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Analysis of the impact of university policies on society's environmental perception

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ABSTRACT

Today's society is showing great interest in achieving sustainable development in all socio-economic facets, and higher education institutions stand out as being proactive in this regard. University campuses are successfully implementing policies to curb climate change, energy and water conservation, waste recycling and green transport. In this struggle, education plays an essential role in shaping a population that is aware of the situation and willing to stop —and if possible undo— the damage caused. This study is aimed at evaluating universities' capacity to foster society's environmental perception and commitment. The analysis, which focuses on the Spanish and Italian campuses assessed by GreenMetric during the period 2018–2022, has a twofold objective: to identify the sustainable actions that have a direct impact on students' and researchers' awareness; and to analyse the efficiency of the environmental policies implemented by those responsible for these educational centres, as well as the differences between the two countries' universities. To that end, a panel data model is estimated on a sample composed of the pillars of GreenMetric, with DEA-bootstrap and the sequential Malmquist index then used to assess the efficiency of the actions undertaken. The results reveal the importance of the waste and transport policies implemented on campuses when it comes to the arduous task of kindling society's interest in the environment. Furthermore, both countries show increasing engagement, with productivity improvements of over 36% in the case of Italy.

1. Introduction

Twenty-first century society is facing an unprecedented challenge: it must curb climate change (CC) to protect the planet from irreversible damage that could hinder the development of everyday life. Major socioeconomic transformations are needed to ensure we reach the turning point at which sustainable development can be guaranteed [1]. According to Sarkodie and Strezov [2], the implementation of the required adaptation strategies is strongly conditioned by the level of development, meaning that in Africa, for example, it is difficult to fulfil the task of mitigating CC.

The consequences of CC know no borders: all territories are suffering the effects of the relentless rise in global warming [3,4]. However, society does not have a homogeneous perception of these impacts: the socio-cultural and territorial milieu provoke widely differing reactions [5,6]. In places where high temperatures, pollution, drought, floods, and so on are causing countless losses, inhabitants are more aware of the seriousness of the problem [7,8]. Authors such as Yazar et al. [9] demonstrate that race, income, proximity to green spaces, place attachment and political ideology influence citizens' climate vulnerability. Etana et al. [10] claim that this feeling of risk is also influenced by the cultural level of society. It is impossible to fight against the unknown; educational strategies play a fundamental role in raising the alarm about the present danger, and pointing to possible actions to combat it [11].

Basic issues related to knowledge about CC and how it affects the population shape the intensity of mitigation and adaptation decisions and actions [12]. Humanity finds itself faced with a complex issue and armed with limited powers; it needs a joint learning process for educators and students that stimulates critical thought and drives the implementation of decisive actions [13]. Environmental literacy, which refers to cognitive knowledge, sustainable values and ecological behaviour, facilitates a change in behaviour and attitudes, and helps to address the consequences of CC [14]. It is about educating citizens and raising their awareness of the problem from an early age.

The Sustainable Development Goals (SDGs) seek to promote

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sustainable development in alignment with environmental protection, among other things, as a way to safeguard the future of the planet. Specifically, SDG13 is focused on Climate Action, the success of which lies in environmental education (EE) as set out in target 13.2 [15]. More than 50 years ago, Stapp [16] defined the concept of EE as being aimed at educating citizens on issues related to the biophysical environment and its associated problems, as a way of motivating them to play a part in reaching a solution. It is about achieving universal participation, to which end it is necessary to develop and improve environmental attitudes, values and knowledge [17].

The scientific community has reacted positively to the importance of cultivating a climate-focused culture, producing an extensive literature aimed at defining the actions needed to raise people's interest. Recent publications have covered issues such as environmental literacy [18,19], education policies [20,21], learning systems [22,23] and educational institutions [24,25], with studies providing pertinent conclusions that enable a better understanding of the central objectives and help guide decision-makers on the actions to be taken. Glackin and King [26] examine EE policies and identify a prevalence of learning *about* the environment rather than *for* the environment. Universities demand innovative methods, with mitigation being incorporated into all subjects, while encouraging teachers to share experiences [27].

Citizens' awareness shapes their actions; hence the importance of offering an education defined by the search for environmentally-friendly activities. This research provides evidence of the association between the "green management" of universities and the EE activities implemented. Thus, the objective of the paper centres on the analysis of pro-environmental activity in the universities of two Mediterranean countries, Spain and Italy, which a priori can be expected to show similar behaviour as they are subject to the same European regulations on CC. The study, which is conducted using statistical information from the GreenMetric index for the period 2018–2022, provides answers to the following questions.

Q1. Which actions by universities promote environmental awareness?

Q2. Are there differences between the levels of sustainability efficiency achieved by Spanish and Italian universities?

The study is conducted by first estimating a panel data model in which environmental strategies explain the implementation of environmental teaching as well as the development of research carried out to guarantee sustainability. Second, the efficiency levels reached and the productivity changes that have occurred are calculated using a variant of the Data Envelopment Analysis (DEA) method, DEA-Bootstrap, and the Sequential Malmquist Index (SMI) respectively.

The results represent a novel contribution to the literature and can be used to guide the sustainability policies implemented as part of universities' internal management. They offer a detailed assessment of the actions carried out by the educational centres that are most involved with environmental education, they are extending the research of Atici et al. [28] where the Greenmetric pillars of academic performance in any educational setting are analysed. This will facilitate the identification of aspects that need reinforcing in order to further foster the environmental perception of the future managers of countries' economic activities. Additionally, the distinct focus on efficiency, calculated on the basis of environmental variables, represents a move away from the purely academic assessment traditionally applied in universities [29–31]. In particular, Agasisti and Perez-Esparrells [32] compare the efficiency of Italian and Spanish universities in a purely academic environment. The proposed paper focuses on the sustainable development implemented by higher education institutions, which is vital for society.

The paper is structured as follows. In section 2, a literature review is conducted to determine the progress made by educational centres in their efforts to convey the importance of achieving sustainable development. The methods and variables used are presented in section 3. The results of the research are analysed in section 4. Lastly, the conclusions, the contribution of the study and the limitations are summarized in section 5.

2. Literature review

The greatest challenge currently facing humanity is how to slow CC and implement the necessary actions. It requires the active involvement of all economic sectors all over the world. The actions of an isolated group will never be enough to achieve the desired results [33]. It entails changing consumption habits in order to reduce greenhouse gas emissions through the efficient use of resources, along with the transition to renewable energy [34]. The greater people's willingness to change their carbon-emission-generating routines, the more effective the public interventions aimed at CC mitigation will be [35].

This process of global transformation aimed at meeting the different goals set out in the international agreements on CC comes at a high cost [36]; as such, the population's environmental awareness is a key determinant of countries' willingness to collaborate to this end [37]. Thus, the social perception of the problem shapes the possible application of climate policies, which is influenced by principles and lived environmental experiences [38]. Hence, social, economic and governance readiness determine countries' differing degree of vulnerability to CC [39]. Azócar et al. [40] point to the relevance of education in this global metamorphosis. EE is one of the six key areas established by the United Nations Framework Convention on Climate Change [41], along with training, public awareness, access to information, participation and international cooperation.

The literature has revealed disagreements regarding the relationship between educational level and an appreciation of the risks associated with CC. Authors such as Owusu et al. [42] claim there is a positive association between the two concepts, contradicting the results of Hori and Shaw [43] and Boer et al. [44]. The source of these differences lies not only in people's erroneous and limited understanding. Of the problem, which is heavily influenced by the media, but also in the ineffective didactic approaches used to affect students' behaviour [45]. Jorgenson et al. [46] focus on the need to promote the training of educators who can convey the importance of collective action, multi-actor networks and innovation to foster environmental management. CC should be studied in classrooms as a human issue, within an integrated framework of social, language and literature studies, to prevent it from being exclusively associated with science subjects [47]. Educational programmes that can address the different socio-cultural profiles, values and interests of the students are also recommended [48].

Humankind's changing needs have forced universities to continuously adapt, while remaining committed to social innovation in teaching and research, in an effort to benefit communities [49]. Therefore, higher education institutions have been compelled to promote environmentally sustainable objectives and practices [50]. They follow a two-pronged strategy: working to become emission-free institutions, and to introduce environmental issues into their teaching [51]. In short, the aim is to offer educational services oriented to the social good, with universities bearing a huge responsibility for educating a society committed to CC mitigation [25]. In the long term, this citizen awareness can spread to all sectors of society, resulting in a world capable of combatting harmful activities. To do all this, however, it is necessary to break free from organizational inertia and the rules associated with governance—issues that sometimes constitute barriers that are difficult to overcome [52].

Since CC affects multiple aspects of sustainable development, some studies combine CC education and education for sustainable development. According to Bushell et al. [53], universities should get to heart of the problem and avoid focusing on more trivial issues relating to sustainability. The importance of this task requires global engagement from all higher education institutions, with managers, faculty members and administrative staff carrying out joint activities at the level required by the commitment made.

In this area, the GreenMetric index is extremely useful for decision-makers, as it provides a homogeneous assessment of the degree of environmental engagement of universities around the world. The results indicate the strengths and weaknesses of the different educational centres when it comes to raising public awareness [54]. The concept of a “green university” should be carried over to the institutions as a whole, going beyond teaching and research activities to delve into environmentally-friendly services that stimulate students’ environmental perception. Atici et al. [28] argue that the sustainability policies applied by the management of these institutions are an important way for them to improve their international competitiveness. All the dimensions are relevant and increasingly form part of universities’ strategic plans, where issues such as waste management, green buildings or sustainable mobility are included alongside an academic offer centred around CC mitigation [55].

3. Data and methodology

To fulfil the proposed research objective, different methodologies are applied sequentially, providing answers to the questions raised (Fig. 1). The aim is to determine, first of all, which activities carried out on campus are stimulating the community’s environmental perception, measured in terms of the demand for environmental courses or research carried out on issues related to CC mitigation. The analysis then turns to the efficiency of the sustainability actions implemented by those in charge of the educational centres, aimed at making them environmentally-friendly places, raising public awareness, and setting an example for all the other socioeconomic sectors in the country to follow.

3.1. UI GreenMetric’s Spanish and Italian universities

UI GreenMetric, produced by Universitas Indonesia since 2010, evaluates universities’ degree of engagement with CC in their quest to become “green”, while educating future decision-makers. The global score is calculated from the individual assessments of six dimensions with different weightings: (1) Setting & Infrastructure (15%), the centre’s overall climate policy; (2) Energy & CC (21%), the energy efficiency of the buildings; (3) Waste (18%), waste treatment; (4) Water (10%), water use optimization programmes; (5) Transportation (18%), supporting an environmentally-friendly transportation system; (6) Education & Research (18%), students’ and researchers’ concern about the climate. In sum, this index offers a uniform assessment of more than 900 campuses, computing for each one the degree of engagement with the sustainability issues of the day, and pointing to the strengths and weaknesses around which the future actions of each centre can be oriented. The wide-ranging scientific output produced on the basis of this index supports its use here [28,56–58].

Specifically, in this research we use the UI GreenMetric statistics for Spanish and Italian universities assessed during the period 2018–2022. Greenmetric divides university campuses by typologies (urban and rural) and size. In this paper, all types of campuses have been used. In order to have a balanced sample, we have had to eliminate campuses lacking information for any of the years in the analysed period. The sample has thus been reduced to 24 Spanish and 20 Italian universities

Fig. 1. Research stages.

for the five-year period. The descriptive statistics for those universities are shown in Table 1.

The descriptive statistics show the superior performance of the Italian campuses during the period 2018–2022: they register a maximum total score of 9050 points compared to their Spanish counterparts with 8700. However, the dispersion of the Italian sample is almost 200 points higher (Italian SD 1458, Spanish SD 1270), attesting to the variety in the profile of the evaluated institutions. Focusing the analysis on the dimensions, it can be seen that the management of certain Italian universities has allowed them to reach the established target levels in some cases; specifically *Waste* (1800), *Water* (1000), *Transportation* (1800) and *Education & Research* (1800), while Spanish universities do so in only two dimensions, *Waste* and *Education & Research*.

These results reveal that some universities in both countries have managed to spark students’ and researchers’ interest in environmental issues, with the sustainability courses offered and scientific output in this discipline reaching the target of 1800 points. However, there is significant variation in this dimension: other universities in Spain and Italy have scored only 525 and 300 points, respectively, reflecting the need for greater involvement by their managers.

3.2. Methodology: panel data regression, DEA-bootstrap and Sequential Malmquist Index

Panel data models are traditionally estimated from generalized least squares (GLS), yielding efficient estimators. However, Hahn et al. [59] indicate that when the covariance matrix is unknown and needs to be estimated, the GLS method is not feasible, and the Feasible Generalized Least Squares (FGLS) technique is more suitable. This methodology can simultaneously address the problem of heteroscedasticity and serial correlation. In this way, the data have been subjected to various econometric tests to identify the most appropriate way to obtain reliable and robust estimators, seeking to avoid problems related to autocorrelation and heteroskedasticity.

First, the Breusch-Pagan test, also known as the Lagrange multiplier test for random effects, is applied in order to determine whether it is more appropriate to perform an estimation with Pooled OLS or a random effects panel data regression [60]. Second, the Wooldridge test checks for autocorrelation [61], while the modified Wald test is used to identify heteroskedasticity [62,63]. If the tests confirm the presence of both problems, the estimation of a panel model with fixed or random effects would lead to biased results, meaning it would be more appropriate to use FGLS. This method has recently been successfully applied in very different contexts: poverty of rural households [64–66], green energy consumption [67] and environmental innovation [68], among others.

The study of the association between the “green management” of universities and environmental learning and research activities is based on the estimation of the following equation,

$$Ln(E\&R_{it}) = \beta_0 + \beta_1\, Ln(SI_{it}) + \beta_2\, Ln(ECC_{it}) + \beta_3\, Ln(WS_{it}) + \beta_4\, Ln(WT_{it}) + \beta_5\, Ln(TR_{it}) + \omega_0 \tag{1}$$

where, *E&R*, Education & Research; *SI*, Setting & infrastructure; *ECC*, Energy & CC; *WS*, Waste; *WT*, Water; *TR*, Transportation; ω, i, and t are the error term, universities, and time, respectively.

Next, the efficiency analysis has been carried out using DEA-bootstrap. DEA is a non-parametric technique that can be used to measure the relative efficiency of decision making units (DMUs) based on the construction of a production function formed by various inputs and outputs. There are two possible orientations: maximizing the volume of outputs that can be produced with the available inputs (output-orientation); or vice versa, minimizing the use of resources needed to reach a certain level of output (input-orientation). The original proposal was put forward by Charnes et al. [69], who developed the model under the assumption of constant returns to scale, where there is a constant

Table 1
Descriptive statistics of UI GreenMetric's Spanish and Italian universities (2018–2022).

	Spanish universities						
	Total Score	Setting & Infrastructure	Energy & CC	Waste	Water	Transportation	Education & Research
Min	2775	200	375	600	10	235	525
Max	8700	1300	2025	1800	900	1500	1800
Media	6395	783	1333	1309	580	1073	1324
SD	1270	255	284	327	169	268	280
Nº obs.	120	120	120	120	120	120	120
	Italian universities						
	Total Score	***Setting & Infrastructure***	***Energy & CC***	***Waste***	***Water***	***Transportation***	***Education & Research***
Min	2175	125	200	450	10	325	300
Max	9050	1325	1975	1800	1000	1800	1800
Media	6641	811	1234	1459	586	1206	1345
SD	1458	286	392	284	276	334	293
Nº obs.	100	100	100	100	100	100	100
Target	**10,000**	**1500**	**2100**	**1800**	**1000**	**1800**	**1800**

proportional relationship between inputs and outputs. Based on that model, Banker et al. [70] addressed the calculation of efficiency in an environment of variable returns to scale (VRS), allowing the dimensions of the DMUs to vary.

The inputs and outputs used measure university management. In some cases, they are qualitative variables meaning stochastic noise could influence the result. To avoid this problem, we propose a variant of DEA, DEA-bootstrap, which calculates the score by resampling, thus bypassing stochastic noise, thus ensuring the result is closer to reality [71]. Given the characteristics of the variables used, we have opted for a VRS output-oriented model, meaning that the inefficiency identified is the result of poor use of the inputs. We have also had to change the inputs into "values to improve" by subtracting the corresponding value from the target set for each indicator [72]. The efficiency level can take a value of one (maximum efficiency) or an amount over 1 indicates inefficiency; specifically, how much the output must improve to be completely efficient. To prevent isolated events from leading to erroneous conclusions, an intertemporal analysis has been conducted. The comparison between the analysed universities is also facilitated by the construction of a single production possibilities frontier [73–75].

Finally, the changes in productivity have been calculated using the SMI, avoiding the possibility of technological regress that would derive from the application of the original MI [76]. The SMI can take values greater than, equal to or less than one, where the amount in excess of unity represents the growth in productivity that occurred during the analysed period. This improvement may stem from technological advances as a result of innovation (technological change, TC), and/or to progress in efficiency levels as a result of better use of available resources (efficiency change, EC).

Both DEA and the MI have been well received in the scientific community. They have been successfully applied in a wide range of fields such as education [77,78], innovation systems [79,80] and even issues related to CC [81,82]. The calculations have been carried out using the DeaR statistical package, a library developed for R Studio [83].

4. Results and discussion

Universities are obliged to promote sustainable practices in order to reduce their carbon footprint and contribute to the fight against CC. This study seeks to determine whether the environmental policies implemented by higher education institutions (*Setting & Infrastructure, Energy & CC, Waste, Waster, and Transportation*) have raised the awareness of students and researchers (*Education & Research*). The dependent variable, *Education & Research*, refers to the number of courses offered and research activities in the field of sustainability, the demand for which is influenced by the engagement of all members of the university community [84]. In this context, the evidence provided allows us to answer the questions raised.

Q1. Which actions by universities promote environmental awareness?

The optimal procedure for estimating equation (1) is FGLS, due to the presence of autocorrelation and heteroskedasticity in the data. The Breusch-Pagan test supports the use of panel data rather than pooled-OLS for the estimation. The Wooldridge test and Wald test identify the existence of autocorrelation and heteroskedasticity, respectively (p-value: 0.000). In addition, the presence of multicollinearity between the variables used has been ruled out (Table 1A, appendix). The results in Table 2 reveal the influence of the dimensions *Energy & CC*, *Waste*, and *Transportation*, all of which turn out to be significant and positive.

The coefficients have been standardized in order to be able to adequately assess the package of environmental policies that has the greatest impact on the *Education & Research* of the university population. In this respect, *Waste* has the strongest relationship with *Education & Research* (0.1117), followed by *Energy & CC* (0.0781), and *Transportation* (0.0477). *Waste* is associated with the installation of sustainable waste management systems on campuses. It is found to have a major influence on environmental awareness, leading to an increase in the demand for teaching and research in this area. Perchinunnoa and Cazzolle [85] also confirm the close relationship between *Waste* and *Education & Research*. They find that, according to the GreenMetric assessment, the most sustainable campuses have high scores in both dimensions. These results complement the analysis by Atici et al. [28] of the factors that have the greatest impact on academic performance, which shows *Waste* to be the

Table 2
FGLS regression results.

Variables	Standardized coefficients
Ln (SI)	−0.0004
Ln (ECC)	0.0781***
Ln (WS)	0.1117***
Ln (WT)	−0.0133
Ln (TR)	0.0477***
Wald Chi2(6)	377.5
Prob > chi2	0.000
Breusch-Pagan Lagrange multiplier test for random effects	60.65 (p-value: 0.000)
Wooldridge test for autocorrelation in panel data	14.54 (p-value: 0.000)
Modified Wald test	8014.42 (p-value: 0.000)

Note (1): Dependent variable: Education & Research. Note (2): ***p < 0.01.

most influential, followed by *Transportation* and *Water*. According to Mohamed et al. [86], all universities carry out campaigns and activities related to waste management, achieving a high success rate with a relatively simple implementation process.

The dimension *Energy & CC* assesses university policies aimed at boosting the energy efficiency of buildings, while also protecting nature and the resources to mitigate CC. The results reveal that these measures raise the awareness of the university community, such that members show greater interest in EE. The energy sector is one of the biggest contributors to CC, hence the interest in developing the expertise needed to ensure efficient management [46]. In order to reinforce this dimension, Molthan-Hill et al. [52] propose concrete actions, such as including carbon literacy in curricula and reducing energy costs. Furthermore, they consider it necessary to introduce interdisciplinary options to integrate CC education into all disciplines. Filho et al. [25] advocate support for creative educational approaches that include corporate social responsibility, multiculturality and ethics. In short, it has been shown that CC education programmes contribute to reducing emissions [87].

Lastly, the *Transportation* dimension evaluates the measures implemented on campuses to limit the number of vehicles, promoting the use of public transport and bicycles. Transport is one of the main causes of greenhouse gas emissions [88]. The aim here is to cultivate a healthy climate while reducing universities' carbon footprint. The estimation shows that sustainable transport management raises the interest of students and researchers. Safarkhani and Örnek [89] corroborate its importance, recommending some specific measures to promote on campuses: using zero-emission vehicles, constructing pedestrian walkways, limiting parking areas, and providing shuttle buses to reduce the use of private cars.

Having identified the dimensions *Waste, Energy & CC* and *Transportation* as factors that influence *Education & Research*, we now use these as inputs and as the output, respectively, to calculate the sustainability efficiency levels and thus answer the second question raised. In this stage of the research, we compute the levels of efficiency and productivity in terms of sustainability for all Spanish and Italian universities during the period 2018–2022.

> Q2. Are there differences between the levels of sustainability efficiency achieved by Spanish and Italian universities?

Table 3 shows the results of the intertemporal DEA-bootstrap corresponding to the mean values for the total sample (Spanish and Italian universities) and the two groups separately, allowing us to evaluate the differences between them. The universities in question are all located in two European Mediterranean countries, and according to Agasisti and Perez-Esparrells [32], they have similar intrinsic components, meaning they constitute an appropriately homogeneous sample to perform the analysis.

The values of the efficiency levels are higher than unity, with the amount in excess indicating how much the *Education & Research* dimension needs to improve to be completely efficient with the inputs used (*Energy & CC, Waste* and *Transportation*). On average, no notable differences are observed between the two countries: Spanish universities would have to improve their output by 45% to be efficient, compared to 47.4% for Italian universities. This better performance of Spanish

Table 3
Efficiency levels, DEA-bootstrap (2018–2022).

	Total	Spanish universities	Italian universities
Mean efficiency	1.461	1.450	1.474
Max efficiency	1.075	1.075	1.103
Min efficiency	2.738	2.410	2.738
Standard deviation	0.324	0.322	0.336
N° universities	220	120	100

universities compared to Italian universities differs from the results of Agasisti and Perez-Esparrells [88]. In their efficiency approach to purely academic performance, Italy outperforms Spain. In addition, there is wide dispersion in both Spain and Italy (0.322 y 0.336, respectively), highlighting the lack of uniformity in the actions undertaken. Some universities' sustainability policies have achieved high efficiency levels (1.075 in Spain and 1.103 in Italy), whereas others need to rethink these policies because they are not generating the desired results (2.410 and 2.738 in Spain and Italy, respectively).

No-one is exempt from the responsibility to mitigate CC. Universities must collaborate by developing activities focused on this task. In addition, their role as centres of learning means they have to shape a society committed to protecting the planet. Their actions should thus be focused on raising the awareness of the university community [90]. Nevertheless, the results show that there are still some universities whose policies are not achieving this goal; they need to restructure their policies to reach the desired levels of efficiency. According to the UNESCO report [91], the idea that quality education should revolve around the concepts of sustainable development is attracting ever more adherents. CC is the primary challenge facing humanity, but we have yet to arrive at a uniform perception of the problem [92].

The universities that are lagging furthest behind (Universitat de les Illes Balears in Spain with 2.410, and Universita di Macerata in Italy with 2.738) should observe and try to emulate the actions carried out by centres such as Universidad Autónoma de Madrid (UAM) or Universita degli Studi di Torino (Table 2A, appendix). These universities are shown to have implemented highly effective sustainability policies, agreeing with Puertas and Marti [93], where Universita degli Studi Dell'aquila was the university of reference to 175 universities. Indeed, in order to be completely efficient, they need only improve their offer of environmental courses and research by 7.5% and 10.3%, respectively. Specifically, the UAM has a long tradition of contributing to sustainability in its teaching, research and operations. This institution has promoted several projects focused on ensuring compliance with the SDGs in the university system [94]. Ultimately, educational centres must show the commitment needed to train society in sustainable skills, values and behaviours. It has been shown that certain policies implemented in universities kindle society's desire to mitigate CC.

In order to delve deeper into identifying patterns of performance in university models, we explore the potentially significant differences between the GreenMetric dimensions corresponding to the universities classified according to their efficiency (Table 4). Using the Kruskal-Wallis test, we have identified whether the policies implemented by the campuses with the highest level of efficiency (efficiency score >0.7) are significantly different from the rest (efficiency score <0.7). The efficiency score has been calculated using Shepard's distance, that is, the inverse value of the efficiency level (1/value).

The results of Chi-squared (p-value <0.05) show that all the dimensions have turned out to be significant, revealing substantial differences between the variables for the most and least efficient universities. In the Spanish universities, the most efficient centres register values for their sustainable activities that surpass the others by more than 25%, reaching 40% in *Education & Research* (1481.47 points versus 1060.61). This means that the Spanish centres with the highest efficiency level offer more courses in which the contents are related to sustainability. Similarly, in Italy there are notable differences, particularly a difference of 31% in *Energy & CC* (1382.55 points versus 1052.89), indicating that more efficient institutions make more investments in energy-efficient appliances usage, implementation of intelligent buildings, renewable energy usage policy, total electricity usage, climate change adaptation and mitigation programs. The universities lagging furthest behind should promote sustainability by following the example of those that hold the top positions.

Next, the SMI is used to calculate the productivity growth of universities during the period 2018–2022. By so doing, we can identify the source of the progress and discern where to focus in order to achieve

Table 4
Kruskal-Wallis test on the dimensions of the GreenMetric index.

	Mean dimension score Eff. score <0.7	Mean dimension score Eff. score >0.7	Kruskal-Wallis Chi-squared (p-value)
	Total		
Energy and CC	1102.72	1416.35	44.484(0.000)
Waste	1226.67	1481.54	30.059(0.000)
Transportation	987.56	1234.77	29.753(0.000)
Education and Research	1126.53	1476.23	78.147(0.000)
N° universities	18	26	
	Spanish Universities		
Energy and CC	1152.56	1441.13	26.325(0.000)
Waste	1115.00	1426.00	22.037(0.000)
Transportation	929.44	1159.13	15.831(0.000)
Education and Research	1060.61	1481.47	62.294(0.000)
N° universities	9	15	
	Italian Universities		
Energy and CC	1052.89	1382.55	17.600(0.000)
Waste	1338.33	1557.27	13.181(0.000)
Transportation	1045.67	1337.91	18.483(0.000)
Education and Research	1192.44	1469.09	21.197(0.000)
N° universities	9	11	

improvements. We again use the Kruskal-Wallis test to check whether there are significant differences between the changes that occurred in the Italian and Spanish universities (Table 5).

The results in Table 5 show notable advances in productivity in both countries: 36% in Italy compared to 13.5% in Spanish campuses. This is mainly due to technological improvements (TC, 34.1% and 27.4%, respectively). Conversely, both Italian and Spanish universities have paid less attention to making progress in efficiency (EC), with the former registering gains of only 1.9% and the latter even deteriorating by 10.9%. The Kruskall-Wallis test confirms the existence of significant differences in productivity change due to different EC performance.

Overall, the results show that the actions of Spanish universities are more appropriate for raising public awareness, with the UAM particularly standing out. In addition, there is growing interest in improving productivity through the introduction of innovative advances, sometimes supported by European climate policies [95].

5. Conclusions

Higher education institutions have an obligation to educate the population on sustainable values, giving people the capacity not only to mitigate CC but also to reverse the damage caused. With this objective, universities are introducing environmentally friendly practices into various aspects of their operations, such as waste management, water saving, or sustainable transport, among others measures, aspiring to become carbon-neutral institutions. However, the relevance of these policies curbing CC, also they should be for them to become appropriate instruments for raising the awareness of the university community and the general public. The focus of the research has been limited to the Spanish and Italian universities evaluated by the GreenMetric during the period 2018–2022, in order to ensure that isolated issues do not lead to erroneous conclusions.

The results obtained confirm that these institutions sometimes diverge from the established target. They should review the actions aimed at water saving and the development of sustainable buildings, which are not currently being implemented in university communities. The demand for sustainability education and the research carried out in this field are being driven by other policies, such as waste management, energy and transport. Furthermore, it has been found that all the universities analysed have made productivity gains, even if the starting point was less than ideal. Technological advances have been the driving force, with the introduction of innovative sustainable practices that have facilitated the progress achieved. However, the need to improve the efficiency of the use of available resources has been largely overlooked.

When comparing universities, Spanish ones are seen to perform slightly better, although overall they leave a lot of room for improvement. While some universities, such as UAM or Universita degli Studi di Torino, have been found to show near-maximum levels of efficiency, others require profound changes. An in-depth analysis of these two institutions is needed in order to facilitate the implementation of the most appropriate sustainability policies; that is, to make these universities models of the behaviour to be emulated by the universities lagging furthest behind.

Author statement

Rosa Puertas: Conceptualization, Methodology. Luisa Marti: Data curation, Writing- Original draft preparation. Jose Manuel Guaita: Supervision. Rosa Puertas, Luisa Marti and Jose Manuel Guaita: Writing- Reviewing and Editing.

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- "Renewable energy production capacity and consumption in Europe" *Science of the Total Environment* (2022)

- "Analysis of compliance with the Sustainable Development Goals at the municipal level: the case of Spain and Italy", *Sustainable Development* (2022)
- "Eco-innovation and determinants of GHG emissions in OECD countries", Journal of Cleaner Production (2021)

Data availability

I have shared to link to my data

Table 5
Results of the SMI and Kruskal-Wallis test (2018–2022).

	SMI	TC	EC
	Mean value by nationality of universities		
Total	1.240	1.305	0.950
Spain	1.135	1.274	0.891
Italy	1.366	1.341	1.019
	Kruskal-Wallis Test		
Chi-squared	12.836	1.773	10.427
p-value	0.000	0.183	0.001

Appendix

Table 1A
Correlation matrix

	SI	ECC	WS	WT	TR	E&R
SI	1					
ECC	0.434	1				
WS	0.467	0.443	1			
WT	0.405	0.608	0.455	1		
TR	0.484	0.584	0.637	0.490	1	
E&R	0.415	0.591	0.632	0.504	0.621	1

Note: SI: Setting & Infrastructure; ECC: Energy & Climate Change; WS: Waste; WT: Water; TR: Transportation; E&R: Education & Research.

Table 2A
Efficiency levels of Spanish and Italian universities (2018–2022)

Spain	Efficiency	Italy	Efficiency
Universidad Autónoma de Madrid	1.075	Universita degli Studi di Torino	1.103
Universitat Politècnica de València	1.129	Politecnico di Milano	1.193
Universidad de Alcalá	1.166	Universita di Bologna	1.210
Universidad de A Coruña	1.169	Politecnico di Torino	1.215
Universitat de Valencia	1.173	Universita degli Studi dell'Aquila	1.324
Universidad Rey Juan Carlos	1.183	Università degli Studi di Salerno	1.367
Universitat Autónoma de Barcelona	1.225	Universita degli Studi di Ferrara	1.368
Universidade de Santiago de Compostela	1.244	University of Milano-Bicocca	1.381
Universitat de Girona	1.247	Università Degli Studi di Modena e Reggio Emilia	1.385
Universitat Rovira i Virgili	1.291	Luiss University	1.402
Universidad de Oviedo	1.307	Universita IUAV di Venezia	1.414
Universidad de Jaén	1.356	Universita degli Studi di Bari Aldo Moro	1.431
Universidad Miguel Hernandez	1.373	Universitàdegli Studi di Perugia	1.477
Universidad de Zaragoza	1.386	Universita degli Studi di Padova	1.490
Universidad de Castilla La Mancha	1.417	Università degli Studi di Genova	1.501
Universidad de Salamanca	1.471	Università di Trieste	1.515
Universidad Pontificia Comillas	1.587	Universita Politecnica delle Marche	1.600
Universidade de Vigo	1.609	Universita della Calabria	1.621
Universidad de Navarra	1.617	Università degli Studi di Firenze	1.749
Universidad de La Laguna	1.753	Universita di Macerata	2.738
Universidad de Valladolid	1.762		
Universidad de Alicante	1.882		
Universitat de Vic	1.958		
Universitat de les Illes Balears	2.410		

References

[1] Sachs JD, Schmidt-Traub G, Mazzucato M, Messner D, Nakicenovic N, Rockström J. Six transformations to achieve the sustainable development goals. Nat Sustain 2019;2:805–14. https://doi.org/10.1038/s41893-019-0352-9.

[2] Sarkodie SA, Strezov V. Economic, social and governance adaptation readiness for mitigation of climate change vulnerability: evidence from 192 countries. Sci Total Environ 2019;656:150–64. https://doi.org/10.1016/j.scitotenv.2018.11.349.

[3] Boé J, Somot S, Corre L, Nabat P. Large discrepancies in summer climate change over Europe as projected by global and regional climate models: causes and consequences. Clim Dynam 2020;54:2981–3002. https://doi.org/10.1007/s00382-020-05153-1.

[4] Islam MN, Tamanna S, Noman M, Siemens AR, Islam SMR, Islam MS. Climate change diplomacy, adaptation, and mitigation strategies in south Asian countries: a critical review. In: Islam MN, Amstel Av, editors. India II: climate change impacts, mitigation and adaptation in developing countries. Springer: Springer Climate; 2022. https://doi.org/10.1007/978-3-030-94395-0_1.

[5] Aslam A, Rana IA. Impact of the built environment on climate change risk perception and psychological distancing: empirical evidence from Islamabad, Pakistan. Environ Sci Pol 2022;127:228–40. https://doi.org/10.1016/j.envsci.2021.10.024.

[6] Valizadeh N, Karimi V, Heleileh BF, Hayati D, Bijani M. Formulating of small-scale farmers' perception towards climate change in arid areas: facilitating social interventions for agricultural sustainability. Water Environ J 2022;36(2):199–213. https://doi.org/10.1111/wej.12741.

[7] Xie B, Brewer MB, Hayes BK, McDonald RI, Newell BR. Predicting climate change risk perception and willingness to act. J Environ Psychol 2019;65:101331. https://doi.org/10.1016/j.jenvp.2019.101331.

[8] Wang C, Geng L, Rodríguez-Casallas JD. How and when higher climate change risk perception promotes less climate change inaction. J Clean Prod 2021;321:128952. https://doi.org/10.1016/j.jclepro.2021.128952.

[9] Yazar M, York A, Larson KL. Adaptation, exposure, and politics: local extreme heat and global climate change risk perceptions in the phoenix metropolitan region, USA. Cities 2022;127:103763. https://doi.org/10.1016/j.cities.2022.103763.

[10] Etana D, Wesenbeeck CFA, Buning TC. Socio-cultural aspects of farmers' perception of the risk of climate change and variability in Central Ethiopia. Clim Dev 2021;13(2):139–51. https://doi.org/10.1080/17565529.2020.1737796.

[11] Bradley GL, Babutsidze Z, Chai A, Reser JP. The role of climate change risk perception, response efficacy, and psychological adaptation in pro-environmental behavior: a two nation study. J Environ Psychol 2020;68:101410. https://doi.org/10.1016/j.jenvp.2020.101410.

[12] Harker-Schuch IEP, Mills FP, Lade SJ, Colvin RM. CO2peration – structuring a 3D interactive digital game to improve climate literacy in the 12-13-year-old age group. Comput Educ 2020;144:103705. https://doi.org/10.1016/j.compedu.2019.103705.

[13] Stevenson RB, Nicholls J, Whitehouse H. What is climate change education? Curric Perspect 2017;37. https://doi.org/10.1007/s41297-017-0015-9. 67–7.

[14] Maurer M, Bogner FX. Modelling environmental literacy with environmental knowledge, values and (reported) behaviour. Stud Educ Eval 2020;65:100863. https://doi.org/10.1016/j.stueduc.2020.100863.

[15] Doni F, Gasperini A, Soares JT. What is the SDG 13? In: Doni F, Gasperini A, Soares JT, editors. SDG13 – climate action: combating climate change and its impacts (concise guides to the united Nations sustainable development goals). Bingley: Emerald Publishing Limited; 2020. p. 21–30. https://doi.org/10.1108/978-1-78756-915-720201006.

[16] Stapp WB. The concept of environmental education. Environ Educ 1969;1(1):30–1. https://doi.org/10.1080/00139254.1969.10801479.

[17] Ardoin NM, Bowers AW, Gaillard E. Environmental education outcomes for conservation: a systematic review. Biol Conserv 2020;241:108224. https://doi.org/10.1016/j.biocon.2019.108224.

[18] Szczytko R, Stevenson K, Peterson MN, Nietfeld J, Strnad RL. Development and validation of the environmental literacy instrument for adolescents. Environ Educ Res 2019;25(2):193–210. https://doi.org/10.1080/13504622.2018.1487035.

[19] Ardoin NM, Bowers AW, Wheaton M. Leveraging collective action and environmental literacy to address complex sustainability challenges. Ambio 2023;52:30–44. https://doi.org/10.1007/s13280-022-01764-6.

[20] Reid A. Climate change education and research: possibilities and potentials versus problems and perils? Environ Educ Res 2019;25(6):767–90. https://doi.org/10.1080/13504622.2019.1664075.

[21] Dunlop L, Rushton EAC. Putting climate change at the heart of education: is England's strategy a placebo for policy? Br Educ Res J 2022;48(6):1083–101. https://doi.org/10.1002/berj.3816.

[22] Bentz J. Learning about climate change in, with and through art. Clim Change 2020;162:1595–612. https://doi.org/10.1007/s10584-020-02804-4.

[23] Kaack LH, Donti PL, Strubell E, Kamiya G, Creutzing F, Rolnick D. Aligning artificial intelligence with climate change mitigation. Nat Clim Change 2022;12:518–27. https://doi.org/10.1038/s41558-022-01377-7.

[24] Senevirathne M, Priyankara HAC, Amaratunga D, Haigh R, Weerasinghe N, Nawaratne C, Kaklauskas A. A capacity needs assessment to integrate MOOC-based climate change education with the higher education institutions in Europe and developing countries in Asia: findings of the focused group survey in PCHEI under the BECK project. Int J Disaster Resil Built Environ 2021;12(5):515–27. https://doi.org/10.1108/IJDRBE-07-2020-0074.

[25] Filho WL, Sima M, Sharifi A, Luetz JM, Salvia AL, Mifsud M, Ollooto FM, Djekic I, Anholon R, Rampasso I, Donkor FK, Dinis MAP, Klavins M, Finnveden G, Chari AM, Molthan-Hill P, Mifsud A, Sen SK, Lokupitiya E. Handling climate change education at universities: an overview. Environ Sci Eur 2021;33:109. https://doi.org/10.1186/s12302-021-00552-5.

[26] Glackin M, King H. Taking stock of environmental education policy in England – the what, the where and the why. Environ Educ Res 2020;26(3):305–23. https://doi.org/10.1080/13504622.2019.1707513.

[27] Ho UT, Lepage BA, Fang WT. Environmental education in pre-school teacher training programs in Vietnam: situations and challenges. J Early Child Teach Educ 2022. https://doi.org/10.1080/10901027.2022.2136552.

[28] Atici KB, Yasayacak, Yildiz Y, Ulucan A. Green university and academic performance: an empirical study on UI GreenMetric and world university rankings. J Clean Prod 2021;291:125289. https://doi.org/10.1016/j.jclepro.2020.125289.

[29] Martínez-Campillo A, Fernández-Santos Y. The impact of the economic crisis on the (in)efficiency of public Higher Education institutions in Southern Europe: the case of Spanish universities. Soc Econ Plann Sci 2020;71:100771. https://doi.org/10.1016/j.seps.2019.100771.

[30] Contreras I, Lozano S. Allocating additional resources to public universities. A DEA bargaining approach. Soc Econ Plann Sci 2020;71:100752. https://doi.org/10.1016/j.seps.2019.100752.

[31] Contreras I, Lozano S. Size efficiency, splits and merger gains, and centralized resource reallocation of Spanish public universities. Soc Econ Plann Sci 2022;81:101190. https://doi.org/10.1016/j.seps.2021.101190.

[32] Agasisti T, Pérez-Esparrells C. Comparing efficiency in a cross-country perspective: the case of Italian and Spanish state universities. High Educ 2010;59:85–103. https://doi.org/10.1007/s10734-009-9235-8.

[33] Lamontagne JR, Reed PM, Marangoni G, Keller K, Garner GG. Robust abatement pathways to tolerable climate futures require immediate global action. Nat Clim Change 2019;9:290–4. https://doi.org/10.1038/s41558-019-0426-8.

[34] Nielsen KS, Clayton S, Stern PC, Dietz T, Capstick S, Whitmarsh L. How psychology can help limit climate change. Am Psychol 2021;76(1):130–44. https://doi.org/10.1037/amp0000624.

[35] Verplanken B, Whitmarsh L. Habit and climate change. Curr Opin Behav Sci 2021;42:42–6. https://doi.org/10.1016/j.cobeha.2021.02.020.

[36] Darvas Z, Wolff GB. A Green Fiscal Pact for the EU: increasing climate investments while consolidating budgets. Clim Pol 2022. https://doi.org/10.1080/14693062.2022.2147893.

[37] Chen X, Huang B, Lin CT. Environmental awareness and environmental Kuznets curve. Econ Modell 2019;77:2–11. https://doi.org/10.1016/j.econmod.2019.02.003.

[38] Ruiz I, Faria SH, Neumann MB. Climate change perception: driving forces and their interactions. Environ Sci Pol 2020;108:112–20. https://doi.org/10.1016/j.envsci.2020.03.020.

[39] Sarkodie SA, Ahmed MY, Owusu PA. Global adaptation readiness and income mitigate sectoral climate change vulnerabilities. Humanit Soc Sci Commun 2022;9:113. https://doi.org/10.1057/s41599-022-01130-7.

[40] Azócar G, Billi M, Calvo R, Huneeus N, Lagos M, Sapiains R, Urquiza A. Climate change perception, vulnerability, and readiness: inter-country variability and emerging patterns in Latin America. J Environ Stud Sci 2021;11:23–36. https://doi.org/10.1007/s13412-020-00639-0.

[41] United Nations Framework Convention. Climate change. United Nations framework convention on climate change. 1992. https://unfccc.int/resource/docs/convkp/conveng.pdf.

[42] Owusu M, Nursey-Bray M, Rudd D. Gendered perception and vulnerability to climate change in urban slum communities in Accra, Ghana. Reg Environ Change 2019;19:13–25. https://doi.org/10.1007/s10113-018-1357-z.

[43] Hori T, Shaw R. Global climate change perception, local risk awareness, and community disaster risk reduction: a case study of Cartago City, Costa Rica. Risk Hazards Crisis Publ Pol 2012;3:77–104. https://doi.org/10.1002/rhc3.19.

[44] Boer J, Botzen W, Terpstra T. Flood risk and climate change in the Rotterdam area, The Netherlands: enhancing citizen's climate risk perceptions and prevention responses despite skepticism. Reg Environ Change 2016;16:1613–22. https://doi.org/10.1007/s10113-015-0900-4.

[45] Rousell D, Cutter-Mackenzie-Knowles A. A systematic review of climate change education: giving children and young people a 'voice' and a 'hand' in redressing climate change. Child Geogr 2020;18(2):191–208. https://doi.org/10.1080/14733285.2019.1614532.

[46] Jorgenson SN, Stephens JC, White B. Environmental education in transition: a critical review of recent research on climate change and energy education. J Environ Educ 2019;50(3):160–71. https://doi.org/10.1080/00958964.2019.1604478.

[47] Siegner A, Stapert N. Climate change education in the humanities classroom: a case study of the Lowell school curriculum pilot. Environ Educ Res 2020;26(4):511–31. https://doi.org/10.1080/13504622.2019.1607258.

[48] Kuthe A, Keller L, Körfgen A, Stötter H, Oberrauch A, Höferl KM. How many young generations are there? – a typology of teenagers' climate change awareness in Germany and Austria. J Environ Educ 2019;50(3):172–82. https://doi.org/10.1080/00958964.2019.1598927.

[49] Bayuo BB, Chaminade C, Göransson B. Unpacking the role of universities in the emergence, development and impact of social innovations – a systematic review of the literature. Technol Forecast Soc Change 2020;155:120030. https://doi.org/10.1016/j.techfore.2020.120030.

[50] Helmers E, Chang CC, Dauwels J. Carbon footprinting of universities worldwide: Part I—objective comparison by standardized metrics. Environ Sci Eur 2021;33:30. https://doi.org/10.1186/s12302-021-00454-6.

[51] Baumber A, Luetz JM, Metternicht G. Carbon neutral education: reducing carbon footprint and expanding carbon brainprint. In: Filho LW, Azul A, Brandli L, Özuyar P, Wall T, editors. Quality education. Encyclopedia of the UN sustainable development goals. Springer; 2019. https://doi.org/10.1007/978-3-319-69902-8_13-1.

[52] Molthan-Hill P, Worsfold N, Nagy GJ, Filho WL, Mifsud M. Climate change education for universities: a conceptual framework from an international study. J Clean Prod 2019;226:1092–101. https://doi.org/10.1016/j.jclepro.2019.04.053.

[53] Bushell S, Buisson GS, Workman M, Colley T. Strategic narratives in climate change: towards a unifying narrative to address the action gap on climate change. Energy Res Social Sci 2017;28:39–49. https://doi.org/10.1016/j.erss.2017.04.001.

[54] Suwartha N, Sari RF. Evaluating UI GreenMetric as a tool to support green universities development: assessment of the year 2011 ranking. J Clean Prod 2013;61:46–53. https://doi.org/10.1016/j.jclepro.2013.02.034.

[55] Fissi S, Romolini A, Gori E, Contri M. The path toward a sustainable green university: the case of the University of Florence. J Clean Prod 2021;279:123655. https://doi.org/10.1016/j.jclepro.2020.123655.

[56] Cardozo NH, da Silveira Barros SR, Quelhas OLG, Filho ERM, Salles W. Benchmarks analysis of the higher education institutions participants of the GreenMetric World University Ranking. In: Leal Filho W, Tortato U, Frankenberger F, editors. *Universities and sustainable communities: Meeting the Goals of the agenda 2030*. World sustainability series. Springer; 2020. https://doi.org/10.1007/978-3-030-30306-8_40.

[57] Karasan A, Kutlu Gündoğdu F, Aydın S. Decision-making methodology by using multi-expert knowledge for uncertain environments: green metric assessment of universities. Environ Dev Sustain 2022. https://doi.org/10.1007/s10668-022-02321-7.

[58] Matana JS, Leite MA, Barbosa V. The role of HEIs to achieve SDG7 goals from Netzero campuses: case studies and possibilities in Brazil. Int J Sustain High Educ 2023;24(2):462–80. https://doi.org/10.1108/IJSHE-07-2021-0282.

[59] Hahn J, Hausman J, Kuersteiner G. Estimation with weak instruments: accuracy of higher-order bias and MSE approximations. Econom J 2004;7(1):272–306. https://doi.org/10.1111/j.1368- 423X.2004.00131.x. 2004.

[60] Baltagi BH. Econometric analysis of panel data. John Wiley & Sons Ltd; 2005.

[61] Drukker DM. Testing for serial correlation in linear panel-data models. STATA J 2003;2:168–77.

[62] Lütkepohl H, Burda MM. Modified Wald tests under nonregular conditions. J Econom 1997;78(2):315–32. https://doi.org/10.1016/S0304-4076(96)00015-2.

[63] Greene W. Econometric analysis. Nueva Jersey: Prentice Hall; 2003.

[64] Leekoi P, Abdul Jalil AZ, Harun M. Vulnerability to poverty of rural households in pattani province: a feasible generalized least squares (FGLS) approach. Glob Bus Manage Rev 2018;10(1):13–25.

[65] Guntukula R, Goyari P. The impact of climate change on maize yields and its variability in Telangana, India: a panel approach study. J Publ Aff 2020;20:e2088. https://doi.org/10.1002/pa.2088.

[66] Hoang HH, Huynh CM. Climate change, economic growth and growth determinants: insights from Vietnam's coastal south-central region. J Asian Afr Stud 2021;56(3):693–704. https://doi.org/10.1177/0021909620940345.

[67] Mumuni S, Mwimba T. Modeling the impact of green energy consumption and natural resources rents on economic growth in Africa: an analysis of dynamic panel ARDL and the feasible generalized least squares estimators. Cogent Econ Finance 2023;11:1. https://doi.org/10.1080/23322039.2022.2161774.

[68] Hung BQ, Nham NTH, Ha LT. The importance of digitalization in powering environmental innovation performance of European countries. J Innov Knowl 2023;8(1):100284. https://doi.org/10.1016/j.jik.2022.100284.

[69] Charnes A, Cooper W, Rhodes E. Measuring the efficiency of decision making units. European Journal of Operations Research 1978;2(6):429–44. https://doi.org/10.1016/0377-2217(78)90138-8.

[70] Banker R, Charnes A, Cooper W. Models for estimation of technical and scale inefficiencies in Data Envelopment Analysis. Manag Sci 1984;30:1078–92.

[71] Simar L, Wilson PW. Statistical inference in nonparametric frontier models: the state of the art. J Prod Anal 2000;13:49–78. https://doi.org/10.1023/A:1007864806704.

[72] Marti L, Puertas R. European countries' vulnerability to COVID-19: multicriteria decision-making techniques. Econ Res Ekon Istraž 2021;34(1):3309–20. https://doi.org/10.1080/1331677X.2021.1874462.

[73] Cruz-Cázares C, Bayona-Sáez C, García-Marco T. You can't manage right what you can't measure well: technological innovation efficiency. Res Pol 2013;42(6–7):1239–50. https://doi.org/10.1016/j.respol.2013.03.012.

[74] Puertas R, Marti L, Guaita-Martinez JM. Innovation, lifestyle, policy and socioeconomic factors: an analysis of European quality of life. Technol Forecast Soc Change 2020;160:120209. https://doi.org/10.1016/j.techfore.2020.120209.

[75] Bresciani S, Puertas R, Ferraris A, Santoro G. Innovation, environmental sustainability and economic development: DEA-Bootstrap and multilevel analysis to compare two regions. Technol Forecast Soc Change 2021;172:121040. https://doi.org/10.1016/j.techfore.2021.121040.

[76] Tulkens H, Eeckaut PV. Non-parametric efficiency, progress and regress measures for panel data: methodological aspects. Eur J Oper Res 1995;80(3):474–99. https://doi.org/10.1016/0377-2217(94)00132-V.

[77] Song Y, Schubert T, Liu H, Yang G. Measuring scientific productivity in China using malmquist productivity index. J Data Inf Sci 2019;4(1):32–59. https://doi.org/10.2478/jdis-2019-0003.

[78] Agasisti T, Yang GL, Song YY, Tran CTTD. Evaluating the higher education productivity of Chinese and European "elite" universities using a meta-frontier approach. Scientometrics 2021;126:5819–53. https://doi.org/10.1007/s11192-021-03978-z.

[79] Barbero J, Zabala-Iturriagagoitia JM, Zofío JL. Is more always better? On the relevance of decreasing returns to scale on innovation. Technovation 2021;107:102314. https://doi.org/10.1016/j.technovation.2021.102314.

[80] Zabala-Iturriagagoitia JM, Aparicio J, Ortiz L, Carayannis EG, Grigoroudis E. The productivity of national innovation systems in Europe: catching up or falling behind? Technovation 2021;102:102215. https://doi.org/10.1016/j.technovation.2020.102215.

[81] García-Mollá M, Puertas R, Sanchis-Ibor C. Application of data envelopment analysis to evaluate investments in the modernization of collective management irrigation systems in valencia (Spain). Water Resour Manag 2021;35:5011–27. https://doi.org/10.1007/s11269-021-02986-1.

[82] Castro-Pardo M, Fernández Martínez P, Pérez Zabaleta A. An initial assessment of water security in Europe using a DEA approach. Sustain Technol Entrepreneurship 2022;1(1):100002. https://doi.org/10.1016/j.stae.2022.100002.
[83] Coll-Serrano V, Benítez R, Bolos VJ. Data envelopment analysis with dear. Spain: University of Valencia; 2018.
[84] UI Green Metric World University Ranking. Collective actions for transforming sustainable universities in the post-pandemic time. Green Metric 2022. https://greenmetric.ui.ac.id/publications/guidelines/2022/english.
[85] Perchinunno P, Cazzolle M. A clustering approach for classifying universities in a world sustainability ranking. Environ Impact Assess Rev 2020;85:106471. https://doi.org/10.1016/j.eiar.2020.106471.
[86] Mohamed NH, Noor ZZ, Sing CLI. Environmental sustainability of universities: critical review of best initiatives and operational practices. In: Yaser A, editor. Green engineering for campus sustainability. Singapore: Springer; 2020. https://doi.org/10.1007/978-981-13-7260-5_2.
[87] Cordero EC, Centeno A, Todd AM. The role of climate change education on individual lifetime carbon emissions. PLoS One 2020;15(2):e0206266. https://doi.org/10.1371/journal.pone.0206266.
[88] Miklautsch P, Woschank M. A framework of measures to mitigate greenhouse gas emissions in freight transport: systematic literature review from a Manufacturer's perspective. J Clean Prod 2022;366:132883. https://doi.org/10.1016/j.jclepro.2022.132883.
[89] Safarkhani M, Örnek MA. The meaning of green campus in UI GreenMetric World University Rankings perspective. ITU J Fac Archit 2022;19(2):315–34. https://doi.org/10.5505/itujfa.2022.22566.
[90] Kummitha HR, Kummitha RKR. Sustainable entrepreneurship training: a study of motivational factors. Int J Manag Educ 2021;19(1):100449. https://doi.org/10.1016/j.ijme.2020.100449.
[91] UNESCO. Education for sustainable development: a roadmap, vol. 66. France: United Nations Educational, Scientific and Cultural Organization; 2020.
[92] Donkor FK, Howarth C, Ebhuoma E, Daly M, Vaughan C, Pretorius L, Mambo J, MacLeod D, Kythreotis A, Jones L, Grainger S, Golding N, Anderson JA. Climate services and communication for development: the role of early career researchers in advancing the debate. Environ Commun 2019;13(5):561–6. https://doi.org/10.1080/17524032.2019.1596145.
[93] Puertas R, Marti L. Sustainability in universities: DEA-GreenMetric. Sustainability 2019;11:3766. https://doi.org/10.3390/su11143766.
[94] Benayas J. Sustainability competences and pedagogical approaches at the Universidad autónoma de Madrid. In: Lozano R, Barreiro-Gen M, editors. Developing sustainability competences through pedagogical approaches. Strategies for sustainability. Springer; 2021. https://doi.org/10.1007/978-3-030-64965-4_12.
[95] European Commission. Delivering the European green deal. 2020. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en.

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