Assessment of quality and efficiency in higher education system. Empirical study for the EU countries

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Abstract – (150 and 400 words)

High quality and efficient education are fundamental to a country's development. As a result, the continuous assessment of the quality and efficiency of education remains a subject of constant debate. This has led to an increased interest in developing evaluation methods that are as reliable as possible. In this paper, we assess the quality and efficiency of higher education by constructing composite quality and efficiency indices, using various statistical methods for European Union's countries for the year 2022. For the construction of the composite quality index, we considered nine variables, then we used principal component analysis (PCA) to determine the importance of each variable, whereas the weighting method was applied in order to extract the factor loading coefficients of the score matrix. To construct the composite efficiency index, eight variables were analysed and we applied stochastic frontier analysis (SFA), which estimated a production frontier and measured the random inefficiency of production units. Inefficiency scores were obtained for each country and were combined with the outputs considered in the analysis to provide an overview of the efficiency of decision-making units (DMUs). These results were then correlated with the number of universities included in the international top rankings using the Spearman coefficient. Our findings reveal a positive correlation between the two composite indices and the number of universities featured in these rankings for each country analysed. This confirms that the analysed variables provide insight into the quality and efficiency of higher education system in these countries, which could increase the number of universities included in the international rankings.

Keywords: quality, efficiency, higher education, PCA, SFA, composite index

Jelcodes: B23, C43, I21, I23

1. Introduction

Quality assurance is one of the most important aspects for the education system as it is essential in providing high quality and efficient educational programs to students. In order to ensure the most reliable evaluation, it is essential to clearly establish the processes and structures, especially as interest in higher education grows and student expectations change. Higher education institutions must provide an education that meets high standards, encourages critical thinking and prepares students for the future challenges (Kehm, 2020).

In order to deliver educational programs that seek to align the needs and expectations of students with those of other stakeholders and ultimately the society, higher education institutions have a duty to understand the concepts and frameworks underpinning quality assurance and efficiency. These methods aim to maintain and improve educational standards by analysing and evaluating the quality and efficiency of educational programs. The ultimate goal of educational institutions, through all actions undertaken in quality and efficiency assurance, is to provide students with a relevant, transformative educational experience, containing the necessary information, skills and competencies for professional and personal development, abilities and expertise that will help them in the future workplace.

Contrary to any other service or product, educational services are much harder to evaluate and measure. The outcome is not a good or a service, but the contribution of knowledge, skills and competences brought to each student attending a higher education institution program. These are some of the reasons why there is no clear and generally accepted definition of quality that applies specifically to the higher education sector (Michael, 1998). In addition, in the evaluation of higher education institutions, factors such as their autonomy and independence will constrain the evaluation process (Middlehurst and Gordon, 1995). All these elements have led the accreditation agencies in each country to assess the quality offered by higher education institutions through the processes of evaluation and accreditation of the degrees offered and the educational activity they provide. Although these agencies try to maintain a fair assessment, their impact has not influenced the perception of quality in the sector, and the uncertainties related to the assessment of institutional quality have not been elucidated (Parri, 2006).

This study focuses on the factors that determine the quality and efficiency of the higher education system in the 27 EU countries and tries to assess whether the quality offered by each country and the use of available resources of universities influence the number of universities present in the two major international university rankings: the QS World University Rankings and the Shanghai Ranking.

More specifically, this study aims to build two indices to assess the quality and efficiency of the higher education system, focusing in particular on indicators that measure quality and efficiency. These include the ratio of teachers to students, which reflects the quality of teaching, the number of graduates with mobile degrees from abroad, an indicator of the efforts made by each country to promote internationalisation, and the early dropout rate, to assess the attractiveness of higher education. External factors such as the human development index or GDP are also included in the quality analysis. Among the variables taken into account to measure and test the efficiency, the utilization of resources, were the ratio of the number of teaching staff to the total population of each country, the expenditure allocated to research and development of the higher education sector as a proportion of total government expenditure, the ratio of the number of students enrolled in higher education to the number of graduates, the number of articles published to the number of teaching staff and the unemployment rate of tertiary educated persons. On the basis of these variables, this analysis aims to identify the countries that apply and use the available resources most efficiently to achieve the best results and, at the same time, the best quality.

In the following sections, we will briefly present the literature review on which this study is based, a clarification of the terms 'quality' and 'efficiency', and then the research methodology will be presented. Finally, we will outline the results of the study, and at the end conclusions will be drawn.

2. Literature Review

Higher education evaluation research has expanded over the last hundred years and is now very active (Wiethe-Körprich and Bley, 2017). In the last decades, the number of tertiary education institutions has substantially increased and higher education evaluation has been increasingly studied (Van Mol et al., 2021).

It is important to distinguish between quality and efficiency in production and quality and efficiency in education, so the specific aspects for each of these will be presented below.

Quality is one of the numerous concepts in the field of social sciences whose definition is particularly difficult to determine. Many authors have preferred to develop an understanding of the various aspects that make up the concept vaguely known as quality by societal agreement (Gummesson, 1990) rather than to search for a precise definition.

The quality in production has been defined by many authors, but the most recognised has been highlighted by Crosby (1979) who states the following: quality is in accordance with customer requirements. This definition implies that specifications and requirements are already developed. The next thing to be verified is compliance with these demands.

W. Edwards Deming (1982) defined quality as follows: good quality means a predictable degree of uniformity and reliability with a quality standard tailored to the customer. For Ishikawa (1985) quality is the totality of product quality, service quality, management quality and the quality of the company itself.

According to Brysland and Curry (2001), many authors consider that quality service implies the provision of something intangible in a way that satisfies consumers and ultimately adds value to them. In the opinion of Johnson and Winchell (1988), it refers to all the qualities and attributes of a good or service that influence its ability to satisfy specified or implied needs. Service quality is crucial for every organization as it is perceived as a factor impacting the financial and marketing success of companies (Buttle, 1996).

The concept of quality is a highly complex and difficult to evaluate, especially in HEIs, from a theoretical perspective. Carnerud (2018) and Weckenmann et al. (2015) agree that developing a standardized model for measuring quality is a difficult task. The quality of educational programs in universities differs from the quality of a product line, product units or services offered by for-profit companies. The main purpose of universities involves generating, sharing, promoting, refining and broadening knowledge, skills and intelligence to enhance human well-being.

The concept of "efficiency" refers to achieving the highest level of performance with the least amount of input to generate the greatest amount of output. Efficiency is based on minimizing the number of unnecessary resources, such as personal time and energy, required to produce a given output. In the past, technical efficiency has been described as the ability of a decision-making unit (DMU) to transform its inputs into outputs; the higher this 'transformation ratio', the greater the efficiency achieved (Agasisti and Bonomi, 2014).

The subject of efficiency in education is a heavily debated issue between different parties involved in educational decision-making, such as policy-makers or teachers. One of the reasons for this interest in efficiency in education is linked to increased spending, which is why there is an increased focus on efficiency in the public sector. In the tertiary education sector, universities are perceived as decision-making units that use their financial and human resources to generate teaching, research and outcomes associated with a third mission, that of knowledge dissemination or transfer and community outreach. There have been numerous research studies published over the years exploring the efficiency scores attributed to universities in different countries (Agasisti, Arnaboldi and Azzone 2008; Bonaccorsi, Daraio and Simar 2006; Johnes 2006; Johnes and Johnes 1993; Johnes, Johnes and Thanassoulis 2008; Madden, Savage and Kemp 1997; Thursby 2000) or to different departments within a university (Koksal and Nalcaci 2006; Moreno and Tadepali 2002). Inputs into university activities are assessed on the basis of available financial resources and the people involved, such as academic and non-academic staff, as well as the number of students. The outcomes or outputs are examined by the number of graduates, the number of papers published or the number of research grants obtained. The efficiency of educational offer is determined by how its providers use the resources at their disposal. In a system that is not efficient, there is the alternative of increasing the level of education without higher expenditures or reducing educational resources while maintaining the same level of education (Bessent and Bessent, 1980).

In various studies carried out to determine or measure the quality and efficiency of higher education, several statistical methods have been used over the years. Among the most widely used methods for quality assessment, we could determine principal component analysis (PCA), structural equation modelling (SEM), regression or various combinations of these. Principal Component Analysis (PCA) is a multivariate data analysis technique aimed primarily at reducing the size of observations and thus simplifying the analysis and interpretation of data, as well as facilitating the construction of predictive models, which is why we preferred this method to construct the composite quality index. In terms of efficiency, DEA analysis, SFA analysis, Malmquist Index are widely used. Methods such as DEA and SFA are common in efficiency assessments of universities in different countries or regions. SFA analysis measures efficiency taking into consideration random errors and unit-specific inefficiency, which is why we preferred it for this study. In the following we outline some of the studies that have employed these methods to analyse and evaluate the quality and efficiency of higher education in different countries.

The SFA analysis was used to examine 200 public universities in the U.S. by Robst (1997). Through his study, he was able to reveal that inefficiency arises in public universities that are mainly situated in states whose costs are approximately 20% over the estimated frontier. Among his findings, he could observe that a higher value of efficiency is obtained by states with a higher number of students who enrolled for a two-year study than states with a lower number of these students. One of the study's conclusions was that large university systems tend to be more efficient than small ones.

Another research using SFA analysis was Daghbashyan (2011), which assessed the efficiency of public higher education institutions in Sweden. The study analyses 30 universities from the 2001-2005 period and estimated a cost function based on these data. The variables used as inputs were the number of academic staff, average salary, and the variables used as outputs were the number of enrolled students (which were further divided according to individual fields: humanities, technical fields and medicine) or the number of PhD students. The analysis showed that there were differences between the universities studied, and the efficiency of most of them was above average, with only six universities being below average.

Sav's (2016) study of data from 2004 to 2013 included 378 higher education, public institutions in the US. To determine their efficiency, the researcher used SFA analysis. This analysis corroborated the view that the involvement of the government in funding public HEIs is crucial, as the results showed that any reduction in government funding of public HEIs leads to inefficiency.
In exploring and determining the efficiency of higher education, stochastic frontier analysis (SFA) has been employed broadly to assess technical efficiency, especially in public universities. A notable study by D'Elia and Ferro (2021) applied SFA to a panel of 37 Argentine national universities between 2005 and 2013, highlighting the importance of considering observed and unobserved heterogeneity in efficiency estimates. Their findings pointed to an average inefficiency between 18% and 25%, with significant variation among institutions. The study found that models which incorporate heterogeneity - such as regional differences and university-specific characteristics - resulted in higher efficiency scores, suggesting that failure to consider these factors may lead to biased estimates of inefficiency. This aligns with the broader literature that underlines the role of human resources, such as teacher quality, at the expense of financial inputs in achieving educational outputs.
Cao et al. (2023) developed a model for assessing the quality and sustainability of higher education systems, called the Quality-Sustainability Model (QSM), which involves the use of principal component analysis (PCA) and entropy weighting method (EWM). The study included the evaluation of 13 indicators, among which were innovation capacity, academic integrity, international exchange and government investment, in order to assess tertiary education systems in nine developed countries. The results indicate that Australia is distinguished by quality, due to wide access to education and a low rate of academic misconduct, while the UK stands out for sustainability, due to investment in student education. The QSM model provides a quantitative assessment of higher education systems, highlighting each country's strengths and weaknesses and providing recommendations for improvement.

As higher education assessment work has evolved in the data era, researchers have gradually mapped out many indicators that can measure the quality and efficiency of higher education (Gupta et al., 2015), such as graduate employment rate, number of papers, and gender ratio. It is therefore important to consider these classic elements, which remain important measures of higher education quality and efficiency, when studying new developments that may impact higher education.

3. Data & Methodology

In the study we identified nine variables to assess quality and eight variables to determine the efficiency of higher education for 2022. The datasets for the 27 EU countries were collected by consulting different databases such as OECD, EUROSTAT and CEDEFOP.

In order to construct the composite quality index, we have cautiously selected nine variables for our analysis after a thorough review of the literature on assessing the quality of higher education. These variables are summarised in Table 1.

Table 1: Quality variables overview

Variables	Definition
Early school leavers_18-24 years old	Measures the proportion of young people aged 18-24 who have dropped out of both education and any form of training.
Students enrolled in tertiary education at doctorate level	The total number of people enrolled in doctoral programs in a given calendar year.
Graduates with mobile degrees from abroad	Measures the total number of persons who have graduated from a university in a foreign country (bachelor, master, doctorate) and returned to their home country.
Ratio of students to teaching and academic staff	The ratio of the number of students to the number of teaching and academic staff is a measure of the average size of education groups in tertiary education). It is calculated annually by dividing the total number of students by the total number of teaching and research staff
Citations	The total number of citations received by papers indexed in Scopus for a given journal or country.
Human Development Index	Indicator that measures a country's level of development, combining data on health, education and living standards.

General government expenditure_Tertiary education	Measures the proportion of total government expenditure allocated to tertiary education as a percentage of national GDP.
Gross Domestic Product	The total value of final goods and services produced in a country in 2022.
Employment by level of education_Tertiary education	Measures the share of employed persons having completed tertiary education (levels 5-8 according to ISCED 2011) in the total population aged 20-64.

After a careful review of the literature on how to measure the efficiency of tertiary education, we were able to identify the 8 variables included in the SFA analysis and extract the efficiency scores. To carry out the SFA analysis, input and output variables were required. In Table 2, we outlined the chosen input and output variables.

Table 2: Efficiency variables overview

Variables		Definition
Input	Ratio of academic staff to total population	The ratio of number of teachers to total population measures the population's potential access to higher education.
	Ratio of tertiary education R&D expenditure to total government expenditure	Measures the share of total public expenditure on research and development (R&D) in the tertiary education sector.
	Ratio between the number of students enrolled in higher education and the population aged 20-24	Measures the access and participation in tertiary education.
Output	Skills matching	It measures the match between employee skills and labor market requirements.
	Ratio of published articles to total academic staff	Measures the research productivity of higher education institutions by academic staff.
	Citations per document	The average number of citations received by each article published in a journal in a given period.
	Ratio between the number of graduates and the number of students enrolled	It indicates the proportion of enrolled students who successfully graduate within a given time frame.
	Unemployment rate for tertiary educated persons	It is the annual percentage of the population aged 25-64 with ter tertiary education.

Following the methodology presented by OECD (2008) for the composite index construction, we applied principal component analysis (PCA) to select the components that explain the most important percentage of the total variance and then to select the significant variables explaining each extracted component based on factor loadings. We performed the SFA analysis to determine the stochastic efficiency frontier for each variable in the output following the equation:

$$y_i = \alpha + x_i\beta + \varepsilon_i \qquad i = 1, \dots, N, \qquad (1)$$

where y_i is the output for the *i*-th observation (i= 1, . . ., N);

x_i is the inputs for the i-th observation;

α represents the baseline level of the output yi when all input variables (xi) are zero;

β quantifies the marginal effect of the input variables (xi) on the output (yi);

ε_i is an error term with:

$$\varepsilon_i = v_i - u_i \tag{2}$$

The econometric rationale for this specification is that the production process is exposed to two economically separable random perturbations: the statistical noise represented by v_i and the technical inefficiency represented by u_i (Aigner,1977).

4. Results

The results of the empirical study refer to the values obtained for the composite indices of quality and efficiency of higher education constructed for the twenty-seven EU countries.

Construction of quality index for higher education

Principal Component Analysis (PCA) was used to evaluate the 9 variables taken in the quality analysis and to extract the factor coefficient score matrices. Of these, four principal components were used for further analysis. Principal component analysis was applied using Varimax rotation of the axes. Factors with eigenvalues greater than 1 were selected. Each sub-indicator was assigned weights using the PCA weighting method to obtain a composite index for each country.
Using the PCA method, we were able both to calculate the weights of the importance of the variables in explaining the factors and to identify the importance of the factors in the total variance.
After determining the importance of the variables in explaining each factor, we proceeded to calculate the weights of the importance of the variables and obtained the factor loadings. Weights were assigned to each sub-indicator as shown in Table 3, using the PCA weighting method to obtain a composite index for each country.

Table 3: Weights of importance of the variables in explaining each factor

F1	F2	F3	F4
0.001470074	0.000164368	0.000003580	0.812123998
0.154674615	0.000239439	0.000000019	0.001899934
0.202249869	0.000007803	0.000516586	0.000000711
0.000002514	0.662486819	0.000026057	0.000150357
0.309330935	0.000428795	0.000701951	0.001745586
0.031275867	0.000002167	0.000049174	0.180311129
0.000002852	0.000089969	0.936058862	0.000000002
0.300977734	0.000019408	0.001737251	0.003762419
0.000015539	0.336561231	0.060906520	0.000005864

Source: Authors' calculations

Using the factor loadings from the previous table and the weights of the importance of the variables in explaining each factor, we were able to compute the index values for each country, presented in Table 4.

Table 4: Sub-index values for quality for each country

Country	Sub-index values	Country	Sub-index values
Austria	-0.028562247	Latvia	-0.394188859

Belgium	0.06459941	Lithuania	-0.45801528
Bulgaria	-0.279948191	Luxembourg	-0.714210741
Croatia	-0.623382823	Malta	-0.321334313
Cyprus	-0.196387517	Netherlands	0.540395786
Czechia	-0.26828011	Poland	0.126452842
Denmark	0.306907913	Portugal	-0.292012759
Estonia	-0.183773372	Romania	0.167590392
Finland	0.227849776	Slovakia	-0.508803286
France	0.58406268	Slovenia	-0.242213052
Germany	1.55366832	Spain	0.282121627
Greece	0.086220095	Sweden	0.107322228
Ireland	-0.280084098	Hungary	0.450002139
Italy	0.29399994		

Source: Authors' calculations

Construction of efficiency index for higher education

The next step was to construct the composite efficiency index. We began by applying the SFA analysis, using the equation specified for the SFA model (equation 1) and we estimated the models for each output that are showcase in Table 5.

Table 5. Parameter estimates for the stochastic frontier analysis of cross-sectional data

Output_Variable	Parameters	Coefficient	Standard_Error
Skills matching	β_0	4.5988	0.9653
	β_1	-0.0259	0.4083
	β_2	0.1205	0.5325
	β_3	-0.7131	0.9278
SigmaSq	$\sigma_\varepsilon^2 = \sigma_u^2 + \sigma_v^2$	0.6000	0.7640
Gamma	$\gamma = (\sigma_u^2/\sigma_\varepsilon^2)$	0.9992	0.0292
Ratio of published articles to total academic staff	β_0	-1.8492	2.9582
	β_1	-1.0404	0.5541
	β_2	0.8020*	0.3044
	β_3	-0.7307	0.5485
SigmaSq	$\sigma_\varepsilon^2 = \sigma_u^2 + \sigma_v^2$	1.2450*	0.6132
Gamma	$\gamma = (\sigma_u^2/\sigma_\varepsilon^2)$	0.4521	0.4514
Citations per document	β_0	1.5791	0.4614
	β_1	-0.1078	0.0794
	β_2	0.1204*	0.0541
	β_3	0.0224	0.0814
SigmaSq	$\sigma_\varepsilon^2 = \sigma_u^2 + \sigma_v^2$	0.0275	0.0461
Gamma	$\gamma = (\sigma_u^2/\sigma_\varepsilon^2)$	0.4099	1.8907
Ratio between the number of graduates and the	β_0	-1.8434	3.3962
	β_1	-0.3733	0.5194
	β_2	0.4253	0.2945

number of students enrolled	β_3	-0.8770	0.5217
SigmaSq	$\sigma_\varepsilon^2 = \sigma_u^2 + \sigma_v^2$	0.8391	0.2254
Gamma	$\gamma = (\sigma_u^2/\sigma_\varepsilon^2)$	0.0000	0.0230
Unemployment rate for tertiary educated persons	β_0	-0.0596	1.1393
	β_1	-0.4895*	0.2345
	β_2	0.1966	0.1470
	β_3	0.3323	0.1862
SigmaSq	$\sigma_\varepsilon^2 = \sigma_u^2 + \sigma_v^2$	0.5247	0.2188
Gamma	$\gamma = (\sigma_u^2/\sigma_\varepsilon^2)$	0.9023	0.1299

* is significant at the 0.05 level (2-tailed).

Source: Authors' calculations using R

The results of the stochastic frontier models reveal key insights into the determinants impacting the efficiency of the higher education system. In terms of skills matching, the positive intercept (4.599) indicates a baseline level of matching, with no significant impact of the ratio of academic staff to total population, the ratio of tertiary R&D expenditure to total government expenditure, or the ratio between the number of students enrolled in higher education and the population aged 20-24. However, the high Gamma value (0.999) suggests that inefficiency dominates, indicating concerns in the current system.
As regards to the ratio of published articles to total academic staff, a larger ratio of tertiary education R&D expenditure to total government expenditure significantly increases production (coefficient: 0.802), but a higher ratio of the ratio of academic staff to total population reduces productivity (coefficient: -1.040), indicating potential inefficiencies in academic organisations at larger universities. The moderate value of Gamma (0.452) indicates the role played by both inefficiency and random noise.
Referring to citations per document, higher rates of tertiary education R&D expenditure to total government expenditure have a positive impact on citation rates (coefficient: 0.120), while academic staff to total population rate and the ratio of the number of students enrolled in higher education and the population aged 20-24 show no significant effects. The Gamma value (0.410) suggests moderate inefficiency.
Regarding the ratio between the number of graduates and the number of students enrolled, none of the variables - the ratio of academic staff to total population, the ratio of tertiary education R&D expenditure to total government expenditure, the ratio between the number of students enrolled in higher education and the population aged 20-24 - show significant effects, while the nearly zero gamma value (1.240e-05) indicates the dominance of random noise, implying minimal inefficiency.
With respect to the unemployment rate for tertiary-educated individuals, a higher proportion of academic staff to total population significantly decreases unemployment (coefficient: -0.489), while the ratio of tertiary R&D expenditure to total public expenditure and the ratio of tertiary enrolment to population aged 20-24 show no significant effects. The high gamma value (0.902) suggests that inefficiency is a major factor, although random noise is also present.
Findings emphasise the importance of R&D spending in improving academic productivity and citation rates, while highlighting the inefficiency of larger bodies of academic staff and systemic issues affecting skills mismatches and unemployment rates. Higher education institutions should focus on maximising resource allocation and addressing inefficiencies to improve these outcomes.
Further, the efficiency scores were extracted using equation 2. These scores were then used to construct the composite index for efficiency. Again, PCA analysis was used for aggregation and weighting, and four principal components were also extracted. Weights were assigned to each sub-indicator as shown in Table 6.

Table 6: Weights of importance of the variables in explaining each factor

F1	**F2**	**F3**	**F4**
0.000102742	0.000000000	0.000020233	0.999879312
0.499759827	0.000000001	0.000315593	0.000061040
0.000095469	0.000204238	0.999466924	0.000021646

0.500011072	0.000337097	0.000001141	0.000038002
0.000030889	0.999458665	0.000196108	0.000000000

Source: Authors' calculations

As for the quality index, we used the factor loadings from the previous table and the weights of the importance of the variables in explaining each factor, thus we were able to estimate the efficiency index values for each country, presented in Table 7.

Table 7: Sub-index values for efficiency for each country

Country	Sub-index values	Country	Sub-index values
Austria	0.164607458	Latvia	0.19377454
Belgium	0.115517247	Lithuania	-0.276644015
Bulgaria	0.173973618	Luxembourg	-0.165124997
Croatia	-0.069100387	Malta	-0.801917052
Cyprus	0.580972573	Netherlands	0.913640678
Czechia	-0.200160232	Poland	-0.045420788
Denmark	0.3485009	Portugal	-0.846638849
Estonia	-0.075743806	Romania	0.725342562
Finland	0.516840782	Slovakia	-0.330311711
France	-0.169242471	Slovenia	-0.337596182
Germany	-0.286348195	Spain	-0.31005381
Greece	0.02643997	Sweden	0.294605093
Ireland	-0.593931034	Hungary	0.567243769
Italy	-0.113209816		

Source: Authors' calculations

One of our objectives was to see whether quality and/or efficiency are correlated with the number of universities included in the two major international university rankings: the QS World University Rankings and the Shanghai Ranking for each EU country. To do this, we use Spearman's correlation between the two indices we constructed earlier and the number of universities included in the two rankings and the results are presented in Table 8.

Table 8: Spearman's correlation between the two composite indices and number of universities

Correlations						
			Quality composite index value	Efficiency composite index value	Number of universities in the Top 1200 QS World University Rankings	Number of universities in the Top 1000 Shanghai Ranking
Spearman's rho	Quality composite index value	Correlation Coefficient	1.000	.422*	.574**	.549**
		Sig. (2-tailed)		.028	.002	.003
		N	27	27	27	27
	Efficiency composite index value	Correlation Coefficient	.422*	1.000	.054	-.030

	Sig. (2-tailed)	.028		.789	.881
	N	27	27	27	27
Number of universities in the Top 1200 QS World University Rankings	Correlation Coefficient	.574**	.054	1.000	.704**
	Sig. (2-tailed)	.002	.789		.000
	N	27	27	27	27
Number of universities in the Top 1000 Shanghai Ranking	Correlation Coefficient	.549**	-.030	.704**	1.000
	Sig. (2-tailed)	.003	.881	.000	
	N	27	27	27	27

***. Correlation is significant at the 0.05 level (2-tailed).**

Source: Authors' calculations using SPSS

The Spearman correlation between the quality composite index value and the efficiency composite index value (0.422) is statistically significant at the 0.05 level (p = 0.028), which means that there is a moderate positive relationship between the two indicators by which we have assessed the quality and efficiency of the higher education system in the 27 EU countries. This helps us to confirm that the higher the quality of the education system, the higher the efficiency tends to be, and vice versa. It is likely that improvements in the quality of tertiary education led to higher efficiency.

The correlation between the quality composite index value with the number of universities in the Top 1200 QS Rankings (0.574) is statistically significant at the 0.01 level (p = 0.002), indicating a strong positive relationship between the quality of the tertiary education system in the EU countries and the number of universities present in the top 1200 QS. The higher the composite quality index of each country, the more universities from that country tend to be included in the top QS. The same conclusion can be drawn from the correlation between the quality composite index value with the number of universities in the Top 1000 Shanghai Ranking (0.549). This correlation is again statistically significant at the 0.01 level (p = 0.003), indicating a strong positive relationship between quality and the number of universities in the Top 1000 Shanghai Ranking. The result is similar to the QS Rankings, suggesting consistency between the two rankings.

The correlation between the efficiency composite index value with the number of universities in the Top 1200 QS Rankings (0.054) is not statistically significant (p = 0.789), which means that there is no significant relationship between the composite efficiency index value and the number of universities in the top 1200 QS Rankings. This suggests that the efficiency of the education system is not a determining factor for the presence of universities in this ranking. The same conclusion can be found in the correlation with the number of universities in the Top 1000 Shanghai Ranking (-0.030), which is statistically insignificant (p = 0.881).

5. Conclusions

In this paper, two composite indices were constructed to determine the quality and efficiency of the higher education system in the 27 EU countries. SFA analysis was applied to estimate the technical efficiency and to determine the efficiency scores. The econometric frontier econometric model is estimated according to the specification of the Cobb-Douglas stochastic frontier production model. PCA analysis has been used to extract the principal components and weights in constructing the composite quality and efficiency index, and also to extract the weights of the efficiency scores used to construct the composite efficiency index.

The objectives of the study were to assess the quality and efficiency of the tertiary education system and to see whether these are correlated with the number of universities in each EU country included in the two international university rankings.

According to our results, the Spearman's correlation between the value of the quality composite index and the value of the efficiency composite index is statistically significant, implying that the higher the quality of the education system, the higher the efficiency tends to be and vice versa.

The correlation between the value of the quality composite index and the number of universities in the Top 1200 QS Rankings (is statistically significant at the 0.01 level (p = 0.002), indicating a strong and positive relationship between the two. A similar conclusion can also be drawn from the correlation between the value of the quality composite index and the number of universities in the Top 1000 Shanghai Rankings as it is again statistically significant at the 0.01 level (p = 0.003). The higher the quality composite index of each country is, the more universities from that country tend to be included in the two rankings.

The correlation between the value of the efficiency composite index and the number of universities in the Top 1200 QS Rankings (0.054) is not statistically significant (p = 0.789). The same finding can be seen in the correlation with the number of universities in the Top 1000 Shanghai Rankings (-0.030), which is statistically not significant (p = 0.881). This suggests that the efficiency of the university system is not a determining reason for the presence of universities in these rankings.

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