QUALITY ASSESSMENT IN HIGHER EDUCATION USING A COMPOSITE INDEX. EMPIRICAL EVIDENCE FOR CENTRAL AND EASTERN EU COUNTRIES

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Abstract: Post-secondary education requires a complex organisational structure of higher education institutions, staff and infrastructure. The construction of a comprehensive quality index is necessary to assess the quality of higher education and to improve the higher education system in a country. It is imperative that administrators remain informed about the current state of the system through regular and realistic assessments. Therefore, this study has constructed a composite index to assess the quality of higher education. The quality of higher education in Central and Eastern Europe is analysed using 13 indicators from 11 countries with higher education institutions. Extraction of factor coefficient score matrices was performed by downgrading these indicators using principal component analysis (PCA). Using PCA, two principal components were extracted for analysis and the PCA weighting method was used to determine the importance of each indicator by dual-indicator. Each institution's research activity and the internationalization of higher education were included in this method to determine the efforts made by these institutions. Through the study we observed the differences between the eleven countries in terms of higher education and the importance of each measurement dimension used. These findings can be used to compare the current situation in each country and to find directions for development.
Keywords: higher education; quality evaluation; composite index

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Introduction

Assessing the quality of the higher education system is important for all developed and developing countries. The higher education system is composed of the organizational structure of educational institutions, teachers and non-teachers staff to educate post-secondary students. It has value as a progression of primary and secondary education, not only as an industry in itself, but also as an important source of educated and highly educated citizens in the country. This is the reason why developed countries are keen to improve the quality of the higher education system, which requires a clear and accurate evaluation of the system in order to find progress in its development, especially after Covid-19 has brought many changes in this sector. At the 70th session of the United Nations General Assembly in September 2015, the 2030 Agenda for Sustainable Development also

highlighted the importance of lifelong learning (UNESCO, 2016). Unfortunately, strong evidence suggests that countries can achieve excellent returns by investing limited financial resources in primary and secondary education rather than in universities or technical training (McCowan, 2016), so countries prefer to invest in these instead.

A developed higher education system has value as an industry and also as a source of competent and skilled citizens for the socio-economic development of a nation. It also plays a crucial part in terms of overall sustainable development (Franco et al., 2019). Measuring the quality of higher education systems is more complex because primary and secondary education can visually reflect the quality of education through the level of students. In contrast, higher education carries the complex parts of research missions, academic integrity and transnational exchange. Thus, a qualitative higher education evaluation system is difficult, but indispensable.

The aim of the research is to assess the quality of higher education in Central and Eastern European countries. The literature review on the evaluation of higher education has included some factors that are inevitably taken into account, they directly reflect the quality of higher education and are undoubtedly elements of the quality of the higher education system in this study, such as the H-index and the financial support provided. After compiling the literature research, a number of these indicators were selected to measure the quality of the higher education through two important dimensions of the tertiary education system, indicators which included financial aid received as a percentage of total public expenditure, international students and the proportion of tertiary enrolment rates. These indicators were analyzed in the empirical study for the 11 countries selected from Central and Eastern Europe, Bulgaria, Czech Republic, Croatia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovenia and Slovakia. In the following sections, the related literature will be reviewed, then the dimensions of measuring the quality of higher education will be presented and then the research methodology will be discussed. Subsequently, the results of the study will be reported. Finally, we will present the limitations and conclusions of the study.

Literature review

Higher education evaluation work has multiplied over the last hundred years and is now veritably active (Wiethe-Körprich and Bley, 2017). In recent decades, the number of higher education institutions has increased significantly and higher education evaluation has been increasingly studied (Van Mol et al., 2021). Currently, the higher education system in each country is integrated into the public system, generally funded by the state and serving public needs (Reymert et al., 2021). Despite the increasing internationalization of academic careers, they are still formed in national contexts. In addition, national research systems differ in terms of research priorities and evaluation systems. Universities also have different levels of control over resources (Sivertsen, 2017). Assessment activities began many years ago and can be traced (Guba and Lincoln, 1981). In the mid-1960s, evaluation began to develop as a scientific field in the United Kingdom and the United States (Worthen and Sanders, 1987). Appraisal activities are widely applied and are generally defined as the recognition, clarification and application of essential criteria to define the value of an object in terms of these criteria (Fitzpatrick et al., 2004). Using the same set of criteria or models for different regional higher education systems makes it easier to identify

differences and look for relative strengths and weaknesses. Through evaluation activities, we can explore directions for the development of higher education.

As higher education continues to change and assessment activities evolve, several important methods and metrics are commonly used in the field, including feedback, formative assessment, and peer assessment (Leihy and Salazar, 2017). These methods have universally good and can be applied to assess the quality of teaching and learning in higher education in various contexts, as well as in primary and secondary education.

Rational use of data and evaluation methods can better ensure the independence of evaluation methods, increase the reliability of research and reduce randomness.

As higher education evaluation activities have evolved in the data era, academics have gradually identified more indicators that can assess the quality of higher education (Gupta et al., 2015), such as graduate employment rate, number of research papers and gender ratio. It is therefore important to consider these classic elements, which remain important measures of higher education quality, when studying new changes that may impact higher education. Green (2016) reviewed existing literature using SEM to study higher education and found that this model is often used to test alternative models, reliability, validity, theoretical support models, and data screening in higher education research models. Big data and data mining techniques have also been applied to evaluations in higher education. Thanassoulis et al. (2017) examined the role of student evaluation in higher education assessment, using a combination of analytic hierarchy process (AHP) and data envelopment analysis (DEA) to help faculty understand the direction of improvement in teaching and learning activities.

In addition, many researchers have developed studies of higher education systems using structural equation modeling (SEM), which can be used to test alternative models, reliability, validity, theoretical support models, and data filtering. Data science research methods, including time-varying cluster sampling algorithms, data mining and relational decision-making algorithms, big data, have all been applied to higher education-related data research and have been used to help develop methodologies and promote better quality teaching and learning methods (Feng, 2021; Liu and Song, 2021). When evaluating higher education, researchers often return to the first hypothesis about the impact of certain factors on the quality of higher education or the relationship between certain academic output data and higher education. These data are then examined by analytical methods such as weight-TOPSIS entropy and logistic modeling (Zhang et al., 2021).

After an evaluation, the quality of the research method or design must be tested, and this process focuses on the reliability and validity of the evaluation. In recent years, big data technologies have often been applied to monitoring and analyzing the quality of higher education. Effective data analysis methods must be used to assess the relevance of indicators, applicability of methods, and representativeness of subject assessment within the study to understand the quality of the evaluation. Xu et al. (2022) assessed the sustainability level of Japanese higher education using factor analysis and principal component analysis. Subsequently, structural validity tests were used to test the rationality of the model, quantitatively assessing the effectiveness of the policy and its impact on reality. Xu et al. (2022) assessed the level of sustainability of Japanese higher education using factor analysis and principal component analysis. Subsequently, structural validity tests were used to test the rationality of the model, quantitatively assessing the effectiveness of the policy and its impact on reality.

Dimensions of measuring the quality of higher education system

Over time it has been observed that summative assessments and quantitative indicators have become preferred elements of quality control and have led to a focus on easily quantifiable objectives of higher education, despite the disadvantages associated with such an approach. (De Weert, 1990). Two dimensions were considered through which higher education could be analyzed: scientific research dimension; institutional dimension.

The scientific research dimension which analyses the interest of universities, through the work carried out by their teaching staff, students and researchers, in terms of innovation and contribution to the development of knowledge in the fields in which they work. The institutional dimension is concerned with the efforts made by universities to attract as many students as possible and to make the transition from high school to university easier.

Scientific research dimension

For this dimension there are differences between countries, indicating different perspectives on countries' priorities for scientific research.

The assessment of scientific output is carried out from two perspectives: some countries focus on the country's scientific position in the world, while others use bibliometric indicators.

The variables analyzed are:

- Number of papers published
- Number of citable papers
- Number of papers cited
- Number of self-cited papers
- H index
- Academic reputation
- Employer reputation

The complexity of the higher education system makes it more challenging to focus on assessment activities, especially when we need to explore their quality. While we can accurately judge and compare a university by its student performance and research outcomes, when looking at the entire higher education system, we have to focus on academic integrity and financial commitment. The literature’s frequency of citations can reflect the Research Value of the higher education system; accordingly, an excessive self-citation rate is associated with speculative behavior. The average number of citations of papers within a country indicates the value of higher education research output, which affects higher education sustainability. The high self-citation rate is a well-known phenomenon of academic speculation, illustrating academic dishonesty as detrimental to higher education’s quality.

Institutional dimension

This dimension monitors various aspects of higher education institutions and its composition varies significantly between the countries analyzed. The main indicators identified can be grouped into the following categories: teaching staff, internationalization of higher education and funding of teaching, research or other related activities.

The variables analyzed are: Financial aid granted - as a percentage of total public expenditure; Faculty/Student ratio; Internationalization of universities; Tertiary education enrolment (% gross)

Government attention is measured by the ratio of financial investment in education to GDP, total expenditure per student, and GDP per capita. They are all financial indicators of the level of higher education. The government's investment in higher education is conducive to quality and higher education development. High government investment in students contributes to building talent within higher education institutions, improving organizational quality, and to sustain the output of higher education talent.

I measure a country's level of international exchange by the percentage of its international students. The cross-border mobility of students can profoundly impact the development of higher education and is a reflection of its good reputation and quality (Abdullah et al., 2017). Therefore, a higher percentage of international students reflects a high level of internationalization in local higher education and a higher quality level. Barriers to educational entry can be measured by the enrolment rate of higher education. Reflecting on how many people have access to higher education in a country or region, high levels of access reflect that the country's higher education system is of higher quality and has the potential to grow and be sustainable. Enrolment rates visually represent how many young people of the right age in a country can enter the higher education system. Higher education enrolment rates are generally higher in developed countries than in developing countries. However, considering that we are assessing the level of higher education within a certain region, these data cannot be compared directly but are divided by the corresponding base, such as the total population of the region, economic base indicators, and the total number of higher education institutions within the region.

Data and methodology

In recent years, several researchers have studied the quality of higher education in some countries. Moreover, inter-university collaboration, partnerships with government and civil societies are key factors influencing the effectiveness of higher education (Wu and Shen, 2016). It is also influenced by economic and social factors, such as funding and investment, and the creation of community partnerships (Barlett and Chase, 2004). Although not all institutions engage in all of these activities, the core initiatives of higher education effectiveness can be identified: academic, operational and administrative (Owens, 2017).

The objective of this paper is to construct a composite index determined by appropriate sub-indices to assess the quality of higher education. Composite indices can significantly improve the performance of database queries. Understanding and using them effectively is essential for researchers using databases.

Indicators are useful for identifying trends and drawing attention to particular problems.

They can also be useful for setting policy priorities and for benchmarking or monitoring performance. A composite indicator is formed when individual indicators are compiled into a single index based on an underlying model. The composite indicator measures multidimensional concepts that cannot be captured by a single indicator. For this study, several variables were selected, that are related to the quality of higher education. This was done through a literature review and an analysis of existing theories. Datasets were collected for Central and Eastern Europe, Bulgaria, the Czech Republic, Croatia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovenia, Slovakia and the Czech Republic

by consulting databases such as the Organization for Economic Co-operation and Development (OECD) database, EUROSTAT and Scimago Journal & Country Rank.
The selection includes 13 variables, which are drawn for the year 2022 and are related to the quality of higher education, as shown in Tabel 1, where the results of descriptive statistics are reported.

Table 1. Variables included in the empirical study

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Number of papers published	11	2999.00	58179.00	15012.1818	15878.58249
Number of citable papers	11	2838.00	54711.00	14153.7273	14933.44471
Number of papers cited	11	3078.00	58833.00	15388.3636	16109.71599
Number of self-cites	11	496.00	15061.00	3282.8182	4230.44699
Number of citations per document	11	.77	1.32	1.0382	.15439
H index	11	208.00	687.00	405.7273	144.12848
Financial aid granted - as a percentage of total public expenditure	11	1.60	17.50	8.2364	4.64742
Academic reputation	11	3.30	46.50	20.2455	13.63190
Employer reputation	11	1.30	53.90	17.1364	15.34857
Faculty/Student ratio	11	4.10	80.30	39.7545	22.61302
Citations by faculty	11	2.00	12.60	6.5455	3.51749
Internationalisation of universities	11	.00	19.10	5.2909	5.53560
Tertiary enrolment (% gross)	11	47.62	94.51	68.8638	13.20087
Valid N (listwise)	11				

*Source: Authors' production using SPSS software

Results

Principal component analysis (PCA) was used to analyze the 13 variables and to extract the factor coefficient score matrices. Of these, two principal components were used for further analysis. Principal component analysis was applied using Varimax rotation of the axes. Factors for which eigenvalues are greater than 1 were selected. Each sub-indicator was assigned weights using the PCA weighting method to obtain a composite index for each country. The model includes indicators such as 'academic integrity' and is applied experimentally to national data to analyze the strengths and weaknesses of the higher education system.
The application of PCA aims both to calculate the weight of the variables' importance in explaining the factors and the importance of the factors in the total variation.
Standardization of the variables leads to new variables with mean equal to zero and variance equal to one. The variance of the statistical variables, before and after component extraction, is shown in Tabel 2.

Table 2. The importance of the variables in explaining the factors

Component Matrix[a]		
	Component	
	1	2
Number of papers published	.984	-.051
Number of citable papers	.984	-.052
Number of papers cited	.983	-.005
Number of self-cites	.957	-.019
Number of citations per document	-.033	.739
H index	.890	-.073
Financial aid granted - as a percentage of total public expenditure	-.021	-.581
Academic reputation	.893	.115
Employer reputation	.897	.108
Faculty/Student ratio	.058	-.631
Citations by faculty	.137	.899
Internationalisation of universities	-.032	.851
Tertiary enrolment (% gross)	.096	-.599
Extraction Method: Principal Component Analysis.		
a. 2 components extracted.		

*Source: Authors' calculations using SPSS software

The eigenvalues of the correlation matrix are shown in the Total Variance Explained output, Initial Eigenvalues column. Following the analysis, the first component explains 48.053% of the total variance of the cloud. The first two components (factor axes), for which the eigenvalues are greater than 1, together explain 72.739% of the total variance, as shown in Tabel 3.

Table 3. Component variances

Total Variance Explained						
	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	6.247	48.053	48.053	6.247	48.053	48.053
2	3.209	24.686	72.739	3.209	24.686	72.739
3	1.108	8.519	81.258			
4	1.017	7.827	89.084			
5	.679	5.226	94.310			
6	.382	2.942	97.252			
7	.203	1.558	98.810			
8	.105	.810	99.620			
9	.029	.226	99.847			
10	.020	.153	100.000			
11	2.133E-16	1.641E-15	100.000			
12	1.189E-16	9.148E-16	100.000			
13	-1.352E-16	-1.040E-15	100.000			
Extraction Method: Principal Component Analysis.						

*Source: Authors' calculations using SPSS software

Calculation of the weight of the importance of variables

After processing the data in SPSS, the factor loadings are obtained and are shown in Table 4. Those values greater than 0.5 were selected to calculate the importance weights of each variable analyzed.

Table 4. Factor loadings

Component Matrix[a]

	Component	
	1	2
Number of papers published	.984	
Number of citable papers	.984	
Number of papers cited	.983	
Number of self-cites	.957	
Number of citations per document		.739
H index	.890	
Financial aid granted - as a percentage of total public expenditure		-.581
Academic reputation	.893	.115
Employer reputation	.897	.108
Faculty/Student ratio		-.631
Citations by faculty	.137	.899
Internationalisation of universities		.851
Tertiary enrolment (% gross)		-.599

Extraction Method: Principal Component Analysis.

a. 2 components extracted.

*Source: Authors' calculations using SPSS software

The values obtained represent the weight of the importance of the variables in explaining a factor as shown in Tabel 5. Each sub-indicator has been assigned weights using the PCA weighting method to obtain a composite index for each country.

Table 5. Weights of importance in explaining each factor

Weights	
F1	F2
0.168158321	0.000009814
0.168238486	0.000010522
0.167949508	0.000000072
0.150835511	0.000000642
0.000000045	0.159715984
0.112311826	0.000029457

0.000000146	0.060513765
0.115183759	0.000056932
0.117218111	0.000042532
0.000001032	0.085112510
0.000092694	0.345392007
0.000000025	0.279750134
0.000010538	0.069365629

*Source: Authors' calculations

The equations for each chosen factor are written with only the variables that explain the factor formation (for which factor loadings are greater than 0.5):
F1 = 0.168158321 * Number of papers published + 0.168238486 *Number of citable papers + 0.167949508 * Number of papers cited + 0.150835511 * Number of self-cites + 0.112311825659246 * H index + 0.115183759288061 * Academic reputation + 0.117218111 * Employer reputation
F2 = 0.159715983904384 * Number of citations per document + 0.0605137647224805 * Financial aid granted - as a percentage of total public expenditure + 0.0851125101915831 * Faculty/Student ratio + 0.345392006699545 * Citations by faculty + 0.279750134485181 * Internationalization of universities + 0.0693656285855632 * Tertiary enrolment (% gross)
The factor values calculated for each country are shown in the Table 6:

Table 6. Factor values for each country

Country	F1	F2
Bulgaria	-0.48531	-0.776475
Czech Republic	0.891903	0.5519729
Croatia	-0.53293	-0.7404276
Estonia	-0.52992	1.4562498
Latvia	-0.73087	0.0811364
Lithuania	-0.44294	-0.1121366
Hungary	0.082505	0.1436624
Poland	2.508724	-0.1813793
Romania	0.100547	0.0817218
Slovenia	-0.38016	0.0637657
Slovakia	-0.48155	-0.5680879

*Source: Authors' calculations

The values presented above (Weighting the importance of the factors with the value of the sub-indices by factors) are multiplied by the sub-indices presented in the table Calculating sub-indices by factors and the values of the indices for each country are shown in Tabel 7:

Table 7. Sub-index values for each country

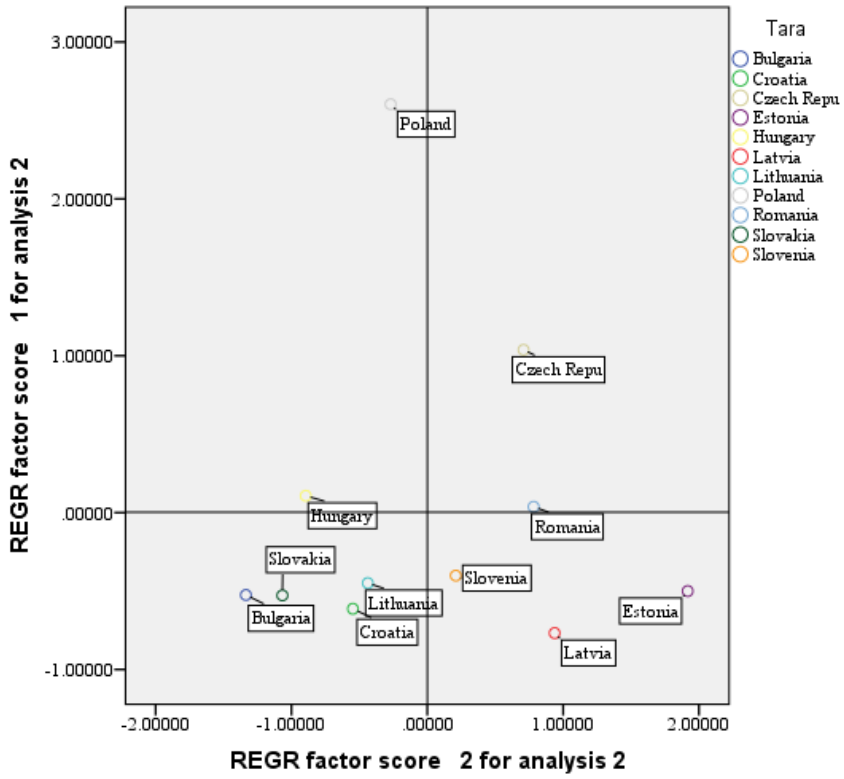
Country	Sub-index values
Bulgaria	-0.584147722
Czech Republic	0.776514212

Croatia	-0.603361774
Estonia	0.144283117
Latvia	-0.455237952
Lithuania	-0.330647647
Hungary	0.103265007
Poland	1.595574272
Romania	0.094157019
Slovenia	-0.229471508
Slovakia	-0.510924639

*Source: Authors' calculations

In Figure 1 shown below we can deduce that higher education in Poland ranks significantly higher than all other countries. Poland has the highest value of factor 1, comprising the scientific research dimension, with the most published articles, citations and the highest H-index.

Figure 1. Component Matrix output



*Source: Authors' calculations using SPSS software

Limitations

The collection of certain statistics is difficult, so there is room for improvement in the selection of indicators. Data was selected from 2022 to construct the composite index, which may have introduced some modelling errors, even though the cumulative variance rate for PCA was reasonable. The current research model has innovatively incorporated academic misconduct and speculative behaviour into assessing the quality of a country or region's higher education system and has validated the model's applicability in eleven countries. Future development of the study could focus on countries with poor statistics on relevant indicators.

Conclusions

The multidimensional approach to the quality of higher education was achieved by considering two dimensions that were analyzed: the institutional dimension and the scientific research dimension. For each dimension, the most relevant variables were selected, according to the literature, data availability and the specificity of the countries taken into analyze. As a result of the principal component analysis, it was possible to determine the factor loadings, with the help of which the weights of each variable contributing to the composite index values were calculated, thus it was possible to determine an index for each of the countries analyzed. With the help of these results it was possible to make a comparative analysis and ranking of the quality of higher education among Central and Eastern European countries. In order to improve the quality of higher education, each member of the higher education system can start from the perspective of what they can do. This is a complex system and many indicators can be used to measure its quality. Thus, all 13 variables in the analysis can have a significant impact on the overall quality of the higher education system. Strengths in individual elements of the dimensions that make up higher education do not lead to an increase in overall levels. For example, Romania publishes quite a lot of articles and is the country with the most cited articles after Poland and the Czech Republic, but the overall quality of higher education is assessed at a lower level.

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