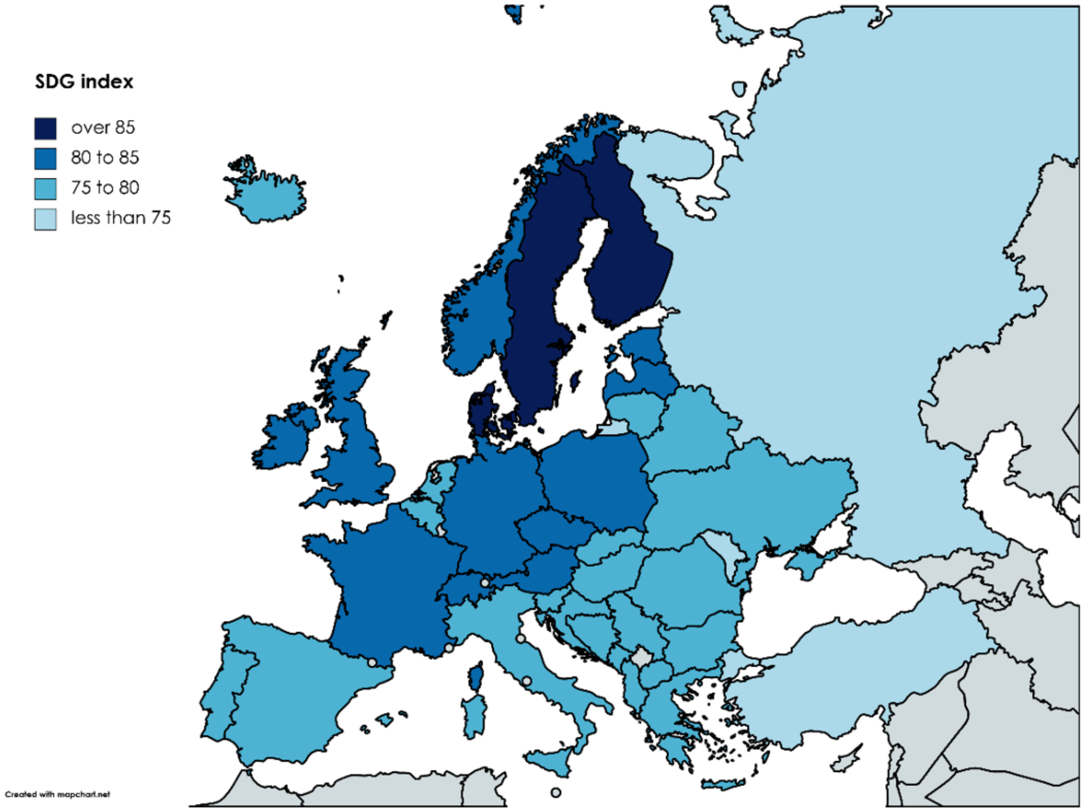

Figure 1: SDG index (Source: mapchart.net, Sachs et al., 2022)

Education is probably one of the most influential factors in this effort. Education for sustainable development received recognition and description in Agenda 21 for promoting education, awareness, and training (UNESCO, 1992). It explicitly articulates the responsibility of both formal and non-formal education systems to cultivate the necessary attitudes in the population, enabling active participation in sustainable development activities and matters. The effect of education on the attitude and awareness of young people towards sustainability is explored by many authors, e.g., Kaur and Kaur (2022), Nousheen et al. (2020), Tang (2018). Another important aspect is how educational institutions themselves follow the SDG strategies. The involvement of universities in global sustainable development and the role of SDGs as fundamental aspects of their strategy concerning teaching, research, and third-mission activities is subject to many scientific papers (e.g., Lozano, 2006; Lozano et al., 2015; Purcell et al., 2019; Mori Junior et al., 2019; Klußmann et al., 2019; Ceulemans et al., 2015).

Part of meeting sustainability goals is comparing with others, for example, through participation in international rankings. However, most major university ranking schemes often stress the importance of research and academic reputation, followed by educational indicators, whereas environmental issues have received little or no attention. As an example, we can name the best-known ranking systems, such as the *Times Higher Education World University Rankings* (THE), sponsored by Thomson Reuters, or the *QS World University Rankings. Both rankings include sustainable development only in auxiliary assessments covering just a partial sample of* higher education institutions (HEIs); see THE Impact Rankings (Thomson Reuters, 2023) and QS Sustainability Rankings (Quacquarelli Symonds, 2023). Nevertheless, rankings that really include environmental aspects and sustainability issues have also begun to emerge, such as the one providing data for our analysis: UI GreenMetric World University Ranking 2022, a survey-based global self-assessment tool for higher education institutions. UI GreenMetric Ranking (UI-GMR) initiative started in 2010 by ranking 95 universities from 35 countries. It became increasingly recognized and prestigious, so in 2021, more than 950 universities from 80 countries participated in the ranking. The universities are ranked according to the values of the composite indicator aggregating information from six areas (environment and infrastructure, energy and climate change, waste, water, transport, education, and research). The relationship between academic performance measured by recognized rankings and environmental responsibility measured by UI-GMR was explored by Galleli et al. (2022) and Atici et al. (2021).

However, certain aspects of the UI-GMR ranking are criticized by some authors. Ragazzi and Ghidini (2017) identified several issues that need to be addressed in order to improve the ranking method, among others, the relativity of scores and the high sensitivity of the ranking. Boer (2013) provides a discussion on alternate evaluation frameworks, among others, a U.S. campus sustainability rating system, The Sustainability, Tracking, Assessment and Rating System (STARS) originating in 2006, Auditing Instrument for Sustainability in Higher Education (AISHE) from the year 2012, Assessing Responsibility In Sustainable Education (ARISE), and the Audit and certification method which reflects ISO methods. As mentioned by Dalal-Clayton and Bass (2002), various approaches can be utilized to assess and report sustainability, such as accounts, converting raw data to a common unit (monetary, area, or energy), or narrative assessments combining text, maps, graphics and tabular data. Nevertheless, the mainstream is represented by indicator-based strategies.

Composite indicators (CI) are regularly used for benchmarking performance but equally often stir controversies about the unavoidable subjectivity that is connected with their construction. In constructing CIs, the normalized sub-indicators are usually added, sometimes with certain weights associated with the sub-indicators. We will depart from that approach in our study using flexible weights obtained by Data Envelopment Analysis (DEA). Engaging the DEA in developing a composite index can address two significant issues: the undesirable reliance on preliminary normalization of sub-indicators and the subjective weighting used for aggregation. Additionally, flexible weighting can promote buy-in from relevant stakeholders, making the final results more widely accepted. Lastly, it is worth noting that DEA analysis can offer valuable insights into the relative performance of evaluated units, such as identifying peer units for those that are inefficient. DEA-based approaches have been used in the context of university evaluations many times, e.g., Thuan et al. (2022) or Ferro and D'Elia (2020).

The objective of this study is twofold. The first aim is to construct an alternative to the global ranking of HEIs focusing on sustainability while mitigating the shortcomings of existing ranking systems. The second objective is to explore the differences between the ranking of universities from different European countries and to find the connection between the position of the HEI in the ranking and the extent to which the country fulfills the Goals of Sustainable Development (SDG). Our results show a significant positive association between the ranking of HEIs and the value of the SDG index in countries of their origin. The rest of the paper is organized as follows: In the second chapter, we describe the data sample and three models used to create an alternative sustainability indicator for universities. The resulting rankings of universities and their comparison with the original UI-GMR ranking are presented in Chapter three. We also demonstrate the interpretation of additional results obtained using tools of DEA methodology (slack analysis and identification of peer units) and possible recommendations in the case of Czech universities. The third chapter ends by comparing results across European countries and investigating their relationship with SDG fulfillment in these countries. The results are discussed in the fourth chapter, and the final chapter concludes the study.

MATERIAL AND METHODS

Composite indicator construction using DEA

The approach used in our study is based on using DEA as an aggregation tool in Multiple Criteria Decision Making (MCDM). In the context of composite indices, it was first used by Mahlberg and Obersteiner (2001) to reassess the Human Development Index. Since then, DEA-based CIs have been used in many application areas, such as assessing European social inclusion policy (Cherchye et al., 2004), technology achievement (Cherchye et al., 2008) or road safety (Shen et al., 2013). A similar model has been tested to assess progress towards achieving the so-called Lisbon objectives (European Commission, 2004, p. 376-378). Many other applications are mentioned in the survey of Greco et al. (2019). The basic properties of the DEA-based CIs are described in the paper of Cherchye et al. (2007), which refers to the method as the Benefit-of-the-Doubt (BoD) approach.

The scientific studies also point out one major issue that often occurs while applying this method as a result of the absence of further constraints: After the optimization process, a multiplicity of the units are assigned the maximum possible value of „efficiency," so their order cannot be determined. That is why we also introduce two alternate approaches to solving this problem. The first one is based on the computation of super-efficiency. In the second one, we allow for more constraints given by the decision maker, controlling, for instance, the lower and upper bounds of the weights of each sub-indicator or their ratios.

Model 1

Driven by the above-mentioned ideas, we first adopted the typical DEA setup for our MCDM-DEA model, which only requires the endogenous weights to be nonnegative. To introduce DEA as a tool for constructing composite indicators, we consider variables in the form of values of m sub-indicators for n units (universities), with the value of sub-indicator i in unit j. In the following, and in line with the more common DEA terminology, we will often refer to sub-indicators as outputs. In contrast to the typical DEA setup, in our analysis, we do not consider any inputs, or more precisely, we use a single input with a uniform value of 1 for all Decision-Making Units (DMUs). Following the ideas formulated in the literature on BoD indicators (e.g., Cherchye et al., 2008), let's define single-valued CI, defined as the weighted average of the m sub-indicators; we use v_i to represent the weight of the i-th sub-indicator. As discussed above, the available expert information does not allow us to specify a priori a unique vector of generally acceptable weights. Therefore, we endogenously select those weights that maximize the value of the composite indicator for the unit under consideration. This gives the following linear programming problem for each j:

$$CI_j = \max_{v_i} \sum_{i=1}^{n} v_i \, y_{ij} \tag{1}$$

subject to

$$\sum_{i=1}^{n} v_i \, y_{ik} \le 1, \forall k = 1, \ldots, n, \tag{2}$$

$$v_i \ge 0, \ \forall i = 1, \ldots, m. \tag{3}$$

We obtain $CI_j \le 1$ for each unit j, with higher values indicating better relative performance. The indices of constraints binding in optimal solutions identify peer units for „inefficient" units. As mentioned by Despotis (2005), this model formally corresponds to the original input-oriented, constant-returns-to-scale DEA model using the sub-indicators to represent the individual outputs and allocating a single 'dummy input' with value unity to each unit.

Model 2

One of the issues of basic DEA models is ranking units having identical scores of unity. To address this problem, Andersen and Petersen (1993) proposed a super-efficiency model used to complete ranking. The model involves executing standard DEA models, assuming that the unit under evaluation is excluded from the reference set, so in the second model, instead of the constraint (2), we consider its modification,

$$\sum_{i=}^{n} v_i \, y_{ik} \le 1, \forall k = 1, \ldots, n, k \ne j \tag{4}$$

In the case of output-oriented models, the super-efficiency score provides a measure of the proportional reduction of outputs that a unit could experience without losing its "efficient" status relative to the frontier created by the remaining units. Additionally, the super-efficiency score serves as a measure of stability. In other words, if the data is subject to changes or errors over time, the score provides a means of evaluating the extent to which these changes could occur without violating the efficient status of the unit (Zhu, 2001). However, it should be noted that under specific conditions concerning returns to scale, the super-efficiency DEA model may not have feasible solutions for some units. A well-known result from the DEA literature is that the super-efficiency model preserves the scores of non-efficient units obtained by the basic model (Andersen and Petersen, 1993).

Model 3

In the last model, we include the ordinal information about the weights of the individual sub-indicators determined by the experts from the GreenMetric team. This is done by adding additional restrictions on the relative weights to the basic DEA model to obtain the so-called Assurance Region (AR) model. These models impose restrictions in the form of lower bounds (LB) and upper bounds (UB) for outputs (or inputs) weights or bounds for their ratios, as in our application:

$$LB_i \le \frac{v_i}{v_{i+1}} \le UB_i, \ \forall i = 1, \ldots, m-1 \tag{5}$$

These models were first used by Thompson et al. (1990) to improve the discrimination power of the basic DEA model. Since then, such weight restrictions have been applied in various applications, and among them, absolute restrictions on weights or the constraints of type (5) are the most common. They are particularly suitable when there is à priori information on marginal substitution rates between inputs and/or outputs. The difference between multi-criteria decision analysis and DEA is that the former aims to identify the trade-off exactly. At the same time, DEA leaves some weight flexibility, see e.g., Dyson and Thanassoulis (1998). In some applications, models with different weights restrictions were used, i.e., Luptáčik and Nežinský (2022), where they measured income inequalities using MCDM-DEA composite indicator with weights restrictions favoring a higher income share in the lower quantiles. Unlike absolute weight restrictions, Charnes et al. (1990) and Thompson et al. (1990) pointed out that by using relative weight restrictions, different oriented DEA models produce consistent results. The issue of imposing additional a priori weights has attracted considerable attention in the DEA literature; see, e.g., Allen et al. (1997) for a survey.

Data

We use the data from UI GreenMetric World University Ranking (2022). The sample covers 950 universities worldwide, but we focused on the European countries only.

While the sample selection can be subject to discussion, it is not feasible to include just countries comparable in terms of climate, legislation, culture, and other conditions. Therefore, considering the sample size, we included not only members of the European Union but also countries whose territories lie fully or at least partially on the European continent. The number of universities representing one country ranged from 1 to 52. The total size of the dataset used in our analysis is 273 HEIs, with some European countries (including Austria, Belgium, Bulgaria, Norway, Serbia, and Sweden) uncovered, as their HEIs do not participate in the UI GMR initiative, so no data is provided from them.

The methodology of UI-GMR is continuously evolving; in the current performance evaluation tool, they collect data on 39 indicators categorized into 6 groups. The relative performance of the universities is measured by sub-indicators corresponding to these categories, see Table 2.

We took the values of the 6 UI-GMR sub-indicators as the output variables in our analysis. Instead of the weighted aggregation of sub-indicators used by the UI-GMR team, we apply the MCDM-DEA model (1) with constraints (2), (3), or (4) (and (5)). As the weight vector of 2022 Ranking was set to $v = (0.15, 0.21, 0.18, 0.1, 0.18, 0.18)$ by experts of the UI-GMR team, we preserve the order of the weights by imposing the inequalities $v_4 \le v_1 \le v_3 = v_5 = v_6 \le v_2$ as the constraints formulated in (5).

Dimension	Indicators
Setting & Infrastructure	• The ratio of open space area to total area • Area on campus covered in forest • Area on campus covered in planted vegetation • Area on campus for water absorbance • The total open space area divided by the total campus population • University budget for sustainable effort
Energy & Climate Change	• Energy-efficient appliances usage are replacing conventional appliances • Smart building implementation • Number of renewable energy sources on campus • The total electricity usage divided by the total campus population (kWh per person) • The ratio of renewable energy produced to energy usage • Elements of green building implementation as reflected in all construction and renovation policy • Greenhouse gas emission reduction program • The ratio of total carbon footprint divided by campus population
Waste	• Recycling program for university waste • Program to reduce the use of paper and plastic on campus • Organic waste treatment • Inorganic waste treatment • Toxic waste handled • Sewerage disposal
Water	• Water conservation program implementation • Water recycling program implementation • The use of water-efficient appliances (water tap, toilet flush, etc.) • Treated water consumed
Transportation	• The ratio of total vehicles (cars and motorcycles) divided by the total campus population • Shuttle service • Zero Emission Vehicles (ZEV) policy on campus • The ratio of Zero Emission Vehicles (ZEV) divided by the total campus population • Ratio of the parking area to total campus area • Transportation program designed to limit or decrease the parking area on campus for the last 3 years • Number of transportation initiatives to decrease private vehicles on campus • Pedestrian path policy on campus
Education & Research	• The ratio of sustainability courses to total courses/subjects • The ratio of sustainability research funding to total research funding • Number of scholarly publications on environment and sustainability published • Number of scholarly events related to environment and sustainability • Number of student organizations related to environment and sustainability • Existence of a university-run sustainability website • Existence of a published sustainability report

Table 2: Dimensions and partial indicators of UI-GMR index (Source: GreenMetric World University Ranking, 2022)

RESULTS

By applying individual models, we obtained a ranking of universities as an alternative to the UI-GMR ranking. Figure 2 shows scatterplots of evaluations of all units involved in the analysis, comparing the results of our models with the original evaluation. The results of Model 3 are depicted on the right-hand side of the figure, while the left-hand side represents the results of Model 2. The results of Model 1 would correspond to

Electronic ISSN 1803-1617 Printed ISSN 2336-2375

Model 2 with values censored from above at 1 on the vertical axis. The higher similarity of the results of Model 3 with the original evaluation is evident, which corresponds to our expectations.

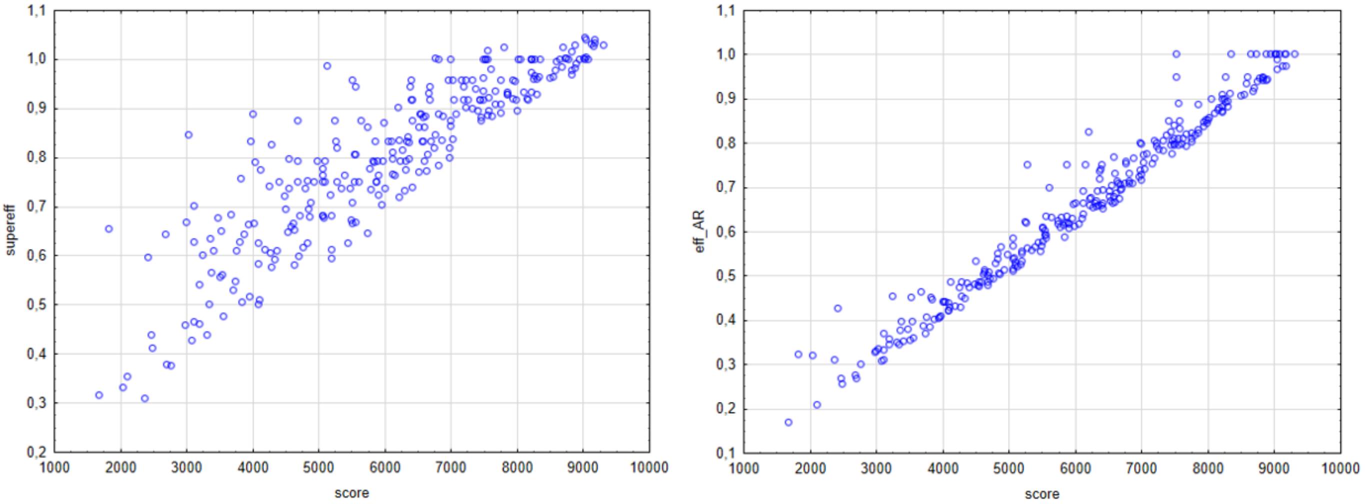

Figure 2: Scores of Models 2, 3 vs. UI-GMR scores (Source: Own calculations)

The Spearman correlation between the results of Model 1 (MCDM-DEA model) and the original UI-GMR ranking of European countries was relatively high, $r_s = 0.95$. However, a drawback of our approach is the inability to compare a large number of universities at the top, as 35 universities reached the highest achievable score of efficiency. Moving to Model 2 (super-efficiency model), we increased the discriminatory power of the analysis, obtaining 16 units with efficiency values higher than one (so-called super-efficient units). In contrast, the ranking of other units remained unchanged. The overview of super-efficient units is presented in Table 3. The rank correlation coefficient between the scores of Model 2 and the original UI-GMR ranking is $r_s = 0.96$.

University	Country	UI-GMR Rank
Wageningen University & Research	Netherlands	1
Leiden University	Netherlands	9
Nottingham Trent University	United Kingdom	2
Universita di Bologna	Italy	8
University of Nottingham	United Kingdom	3
Umwelt-Campus Birkenfeld (Trier University of Applied Sciences)	Germany	5
Politecnico di Torino	Italy	15
University of Groningen	Netherlands	4
Universidad de Alcalá	Spain	22
Perm National Research Polytechnic University	Russia	54
Russian State Agrarian University - Moscow Timiryazev Agricultural Academy	Russia	66
Universita degli Studi di Torino	Italy	17
Universitat Bremen	Germany	7
Kastamonu University	Turkey	11
Universita degli Studi dell'Aquila	Italy	20
Dublin City University	Ireland	103

Table 3: Top-ranked units under Super-efficiency model (Model 2) (Source: Own computations, GreenMetric World University Ranking, 2022)

We achieved the highest level of agreement with the original UI-GMR ranking using Model 3 (AR model), taking into account the order of weight assigned to sub-indicators. The correlation coefficient reached the value $r_s = 0.99$. Similar to Model 1, the maximum score is 1, making it impossible to distinguish the order of units that reach this maximum. Fortunately, only 13 universities are indistinguishable in terms of ranking compared to the baseline Model 1. Table 4 provides an overview of these universities. While the incomparability issue does not arise in the original UI-GMR ranking, the methodology used in our analysis provides far more benchmarking opportunities and recommendations to individual universities.

The dataset includes six Czech universities, so we present their position within the rankings and use them as an example showing how to use the results to derive recommendations for improvement. The applied methodology allowed for the identification of peer units for each university, which opened up space for establishing new cooperation and spreading good practices in the area of social and environmental responsibility. At the same time, we determined dimensions with nonzero slacks that indicate areas with the highest potential for

University	Country	UI-GMR Rank
Wageningen University & Research	Netherlands	1
University of Nottingham	United Kingdom	3
University of Groningen	Netherlands	4
University College Cork	Ireland	6
Leiden University	Netherlands	9
University of Southern Denmark	Denmark	10
Dublin City University	Ireland	11
Hame University of Applied Sciences	Finland	12
Politecnico di Torino	Italy	15
Universidad Complutense De Madrid	Spain	21
University of Eastern Finland	Finland	24
Cyprus International University	Turkey	29
Universita degli Studi di Bari Aldo Moro	Italy	67

Table 4: Top-ranked units under the Assurance region model (Model 3) (Source: Own computations, GreenMetric World University Ranking, 2022)

improvement. They can be interpreted as directions in which university management should concentrate their effort. Detailed information can be found in Table 5. The codes used for the individual dimensions are SI (Setting & Infrastructure), ECC (Energy & Climate Change), WST (Waste), WTR (Water), T (Transportation), and ER (Education & Research). The rankings obtained by Models 1 and 2 are the same as the shift from efficiency to superefficiency, which is order-preserving, and even the scores of nonefficient units remain the same (which is the case of all Czech units in the analysis).

University	UI-GMR rank	Nonzero slacks	Models 1,2	Rank	Model 3	Rank
Czech University of Life Sciences	25	ECC, T	0.996	36	0.950	20
Masaryk University	43	SI, ECC, WST, WTR	0.934	70	0.869	48
Mendel University	128	WST, WTR, T	0.797	150	0.718	119
Palacký University Olomouc	160	SI, WST	0.645	225	0.618	160
University of Hradec Králové	169	WTR, T, ER	0.708	199	0.577	174
Tomas Bata University	209	ECC, WTR, T, ER	0.667	217	0.504	205

Table 5: Scores and rankings of Czech universities (Source: Own computations)

The *Czech University of Life Sciences Prague* (CULS) achieved the highest position in the original UI-GMR ranking, which improved its performance using our DEA-MCDM methodology with one peer unit identified as Politecnico di Torino. The second of Czech universities was *Masaryk University* (MUNI), with two peers from Italy: Politecnico di Torino and Universita di Bologna. Two Italian universities (Politecnico di Torino and Universita degli Studi di Torino) should also be used as a benchmark for the third of Czech HEIs, *Mendel University in Brno* (MENDELU). *Palacký University Olomouc* (UPOL) switched positions with others after the change of methodology; it ranked last among Czech universities in the new evaluation with two Italian peers, Politecnico di Torino, Universita di Bologna, and another peer from The Netherlands: Wageningen University & Research. The ranks of two remaining Czech HEIs remained relatively stable: *University of Hradec Králové* (UHK) with one peer (Wageningen University & Research) was followed by *Tomas Bata University* (UTB) with the same peers as MUNI, Politecnico di Torino and Universita di Bologna.

Based on the Slack analysis, we can identify areas where Czech universities should focus their efforts to improve their performance in the ranking. In Table 5, we can see that the most problematic areas for most Czech universities remain transportation (with the exception of MUNI and UPOL) and water (with the exception of CULS and UPOL). There are also strengths in Czech educational institutions, with particularly strong results in the areas of Setting & Infrastructure (except for MUNI and UPOL) and Education & Research (except for UHK and UTB).

In the last part of the analysis, we compare the performance of universities from different countries and explore its association with the fulfillment of sustainable development goals. First, we present a boxplot of the Model 3 scores of universities in Figure 3 (countries are ordered according to the mean of UI-GMR score). The best results were achieved by universities from the countries at the top positions of the SDG ranking, namely the Netherlands (17.), the UK (11.), Germany (6.), Ireland (9.), Italy (25.), Denmark (2.), and Finland (1.). The number in the brackets represents the country rank among all 163 SDG Ranking 2022 participants (Sachs et al., 2022).

The intensity of the association between UI-GMR performance and the SDG Index can be measured by the Spearman correlation coefficient; in Table 6, we present positive correlations that are statistically significant at the level of 95%. Although the analysis cannot capture the direction of effect or prove causality, it shows a clear positive relationship between university rankings and the SDG index score, showing the level of attainment of sustainability goals in their respective countries.

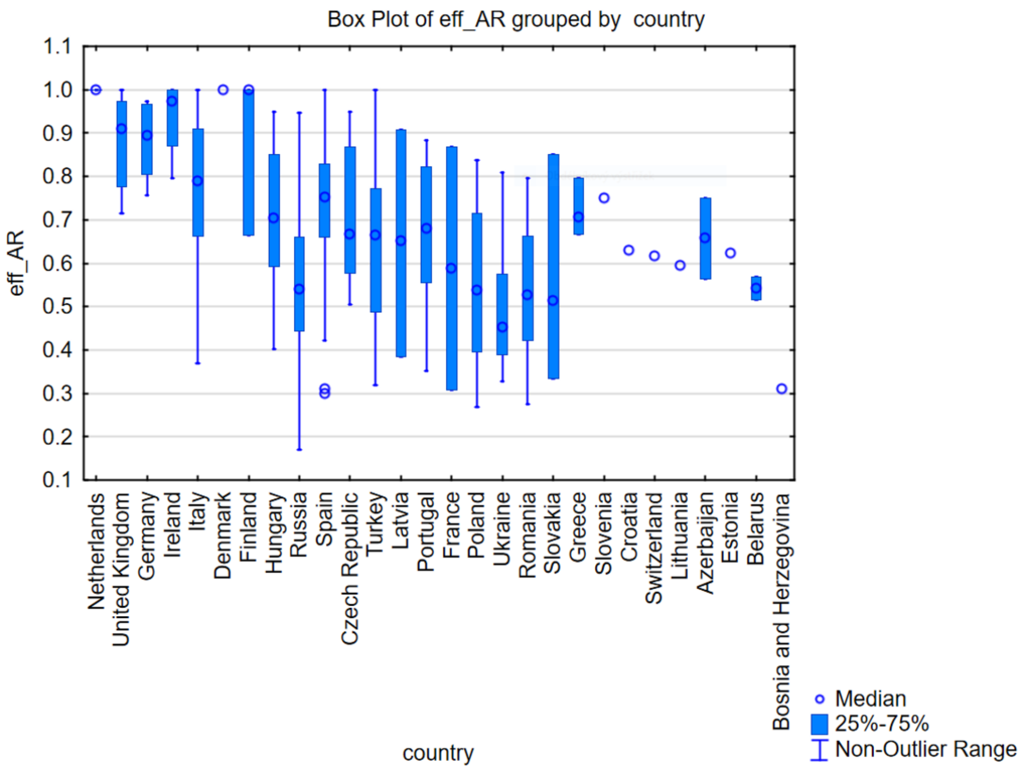

Figure 3: Scores of Model 3 grouped by countries (Source: Own calculations)

SDG index	UI-GMR score	Model 1 score (DEA)	Model 2 score (superef)	Model 3 score (AR)
overall	0.58	0.58	0.57	0.52
Goal 3	0.80	0.76	0.75	0.75
Goal 5	0.52	0.48	0.48	0.46
Goal 6	0.70	0.63	0.63	0.59
Goal 7	0.45	0.46	0.45	0.40
Goal 8	0.50	0.45	0.45	0.48
Goal 9	0.75	0.70	0.70	0.68
Goal 11	0.59	0.55	0.55	0.55
Goal 16	0.62	0.65	0.64	0.64

Table 6: Correlations of UI-GMR score and its alternatives with SDG index (Source: Own computations, Sachs et al. (2022), GreenMetric World University Ranking, 2022)

All methods yield the same results in terms of the sign of the coefficient and its statistical significance. The coefficient values themselves are comparable across methods as well. The strongest correlations are observed for Goals 3 (Good health and well-being) and 9 (Industry, innovation, and infrastructure), followed by Goals 6 (Clean water and sanitation) and 16 (Peace, justice, and strong institutions). Surprisingly, we did not observe a significant correlation between Goal 4 (Quality education) and some of the goals in the area of environmental sustainability. This is noteworthy as one of the common criticisms of the UI-GMR methodology is that it favors environmental goals at the expense of other areas.

An overview of the level of fulfillment of the individual significant SDGs is shown in Figure 4. Here, you can see a generally higher level of goal fulfillment in the northern countries; on the contrary, the worst results can be observed in the southeast. Some of the countries with universities at the top of the UI-GMR ranking also occupy leading positions in the fulfillment of individual SDGs (Finland, Denmark), while others, on the contrary, lag behind in selected goals. As an example, we can name Ireland and the United Kingdom, which have poor performance in SDG7 (Sustainable energy). However, we must point out that this particular goal is largely determined by the geographical and natural conditions of the given country, so it is difficult to influence it through education.

DISCUSSION

There are many studies explaining the potential of HEIs to impact sustainable growth and innovation at the regional level positively. According to research by Fritsch and Aamoucke (2017), the presence of HEIs in a region can benefit regional sustainability by creating and performing new firms. Additionally, the proximity between HEIs and new firms seems to affect the quality of spillovers generated between agents, as Pedro et al. (2022) noted. HEIs should focus on collaborative

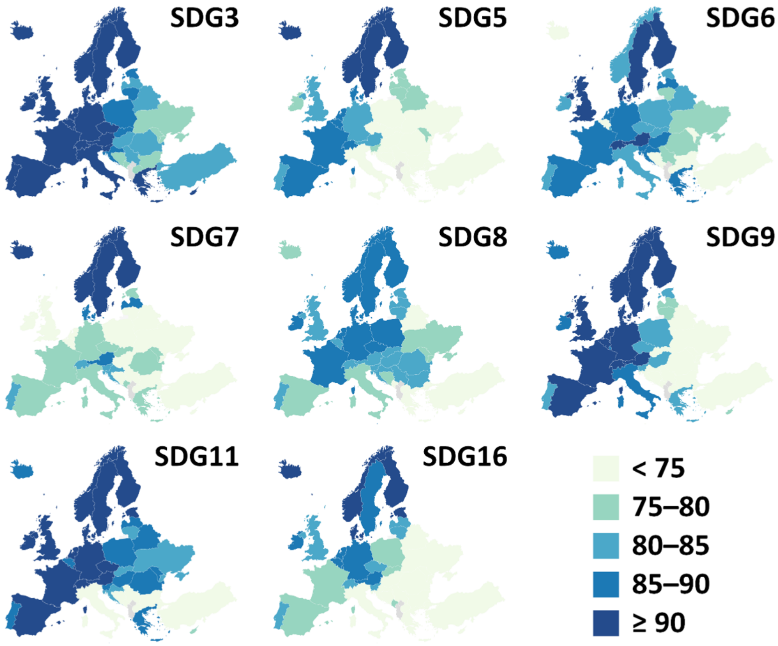

Figure 4: The level of the selected SDGs (Source: Sachs et al., 2022)

activities with industry, government, and society to further reinforce this impact. This can be especially important in structurally weak regions, see Baptista et al. (2011).

Other authors also stress other roles of HEIs beyond the ones mentioned above. According to Kohl et al. (2022), implementing a whole-institution approach toward sustainability could lead to a policymaking role for higher education. HEIs could be more active in policymaking if sustainability was at the core of their own practice. The same authors mention the long-standing tradition of universities' networking to expand knowledge and join forces in teaching, research, and furthering exchange. Hence, the influence of HEIs can be realized through new networks focusing on sustainability, such as the Higher Education Sustainability Initiative (HESI), Association for the Advancement of Sustainability in Higher Education (AASHE), Sustainable Development Solutions Network (SDSN), SDG Accord led by the Global Alliance of Tertiary Education and student Sustainability Networks, etc. In the Czech context, we can mention the UNILEAD project initiated by 24 universities (Masaryk University, 2022). The project aimed to strengthen the role of universities as efficient, responsible, and inclusive public organizations by ensuring more effective cooperation in the transfer of good practices in implementing sustainable development goals.

According to the project participants, „Cooperation between universities and the transfer of good practice helps to remove internal obstacles, whether it is a lack of structure or the belief that it can‘t be better because there is no monitoring and a clearly defined goal for further improvement. In addition, they have the opportunity to approach sustainable development in a truly comprehensive way, rather than limiting themselves to partial measures.“ Other initiatives and declarations are mentioned by Filho (2011), such as COPERNICUS 'Universities Charter on Sustainable Development' (1994), Luneburg Declaration on Higher Education for Sustainable Development (2001), Ubuntu Declaration on Education and Science and Technology for Sustainable Development (2002), Graz Declaration on Committing Universities to Sustainable Development (2005), or G8 University Summit Sapporo Sustainability Declaration (2008). However, the level of formal commitment to concrete efforts resulting from such declarations varies, as mentioned by Filho (2011). The study also mentions results of the survey identifying possible misconceptions preventing universities from the more efficient implementation of sustainable development in their programs and operations, including the following statements: „Sustainability is too abstract“, „Sustainability is too broad“, „We have no personnel to look after it“, „The resources needed do not justify it“, „The theme has no scientific basis“, „There is much competition for funds and resources for sustainability initiatives“.

We hope that insights like the one provided by our study can greatly help the efforts to reach SDG. One of the benefits of the methodology used in our study is the identification of slacks and peer units, which helps to foster the sharing of good practice. Using DEA, the benchmarks are not based upon theoretical bounds but as a linear combination of observed best performances that are close to a unit under evaluation. We have reason to believe that setting achievable targets and comparisons within clusters of similar institutions will serve as a better incentive than if universities were to strive for unattainable goals. The analysis also allows for possible extensions, including dynamic performance evaluation, to measure the progress over time. Similarly, Zaim et al. (2001) proposed a DEA-based aggregate performance index assessing intertemporal performance shifts. Their approach has the advantage of being decomposable into a *catching-up* component, which assesses individual improvement, and an *environmental change* component, which focuses on best practice changes between periods. Consistent assessment of universities‘ progress toward sustainable development is, therefore, a potential area for further research.

Although composite indicators represent a very popular tool for benchmarking performance in various areas, on the other hand, they are often criticized for the subjectivity connected with their construction. Data Envelopment Analysis helps to overcome some issues, particularly the dependence of final results on the preliminary normalization of sub-indicators and the subjective nature of the weights used for aggregating. The analysis can thus provide more acceptable results to subjects under evaluation. The need for flexible weights is evident, especially in a competitive environment or in a context where tensions between the evaluator and individual units may be present. That is why, besides academic contributions, practical applications are also emerging. For example, the European Commission has employed a flexible weighting scheme to assess member states' performance concerning the Lisbon objectives (European Commission, 2004).

While some issues are overcome by the methodology used in our study, others, e.g., those related to using UI-GMR data as mentioned by Ragazzi and Ghidini (2017) or Lauder et al. (2015), remain unaddressed. The key limitations and potential areas for improvement are the selection of sub-indicators and the number of universities participating in the GreenMetric Ranking survey. Possible broadening of the scope and the extent of the survey can bring more relevance to the results and conclusions. As mentioned by Boiocchi et al. (2023), some UI-GMR sub-indicators need to be more adequate for effectively and fairly measuring sustainability development; others require contextual adjustments.

Ranking universities based on sustainable development is a sensitive and complex task that requires careful consideration of context-specific factors. Universities operate in diverse environments, each facing distinct challenges in their pursuit of sustainability. Neglecting the heterogeneity among HEIs can lead to inherently biased results, potentially causing misleading rankings that impact universities' reputations. So, this opens up another promising path for future research in this area: to focus on addressing the heterogeneity of the DMUs. A notable advantage of the DEA-based ranking construction is the possibility of incorporating relevant geographical and socio-economic factors directly into the computational model. The strategies to achieve this are well described in the scientific literature, e.g., Banker and Natarajan (2008). Homogenizing the data plays a crucial role in ensuring that universities are evaluated fairly and meaningfully, and only when considering contextual factors in the analysis can we understand the unique challenges and opportunities that each university encounters.

CONCLUSIONS

The attainment of the Sustainable Development Goals necessitates the active involvement of all stakeholders. This requires having the skills and mindsets t o contribute to the challenges on the path towards sustainability. Universities are influential institutions and can serve as opinion leaders. When they adopt certain practices, they inspire and provide models for other segments of society to adopt and emulate. By studying HEIs' social and environmental responsibility in different institutional and regional contexts, we can gain new insights into their contributions at the regional and national levels, leading to sustainable economic development and promoting innovation and technological entrepreneurship.

It is desirable for the sustainability aspects and considerations presented above to be disseminated further into the awareness of authorities and creators of recognized rankings like THE or the QS World Ranking. These rankings are often seen as proxies for quality and are also used as marketing tools. Placement in a prestigious ranking can significantly increase the number of high-quality students HEI attracts and, consequently, boost its influence on the economy and society. If the university's contribution to SDG goals attainment becomes a direct component of recognized evaluations (e.g., in the form of an expansion of THE Impact ranking), it may act as an inhibitor for their more vigorous promotion. For instance, governments and educational authorities may be more inclined to allocate resources to HEIs that excel in sustainability rankings, thereby promoting environmentally responsible policies at both the institutional and national levels. Furthermore, when sustainability is a prominent factor in rankings, it sends a clear signal to HEIs that integrating sustainability into their curricula is socially responsible and advantageous in terms of their overall performance and reputation. This, in turn, leads to the development of new courses and study programs, equipping students with the knowledge and skills needed to address pressing global issues. In sum, sustainability evaluation and ranking of HEIs go beyond just measuring social and environmental responsibility. They catalyze change, drive policy reforms, inspire curriculum adjustments, and promote sustainable institutional practices.

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