International Journal of Management in Education

ISSN online: 1750-3868 - ISSN print: 1750-385X
https://www.inderscience.com/ijmie

Efficiency in higher education institutions: an analysis of data envelopment analysis applications

Rodrigo Soares Lelis Gori, Daniel Pacheco Lacerda, Fabio Sartori Piran, Nubia Adriane Silva

DOI: 10.1504/IJMIE.2025.10064343

Article History:

Received:	16 November 2023
Last revised:	27 March 2024
Accepted:	29 March 2024
Published online:	30 November 2024

Efficiency in higher education institutions: an analysis of data envelopment analysis applications

Rodrigo Soares Lelis Gori*,
Daniel Pacheco Lacerda,
Fabio Sartori Piran and
Nubia Adriane Silva

Postgraduate Programme in Production Engineering,
Vale do Rio dos Sinos University – UNISINOS,
Cristo Rei – São Leopoldo, Rio Grande do Sul, Brazil
Email: rsgori@ifto.edu.br
Email: daniel.lacerda@ufsc.br
Email: fpiran@unisinos.br
Email: nubia@ifto.edu.br
*Corresponding author

Abstract: Estimating efficiency in higher education has been a challenge due to the complexity and heterogeneity of institutions. Data Envelopment Analysis (DEA) has emerged as the main technique used to evaluate efficiency in the educational field. This study aims to analyse the applications of DEA in evaluating efficiency in Higher Education Institutions (HEIs). This article contributes to the literature by discussing efficiency in higher education and by providing methodological and practical advances. Firstly, we carried out a Content Analysis considering 113 relevant studies in the fields of efficiency evaluation using DEA in HEIs. We identified motivators, results and main methodological approaches. In addition, we identified the need to expand studies focussing on the process of evaluating efficiency in resource allocation using DEA.

Keywords: higher education institutions; DEA; efficiency evaluation; content analysis; motivators; results; resource allocation; methodological approaches; methodological advances; practical advances.

Reference to this paper should be made as follows: Gori, R.S.L., Lacerda, D.P., Piran, F.S. and Silva, N.A. (2025) 'Efficiency in higher education institutions: an analysis of data envelopment analysis applications', *Int. J. Management in Education*, Vol. 19, No. 1, pp.32–59.

Biographical notes: Rodrigo Soares Lelis Gori is a PhD candidate in Production and Systems Engineering. His research focuses on the application of DEA to assess the level of efficiency of educational systems. He has experience in data analysis and quality management.

Daniel Pacheco Lacerda holds a PhD in Production Engineering from the Federal University of Rio de Janeiro in 2009. He is currently a professor at the Federal University of Santa Catarina. His research interests include operations, business process engineering, data envelopment analysis, design science research and Theory of Constraints.

Fabio Sartori Piran holds his PhD degree in Production and Systems Engineering from the University of Vale do Rio dos Sinos – UNISINOS. Currently, he is a Professor at the University of Vale do Sinos. His research interests include cost management, with an emphasis on cost reduction, loss analysis, inventory control and organisation and the implementation of management tools.

Nubia Adriane Silva is a PhD candidate in Production and Systems Engineering. Her research focuses on the application of DEA to assess the level of efficiency of educational and production systems. She has experience in data analysis and quality management.

1 Introduction

Education is one of the most important factors in measuring a society's level of development (Turwelis et al., 2022). Studies show that education is positively related to the economic development of a region (e.g., Hanushek and Kimko, 2000; Hanushek and Woessmann, 2008, 2012), indicating that each additional year of schooling leads to an average growth of 0.6% in the country's Gross Domestic Product (GDP) (OECD, 2020).

The benefits of education accrue to both society and individuals and, as such, the provision of education in many countries is public and subsidised, at least in part, by the government (Johnes, 2006; Johnes et al., 2017). A study conducted by the Organisation for Economic Co-operation and Development (OECD) analysed the financial resources invested in education. The results show that total public resources invested in education represent an average of 10.6% of total government spending, with a range of 7% to 17% (OECD, 2022).

Given this scenario, evaluating efficiency in education becomes crucial. The education sector is characterised by its non-profit nature, the use of multiple inputs generating multiple outputs and the absence of input and output prices, which makes it difficult to assess efficiency (Johnes, 2006; Witte and López-Torres, 2017). Despite the complexity involved, evaluating the efficiency of the use of resources earmarked for education, especially higher education, is essential to understanding the real situation of the administration and setting objectives in line with the country's reality in terms of educational productivity (Smith and Street, 2005; Witte and López-Torres, 2017).

It should be noted that although efficiency and productivity are sometimes considered synonymous, the concept of productivity differs from that of efficiency (Macedo et al., 2023). Efficiency assesses performance by reflecting the relationship between the product obtained and the resources used, taking into account their limited availability (Di Maio et al., 2017). On the other hand, productivity is defined as output divided by input (or resource), representing a static or level concept that can be measured to compare a company's performance at a given time, allowing differences in productivity levels between companies to be analysed (Meireles, 2023). As such, this article will focus on the study of efficiency evaluation, exploring in detail the methodologies and approaches for evaluating and improving organisational efficiency.

Among the techniques for assessing efficiency in education, Data Envelopment Analysis (DEA) stands out as the most widely used (Emrouznejad and Yang, 2018; Johnes and Johnes, 2009; Thanassoulis et al., 2016; Wolszczak-Derlacz, 2017, 2018). For

this reason, several literature reviews have been developed analysing the application of DEA in the field of education. For example, De Witte and López-Torres (2017) reviewed efficiency evaluation techniques, including DEA, highlighting its application in the educational context until 2015. Johnes et al. (2017) provided an overview of the topic of efficiency in education. Johnes (2015) provided an overview of the various problems faced by government, managers and consumers of education, addressing Operations Research (OR) techniques, including DEA. Recently, Mergoni and De Witte (2022) provided a state-of-the-art review of studies that using non-parametric techniques, including DEA, to investigate the combination of efficiency and effectiveness to evaluate public interventions and detect inefficiencies at the policy level, especially in key sectors such as education, health and the environment.

However, to date, no review has focused specifically on the use of DEA to evaluate efficiency in Higher Education Institutions (HEIs). Therefore, this study aims to analyse the applications of DEA in evaluating efficiency in HEIs. We sought to identify the methodological approaches of the list of articles, including publications by year, authors identified, country by volume of publications, input and output category, DEA models, type/orientation of each model, data analysis techniques, types of efficiencies and types of benchmarking, as well as their main relationships.

In this way, this analysis can contribute to comparative studies, increase the potential for application in other regions of the world and raise the quality of the research carried out. Initially, the research identified the motivators and results of the applicability of DEA in evaluating efficiency in HEIs, as well as the main methodological approaches of the DEA technique. As a second contribution, the research identified the need to expand studies focusing on efficiency evaluation in HEIs using DEA in the resource allocation process, especially in emerging countries such as the BRICS group (Brazil, Russia, India, China and South Africa), using internal benchmarking as a central concept.

This study is structured in five sections. The Section 1 presents the introduction. Section 2 describes the methodological procedures. Section 3 presents the results of the study. Section 4 discusses and analyses the results identified. Finally, the last Section 5 presents the final considerations and suggestions for future research.

2 Methodology

The methodology employed in this study was based on a Systematic Literature Review (SLR), using the Literature Grounded Theory (LGT) method (Ermel et al., 2021). LGT is made up of four stages, all of which are duly addressed throughout this work: (i) Literature Review, (ii) Literature Analysis, (iii) Literature Synthesis and (iv) Research Results (Ermel et al., 2021).

The CIMO tool – Context, Intervention, Mechanisms and Outcomes – was used to guide the definition of the research questions (see Table 1). CIMO is an important tool used to specify the four essential parts in the development of systematic review questions (Denyer et al., 2008).

Table 1 CIMO

Context	*Higher Education Institutions*
Intervention	Efficiency evaluation
Mechanisms	Data envelopment analysis (DEA)
Outcomes	Identifying how efficiency is evaluated in HEIs

Source: Adapted from Denyer et al. (2008).

A research protocol was then developed (see Appendix 1). The protocol was validated by four experts, who were selected based on the following requirements: (i) publication of systematic reviews or knowledge on the subject and (ii) researchers with a minimum qualification of a doctorate in their area of research. Table 2 shows the list of experts.

Table 2 Identification of experts

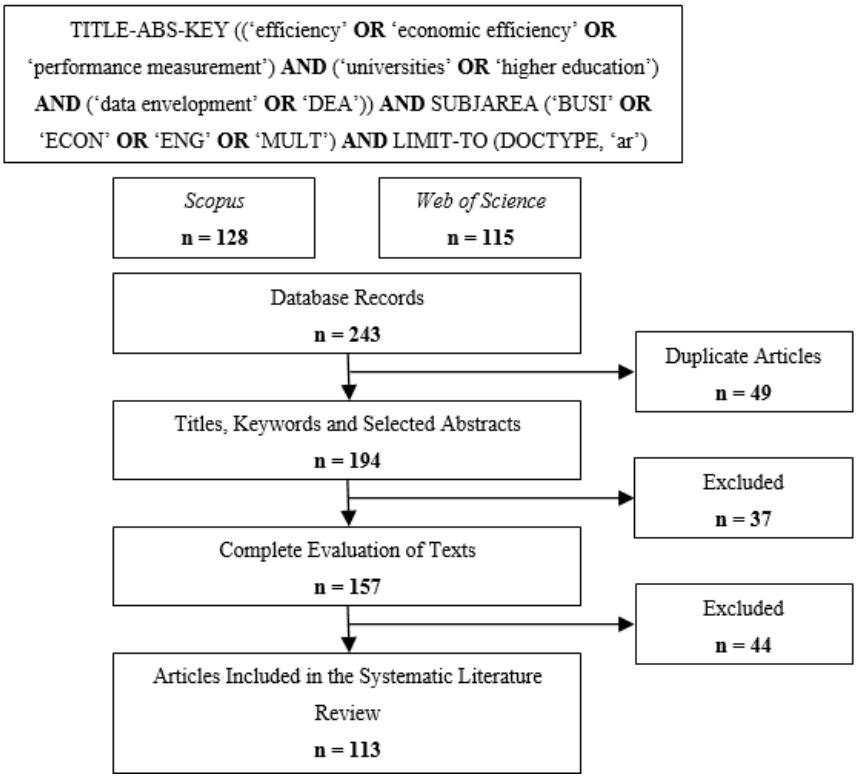
Specialist	*Training*	*Program and Institution to which it is linked*
1	Doctor in Production and Systems Engineering – UNISINOS	School of Management and Business and Polytechnic School – UNISINOS – BR
2	Doctor in Industrial Management and Engineering – University Politecnico di Milano	Department of Management, Economics and Industrial Engineering – University Politecnico di Milano School of Management – Milano, IT
3	Doctor in Business Administration – University of South Wale	Business School – Swansea University – Wales, UK
4	Doctor in Management and Operational Research – University of Aston	Business School – Portuguese Catholic University - Porto, PT

Source: Prepared by the authors.

The search strategy was then outlined and carried out in the Scopus and Web of Science databases, using the terms in Figure 1. The choice of these databases was based on their ability to provide agile access to the main global citation repositories, as well as demobilising advanced tools for tracking, analysing and visualising research (Gauss et al., 2021). About the period and subject area, articles published up to 2022 were consulted, covering research in the areas of business, economics and engineering.

After searching the databases, the textual corpus identified was refined and duplicate articles were excluded, followed by an inspection of the titles, keywords and abstracts (Brunton et al., 2012). Seeking to include only articles that were related to the aim of the study, two reviewers carried out the inspection. The results of this stage were compared and, if any discrepancies in the choice were identified, they were resolved through discussion between the reviewers to ensure agreement. The selected articles were then analysed in depth. Figure 1 illustrates the process of selecting the studies that make up the research, considering the 113 articles analysed.

Figure 1 Search flow, filters and results



Source: Prepared by the authors.

Next, Table 3 presents the exclusionary statistics. Potentially relevant studies were analysed in depth, and those that were within the scope of the research were selected for review (see Appendix 2).

Table 3 Exclusion statistics

Exclusion criteria	*Number of exclusions*	*Percentage (%)*
Duplicate studies	49	37,7
Articles not related to the research objective	44	33,8
No approach to the DEA technique or no approach to efficiency in HEIs	37	28,5
Total	130	100

Source: Prepared by the authors.

The second stage involved analysing the data. A scientific mapping was carried out based on the aggregative review strategy (Ermel et al., 2021; Zimmer, 2006). Vosviewer software was used as a computer resource to manipulate the data.

The next step was to carry out a content analysis, defining a coding system to analyse the studies included in the RSL (Mayring, 2014). After reading and coding the studies, a categorisation was carried out based on Ma and Li (2021), considering: (i) Efficiency in

the Functioning of the Institution; (ii) Efficiency in the Allocation of Resources; (iii) Efficiency in Research/Technological Innovation and (iv) Investment Efficiency.

Additionally, after categorising the articles, the input and output variables were identified. Based on the study by De Witte and López-Torres (2017), categories were created to facilitate the analysis of the list of articles. The inputs were: (i) Research/Innovation; (ii) Server/Collaborator; (iii) Student; (iv) Budget; (v) Infrastructure; and (vi) Other. As for the outputs: (i) Student; (ii) Research/Innovation; (iii) Infrastructure; (iv) Evaluation of the Institution and (v) Other.

Next, the occurrence, co-occurrence and frequency relationships of the methodological variables were analysed. The variables identified include: (i) efficiency; (ii) benchmarking; (iii) DEA model; (iv) orientation and type of each DEA model and (iv) whether the approach used was a single-stage or two-stage DEA analysis.

After the data coding process, a matrix was generated between the Motivators and Results. The aim was to seek an understanding of the Motivators that led HEIs to implement DEA for efficiency evaluation and what Results were achieved as a result. Atlas.ti® data analysis software was used to assist this entire process. The results of this process are presented in the next section.

3 Results

This section begins by analysing the scientific output of the textual corpus surveyed. Between 2016 and 2022, the average number of scientific publications was 12 articles/per year. By considering the output of authors who have contributed to the field and taking into account the bibliographic portfolio analysed, the research listed the total number of publications and citations per author, as can be seen in Table 4. Among the main authors, Jill Jones stands out, followed by Tommaso Agasisti.

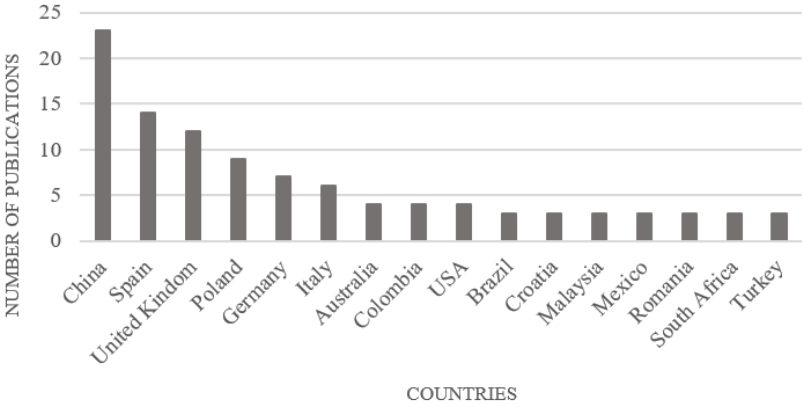
Table 4 Main authors

Author	*Articles*	*Citations*
Jhones, J.	5	728
Agasisti, T.	5	326
Jhones, G.	3	244
Brzezicki, Ł.	3	1
Iee, B.L.	2	132
Bornmann, L.	2	43
Wohlrabe, K.	2	43
Chen, X.	2	24
Kosor, M.M.	2	13

Source: Prepared by the authors.

When considering the main countries with scientific production on the subject, 47 were identified. China leads the way with 23 publications, followed by Spain with 14 publications and the UK with 12 publications. The distribution of the countries' scientific output can be seen in Figure 2.

Figure 2 Main countries with scientific productions



Source: Prepared by the authors.

Table 5 shows the articles grouped according to the research objective, grouping them into four categories, according to Ma and Li (2021). In the Efficiency in the Functioning of the Institution category, the studies aimed to assess, analyse, measure or compare general aspects related to the institutional efficiency of HEIs (Ding et al., 2021; Hoz et al., 2021). The category Efficiency in Resource Allocation addresses the development of more efficient mechanisms, seeking to assist decision-makers in measuring the results of their institutional strategies and policies (Lita, 2018; Madaleno and Moutinho, 2023). The studies in the Research/Innovation Efficiency category have as one of their main objectives to analyse the productivity of HEIs about scientific production and innovation (Du and Seo, 2022; Luo, 2021). Finally, the Investment Efficiency category encompasses studies that address measures to foster investment in higher education (Dumitrescu et al., 2020).

Table 5 Research textual corpus categorisation

Category	*Articles*	*Occurrence (articles)*
Efficiency in the Functioning of the Institution	I7, I9, I10, I11, I14, I15, I16, I17, I19, I20, I21, I26, I27, I28, I29, I30, I34, I35, I36, I38, I39, I40, I41, I43, I44, I46, I48, I51, I52, I54, I56, I57, I58, I59, I60, I61, I66, I67, I69, I70, I71, I72, I73, I74, I75, I77, I78, I79, I80, I82, I85, I86, I87, I88, I89, I90, I92, I93, I96, I97, I98, I99, I100, I101, I102, I103, I104, I105, I107, I108, I110, I112, I113	73
Efficiency in Research/Innovation	I1, I5, I6, I8, I13, I18, I22, I24, I25, I31, I32, I33, I42, I45, I47, I49, I50, I55, I64, I65, I68, I76, I81, I83, I84, I94, I95, I109, I111	29
Efficient Resource Allocation	I2, I3, I4, I12, I23, I53, I62, I63, I91, I106	10
Investment Efficiency	I37	1

Source: Prepared by the authors.

The relationship between the input/output variables, their categories and the occurrence identified in the studies can be seen in Table 6. The main input category was Server/Collaborator, present in 63 articles. When analysing outputs, the main category was Student, identified in 75 articles.

Table 6 Input/output ratio

Variables	*Categories*	*Main variables*	*Articles*	*Occurrence*
Input	Research Innovation	– Research/Innovation Team; – Investment in research/innovation activities; – Number of academic papers published; – Number of patents granted; – Number of research grants; – Number of scientific projects	I1, I2, I5, I6, I8, I13, I17, I18, I20, I22, I24, I31, I33, I35, I36, I42, I47, I49, I50, I51, I64, I65, I68, I92, I93, I94, I95, I102, I107, I109, I111	31
	Server Employee	– Number of teaching staff; – Quantity of administrative staff	I2, I7, I10, I14, I15, I16, I18, I20, I21, I22, I23, I25, I26, I28, I29, I30, I33, I35, I36, I39, I40, I41, I42, I43, I44, I46, I47, I51, I53, I54, I56, I57, I58, I59, I61, I63, I64, I66, I67, I68, I71, I72, I73, I74, I76, I77, I79, I81, I82, I83, I84, I85, I87, I89, I90, I91, I102, I103, I105, I107, I111, I112, I113	63
	Student	– Number of undergraduate students – Number of postgraduate students; – Number of master's/doctoral theses; – Number of courses; – Socio-economic and cultural level	I2, I3, I7, I15, I17, I18, I25, I28, I30, I33, I38, I39, I48, I53, I54, I56, I58, I61, I62, I63, I66, I67, I71, I74, I75, I77, I85, I86, I87, I89, I92, I96, I104, I105, I107, I108, I110, I112	38

Table 6 Input/Output ratio (continued)

Variables	*Categories*	*Main variables*	*Articles*	*Occurrence*
	Budget	– Public funds received; – Personnel costs; – Administrative expenses, – Allocation of budgetary resources; – Financial resources obtained; – Maintenance and Investment Budget; – Government spending on higher education as a percentage of GDP; – Expenditure per student	I3, I6, I8, I12, I14, I16, I18, I20, I23, I26, I32, I35, I36, I37, I38, I40, I41, I43, I46, I48, I52, I54, I55, I58, I60, I62, I66, I67, I68, I70, I71, I74, I79, I80, I81, I82, I83, I84, I85, I88, I89, I94, I97, I98, I99, I100, I101, I103, I105, I106, I108, I110, I111, I113	54
	Infrastructure	– Physical space; – Number of educational institutions; – Number of laboratories – Number of libraries; – Number of books; – Technological resources; – Number of classrooms	I4, I10, I12, I15, I16, I17, I23, I25, I32, I33, I45, I46, I59, I78, I100, I103, I107, I109, I111, I113	20
	Others	– Number of posts in the forum topic; – Number of replies in the forum; – Time spent browsing videos; – Results in national standardised exams	I9, I11, I27, I34, I69	5
Output	Student	– Quantity of undergraduate graduates; – Number of students completing postgraduate studies – Average undergraduate student grades; – Number of scientific monographs; – Student employability; – Social/economic benefits; – Services to the community; – Academic results	I3, I4, I7, I10, I12, I14, I15, I16, I17, I19, I21, I23, I26, I28, I29, I30, I32, I35, I36, I37, I39, I40, I41, I43, I44, I46, I48, I51, I52, I53, I54, I55, I56, I58, I59, I60, I62, I63, I64, I66, I67, I70, I71, I72, I75, I77, I78, I79, I80, I81, I82, I83, I84, I85, I86, I87, I88, I89, I92, I93, I94, I96, I97, I98, I99, I100, I101, I102, I103, I104, I105, I106, I108, I110, I112, I113	75

Table 6 Input/Output ratio (continued)

Variables	*Categories*	*Main variables*	*Articles*	*Occurrence*
	Server Employee	– Quantity of work by the teaching staff; – Human resources	I17, I65	2
	Research Innovation	– Technology transfer agreements (revenue from the sale of patents); – Number of articles published; – Number of patents authorised; – Number of approved research projects; – Citation count; – Number of research grants; – Volume of scientific production; – Software application developed; – Volume of scientific production; – International scientific index	I1, I3, I5, I6, I7, I8, I12, I13, I14, I15, I17, I18, I19, I20, I22, I23, I24, I25, I28, I30, I31, I33, I35, I36, I39, I40, I41, I42, I45, I47, I49, I50, I51, I53, I54, I55, I57, I58, I59, I60, I61, I63, I64, I65, I66, I67, I68, I70, I71, I72, I73, I76, I77, I81, I82, I83, I84, I90, I93, I94, I95, I100, I101, I102, I103, I105, I106, I107, I108, I109, I110, I111, I112, I113	74
	Infrastructure	– Quantity of books; – Infrastructure	I7, I15, I72, I98	4
	Evaluation of the Institution	– National exam score/concept; – Institutional peer evaluation score	I2, I9, I11, I26, I27, I69, I91, I94, I96, I98	10
	Others	– Number of times the ad was shown on the screen; – Financial income collected by the HEI	I34, I38, I74, I78, I111	5

Source: Prepared by the authors.

Another point considered was the identification of the methodological variables of the DEA models (see Table 7). Initially, the types of efficiency were identified. Based on the work of Johnes and Johnes (2004), the types of efficiency observed in this research were technical and allocative. In addition, the orientation and type of each DEA model were identified. The types of benchmarking were also observed, according to the classification by Elmuti et al. (1997), which divides the types into: (i) internal; (ii) external; (iii) functional or industrial and (iv) process or generic. Within the scope of this study, the types of benchmarking observed were internal and external.

Table 7 Co-occurrence analysis methodological variables

Occurrence	*Type of Efficiency*			*Type of Benchmarking*		*DEA Model Orientation*			*DEA Model Type*		
	Allocative	*Technical*		*Internal*	*External*	*Input*	*Output*	*Input/ Output*	*CRS*	*VRS*	*CRS/ VRS*
Allocative	9			3	6	2	7		2	6	1
Technical	104			15	89	16	86	2	31	57	16
Internal	18	3	15			4	13	1	7	8	3
External	95	6	89			14	80	1	26	55	14
Input	18	2	16	4	14				4	9	5
Output	93	7	86	13	80				28	54	11
Input/ Output	2		2	1	1				1		1
CRS	33	2	31	7	26	4	28	1			
VRS	63	6	57	8	55	9	54				
CRS/VRS	17	1	16	3	14	5	11	1			

Source: Prepared by the authors.

Table 8 shows the DEA models used, with the classic model predominating in empirical applications. However, other models were applied, such as Super-efficiency DEA, Network DEA – NDEA and Slack-Based Models – SBM, among others.

Table 8 DEA models

Models	*Occurrence*
Classic	89
Super-Efficiency	10
Network DEA (NDEA)	8
Slack-Based Models (SBM)	2
Inverse DEA (InvDEA)	1
Directional Distance Function (DDF)	1
Centralised DEA (CDEA)	1
Multi-objective DEA (MODEA)	1

Source: Prepared by the authors.

About the number of studies carried out using two-stage DEA approaches, Table 9 shows the complementary techniques used. Most of the articles (57%) conducted a second-stage analysis to relate the efficiency calculated by DEA to exogenous variables. Among the main techniques used to carry out two-stage DEA analyses, Bootstrap Regression, Tobit Regression and the Malmquist Index predominate.

Table 9 Two-step DEA approaches

	Approach	*Occurrence*
Regression	Bootstrap Regression	8
	Tobit Regression	6
	Truncated Regression	5
	Linear Regression	4
	Least Squares Regression (OLS)	2
	Dynamic Panel Regression	1
	Meta Regression	1
	Second Stage Regression	1
Correlation	Spearman Correlation	3
	Pearson Correlation	1
Hypothesis Testing/Other Techniques	Malmquist Index	14
	SFA	5
	Analysis of Variance (ANOVA)	2
	Sensitivity Analysis	2
	K-means Analysis	2
	Cluster Analysis	2
	Markov Chain	1
	AHP	1
	FHD	1
	Theil Index	1
	Hotelling Test	1

Source: Prepared by the authors.

Another point of this analysis was to identify the main Motivators and the main Results of the implementation of the DEA technique for evaluating efficiency in HEIs by continent. Table 10 shows these figures.

Table 10 Co-occurrence analysis motivators x results

		Motivators (M)		*Results (R)*	
		Academic performance	*Research/Innovation productivity*	*Decision-making*	*Institutional performance*
Continent	America	7	5	14	4
	Africa	1	1	3	
	Asia	12	17	30	6
	Europe	29	8	29	16
	Oceania	1	1	3	
R	Decision Making	30	25		
	Institutional Performance	17	3		

Source: Prepared by the authors.

Among the Motivators, Academic Performance and Research/Innovation Productivity stood out. About Results, Decision Making and Institutional Performance were identified. The Academic Performance motivator is related to improving the performance of multiple departments within an institution (Ding et al., 2021; Nkohla et al., 2021). While the Decision-Making outcome provides ways to solve/anise problems in the transformation between knowledge production and results in scientific activities, leading to improvements in the governance structure of HEIs (Lehmann et al., 2018; Zhao et al., 2022). The results are discussed below.

4 Discussions

The results show that China leads the scientific production with 23 studies, as it is an emerging economy country belonging to the BRICS group of countries (Amin and Haq, 2022). However, when analysing the scientific output of the other members of the group, it can be seen that South Africa and Brazil have only 3 studies each, while Russia has 2 and India 1. This scarcity of studies in the BRICS countries stands out as a promising research niche in the field of education, given that their university systems have existed since 1995 and have undergone a transformation over the years, redefining the public/private nature of their educational systems, as well as together representing around 41% of the world's population and generating 25% of the global gross domestic product (Neto et al., 2022; WorldData, 2023).

About inputs and outputs, there was significant convergence between the studies when it came to defining outputs. This agreement is justified by the fact that these are outputs that can drive the evaluation of efficiency in HEIs (Li, 2022). Overall, it can be seen that the results obtained in the studies are highly dependent on the selection of the variables to be included in the evaluation, as well as how they are measured.

The main DEA models, such as classic and super-efficiency, were predominant in studies categorised into efficiency in the functioning of the institution and efficiency in research/innovation. Some models were little applied, e.g., the NDEA. Although NDEA is a growing field of research in the general literature on efficiency (Camanho et al., 2023). We note that the majority of two-stage applications employ regression techniques (Bootstrap Regression, Tobit Regression and Truncated Regression). This preference occurs regardless of the existing discussion around these methods, with Banker and Natarajan (2008) arguing that Ordinary Least Squares (OLS) methods can be applied as second-stage tools, even showing that Tobit regression is not significantly better than simple OLS.

Regarding the orientation and type of DEA models, the output-oriented VRS configuration stands out as the most used. This preference is in line with the studies identified in this research Gebru et al. (2022), Herberholz and Wigger (2021), Nkohla et al. (2021) and Brzezicki et al. (2022), where the aim is to maintain resource consumption and maximise results.

When analysing benchmarking, it was found that external benchmarking was the most widely used. This finding is in line with the study by Macedo et al. (2023), where the authors state that efficiency evaluations based on DEA are often associated with external benchmarking. However, only 18 studies (16%) used internal benchmarking. This percentage indicates that the literature has not explored the use of internal benchmarking very much.

As for the type of efficiency, there was a concentration of studies analysing technical efficiency models (104 articles), while 9 articles analysed allocative efficiency. According to the co-occurrence assessment, there was a concentration of studies – 89 in total – which analysed external benchmarking from the point of view of technical efficiency. Among the studies we highlight: De Pedro et al. (2022); Chen et al. (2021); Kosor et al. (2019) and Moreno-Gómez et al. (2020). These studies tended to define Decision-Making Units (DMUs) in annual periods, i.e., the DMU is the institution or country itself, where data is collected in annual periods over time.

Most of the articles focus on the categories of efficiency in the functioning of the institution and efficiency in research/innovation. Despite the relevance of these categories, we identified that the category of efficiency in resource allocation is something that the literature has not explored much, which corroborates the studies by Nazli et al. (2019) and Zhang et al. (2020). One of the possible causes of this scarcity may be the fact that most of the studies in this review focus on the allocation of budgetary resources only (Abdullah et al., 2018; Alam et al., 2023; Fu and Heenko, 2022; Olariu and Brad, 2022). Studies focusing on the allocation of intangible resources, such as human resources (teaching and administrative staff), physical resources (buildings, classrooms, laboratories and libraries), academic resources (curriculum and books), research resources (laboratories and funding for research projects) and student support resources (psychological support, student housing and financial assistance) can expand research into the allocation of resources in institutions, providing more efficient management in HEIs.

Another point to note was that most of the HEIs in this study have established processes for institutional evaluation, strategic planning and resource allocation. However, these processes are often disconnected, which results in an inefficient allocation of resources. To alleviate inequalities and provide equity between HEIs, or between units that make up a given HEI, the process of allocating resources, e.g., budget resources, can be based on a matrix that takes into account factors such as the number of enrolments, faculty titles, academic efficiency index, dropout rate, among others.

When identifying scientific production by continent, taking into account the Motivators and Results (see Table 10), it was found that the majority of studies from countries on the European and American continents focus on the Academic Performance Motivator (Herberholz and Wigger, 2021; Kosor et al., 2019; Papadimitriou and Johnes, 2019; Perović and Kosor, 2020). While most countries on the Asian continent focus on the Research/Innovation Productivity Driver (Du and Seo, 2022; Khurizan et al., 2018; Luo, 2021; Sing and Imen, 2022). With regard to Results, Decision Making was a common point between Asia, America and Europe. As such, DEA is an important tool for evaluating multiple options in decision-making processes. It offers a structured approach to analysing perspectives and predictabilities in order to make compensatory or non-compensatory decisions based on explicitly defined criteria (Nepomuceno et al., 2024). This corroborates the studies by Serkani et al. (2022), Ranjan and Singh (2021), Mousa and Ghulam (2019), Abdullah et al. (2018), where applying DEA models allowed managers to identify weaknesses and improve the overall efficiency of the institution by focusing on deficiencies.

Finally, the analysis of the matrix presented in Table 9 revealed a concern on the part of the HEI with the pursuit of strategic initiatives in Decision Making associated with Academic Performance and Research/Innovation Productivity. This finding is in line with the authors Rodionov and Velichenkova (2020), Serkani et al. (2022) and Vilela et al. (2021). In these studies, the results suggest the need for actions with managerial

implications to optimise and improve academic performance and productivity in research/innovation. The conclusions of this study are presented below.

5 Conclusions

This study provides a comprehensive analysis of the applications of the DEA technique in evaluating efficiency in HEIs. In reviewing the 113 articles, the literature examined reveals a significant global interest in this topic, highlighting the strategic importance attributed to efficiency in HEIs around the world. The results obtained suggest that strengthening the connections between institutional evaluation, strategic planning and the budgeting process of a HEI are essential for a satisfactory allocation of resources.

The main contributions of this study were: (i) identification of the main methodological approaches, providing a comprehensive overview of current practices in the application of DEA in HEIs; (ii) identification of the main Motivators and the main Outcomes, highlighting the need to align institutional objectives with efficiency strategies, as evidenced by the emphasis on Academic Performance and Research/Innovation Productivity; (iii) the importance of improving the process of allocating budgetary resources, based, e.g., on a matrix that takes into account factors such as the number of enrolments, the qualifications of teaching staff, the academic efficiency index and the drop-out rate, in order to optimise and ensure equity between institutions and (iv) the need to expand studies involving the BRICS countries, focusing on the applicability of DEA in evaluating efficiency in HEIs, using internal benchmarking as a central concept, which will provide a more comprehensive and personalised understanding of educational dynamics in different contexts.

As a limitation, although we used appropriate keywords for this study and searched the most relevant scientific databases, the use of other keywords in other databases may produce different results. We, therefore, suggest that future research explore new methodological variables and emerging challenges in evaluating efficiency using the DEA technique in HEIs.

Acknowledgements

Prof. Daniel Pacheco Lacerda was supported by a research grant of CNPq – Brazil (CNPq process No. 313744/2023-8). Prof. Fabio Sartori Piran was supported by Fapergs (22/2551-0000625-6). Prof. Rodrigo Soares Lelis Gori was supported by IFTO (Process 23235.019925/2020-28).

References

Abdullah, D., Tulus, Suwilo, S., Efendi, S., Zarlis, M. and Mawengkang, H. (2018) 'A research framework for data envelopment analysis with upper bound on output to measure efficiency performance of higher learning institution in Aceh province', *International Journal on Advanced Science, Engineering and Information Technology*, Vol. 8, No. 2, pp.336–341. Doi: 10.18517/ijaseit.8.2.3625.

Alam, T.E., González, A.D. and Raman, S. (2023) 'Benchmarking of academic departments using data envelopment analysis (DEA)', *Journal of Applied Research in Higher Education*, Vol. 15, No. 1, pp.268–285. Doi: 10.1108/JARHE-03-2021-0087.

Altamirano-Corro, A. and Peniche-Vera, R. (2014) 'Measuring the institutional efficiency using dea and ahp: the case of a mexican university', *Journal of Applied Research and Technology*, Vol. 12, No. 1, pp.63–71. Doi: 10.1016/S1665-6423(14)71606-2.

Amin, M.Y. and Haq, Z.U. (2022) 'BRIC without B: does ownership structure matters for firm performance in emerging economies?', *Quality and Quantity*, Vol. 56, No. 1, pp.217–226. Doi: 10.1007/s11135-021-01124-8.

Banker, R.D. and Natarajan, R. (2008) 'Evaluating contextual variables affecting productivity using data envelopment analysis', *Operations Research*, Vol. 56, No. 1, pp.48–58. Doi: 10.1287/opre.1070.0460.

Brunton, G., Stansfield, C. and Thomas, J. (2012) *Finding Relevant Studies. An Introduction to Systematic Reviews*, Sage Publications.

Brzezicki, Ł., Pietrzak, P. and Cieciora, M. (2022) 'Efficiency of the education system (primary, secondary and tertiary) in particular voivodeships of Poland', *Economy of Regions*, Vol. 18, No. 2, pp.494–508. Doi: 10.17059/ekon.reg.2022-2-14.

Camanho, A.S., Silva, M.C., Piran, F.S. and Lacerda, D.P. (2023) 'A literature review of economic efficiency assessments using data envelopment analysis', *European Journal of Operational Research*, Vol. 55, pp.571–591. Doi: 10.1016/j.ejor.2023.07.027.

Chen, Y., Ma, X., Yan, P. and Wang, M. (2021) 'Operating efficiency in Chinese universities: an extended two-stage network DEA approach', *Journal of Management Science and Engineering*, Vol. 6, No. 4, pp.482–498. Doi: 10.1016/j.jmse.2021.08.005.

Cordero-Gutiérrez, R. and Lahuerta-Otero, E. (2020) 'Social media advertising efficiency on higher education programs', *Spanish Journal of Marketing - ESIC*, Vol. 24, No. 2, pp.247–262. Doi: 10.1108/SJME-09-2019-0075.

De Pedro, E.M., Leitão, J. and Alves, H. (2022) 'Do socially responsible higher education institutions contribute to sustainable regional growth and innovation?', *International Journal of Sustainability in Higher Education*, Vol. 23, No. 8, pp.232–254. Doi: 10.1108/IJSHE-09-2021-0400.

De Vilela, B..A., Cavalcanti, J.M.M., De Freitas, K.A. and De Carrieri, A.P. (2021) 'Quality assessment of scientific papers: excellence or legitimization of research practices?', *Brazilian Business Review*, Vol. 18, No. 6, pp.700–721. Doi: 10.15728/bbr.2021.18.6.6.

De Witte, K. and López-Torres, L. (2017) 'Efficiency in education: a review of literature and a way forward', *Journal of the Operational Research Society*, Vol. 68, No. 4, pp.339–363. Doi: 10.1057/jors.2015.92.

Denyer, D., Tranfield, D. and Van Aken, J.E. (2008) 'Developing design propositions through research synthesis', *Organization Studies*, Vol. 29, No. 3, pp.393–413. Doi: 10.1177/0170840607088020.

Di Maio, F., Rem, P.C., Baldé, K. and Polder, M. (2017) 'Measuring resource efficiency and circular economy: a market value approach', *Resources, Conservation and Recycling*, Vol. 122, pp.163–171. Doi: 10.1016/j.resconrec.2017.02.009.

Ding, T., Yang, J., Wu, H., Wen, Y., Tan, C. and Liang, L. (2021) 'Research performance evaluation of Chinese university: a non-homogeneous network DEA approach', *Journal of Management Science and Engineering*, Vol. 6, No. 4, pp.467–481. Doi: 10.1016/j.jmse.2020.10.003.

Du, Y. and Seo, W. (2022) 'A comparative study on the efficiency of R&D activities of Universities in China by region using DEA–Malmquist', *Sustainability (Switzerland)*, Vol.14, No. 16, pp.1–13. Doi: 10.3390/su141610433.

Dumitrescu, D., Costică, I., Simionescu, L.N. and Gherghina, S.C. (2020) 'A DEA approach towards exploring the sustainability of funding in higher education: empirical evidence from Romanian public universities', *Amfiteatru Economic*, Vol. 22, No. 54, pp.593–607. Doi: 10.24818/EA/2020/54/593.

Elmuti, D., Kathawala, Y. and Lloyed, S. (1997) 'The benchmarking process: assessing its value and limitations', *Industrial Management-Chicago Then Atlanta*, Vol. 39, pp.12–19.

Emrouznejad, A. and Yang, G.L. (2018) 'A survey and analysis of the first 40 years of scholarly literature in DEA: 1978–2016', *Socio-Economic Planning Sciences*, Vol. 61, pp.4–8. Doi: 10.1016/j.seps.2017.01.008.

Ermel, A.P.C., Lacerda, D.P., Morandi, M.I.W.M. and Gauss, L. (2021) 'Literature grounded theory (LGT)', *Literature Reviews*, Springer International Publishing, pp.85–145. Doi: 10.1007/978-3-030-75722-9_6.

Fu, Y. and Heenko, M. (2022) 'Analysis of regional differences in government funding performance in higher education – a case study of China', *Investment Management and Financial Innovations*, Vol. 19, No. 1, pp.106–120. Doi: 10.21511/imfi.19(1).2022.08.

Gao, Q. and Wang, Q. (2023) 'A study on the spatial–temporal evolution of innovation efficiency in Chinese universities in the context of the digital economy', *Sustainability (Switzerland)*, Vol. 15, No. 1. Doi: 10.3390/su15010039.

Gauss, L., Lacerda, D.P. and Cauchick Miguel, P.A. (2021) 'Module-based product family design: systematic literature review and meta-synthesis', *Journal of Intelligent Manufacturing*, Vol. 32, No. 1, pp.265–312. Doi: 10.1007/s10845-020-01572-3.

Gebru, M.G., Khan, M.S. and Raza, S. (2022) 'Is there complementarity between teaching and research? Evidence from Pakistani higher education institutions', *Education Research International*. Doi: 10.1155/2022/8503187.

Gralka, S., Wohlrabe, K. and Bornmann, L. (2019) 'How to measure research efficiency in higher education? Research grants vs. publication output', *Journal of Higher Education Policy and Management*, Vol. 41, No. 3, pp.322–341. Doi: 10.1080/1360080X.2019.1588492.

Hanushek, E.A. and Kimko, D.D. (2000) 'Schooling, labor-force quality, and the growth of nations', *American Economic Review*, Vol. 90, No. 5, pp.1184–1208. Doi: 10.1257/aer.90.5.1184.

Hanushek, E.A. and Woessmann, L. (2008) 'The role of cognitive skills in economic development', *Journal of Economic Literature*, Vol. 46, No. 3, pp.607–668. Doi: 10.1257/jel.46.3.607.

Hanushek, E.A. and Woessmann, L. (2012) 'The economic benefit of educational reform in the european union', *CESifo Economic Studies*, Vol. 58, No. 1, pp.73–109. Doi: 10.1093/cesifo/ifr032.

Herberholz, L. and Wigger, B.U. (2021) 'Efficiency of european universities: a comparison of peers', *Research Policy*, Vol. 50, No. 9. Doi: 10.1016/j.respol.2021.104314.

Hoz, E.D., La, Zuluaga, R. and Mendoza, A. (2021) 'Assessing and classification of academic efficiency in engineering teaching programs', *Journal on Efficiency and Responsibility in Education and Science*, Vol. 14, No. 1, pp.41–52. Doi: 10.7160/ERIESJ.2021.140104.

Johnes, G. and Johnes, J. (2004) *International Handbook on the Economics of Education*, Edward Elgar Publishing.

Johnes, G. and Johnes, J. (2009) 'Higher education institutions' costs and efficiency: taking the decomposition a further step', *Economics of Education Review*, Vol. 28, No. 1, pp.107–113. Doi: 10.1016/j.econedurev.2008.02.001.

Johnes, J. (2006) 'Data envelopment analysis and its application to the measurement of efficiency in higher education', *Economics of Education Review*, Vol. 25, No. 3, pp.273–288. Doi: 10.1016/j.econedurev.2005.02.005.

Johnes, J. (2015) 'Operational research in education', *European Journal of Operational Research*, Vol. 243, No. 3, pp.683–696. Doi: 10.1016/j.ejor.2014.10.043.

Johnes, J., Portela, M. and Thanassoulis, E. (2017) 'Efficiency in education', *Journal of the Operational Research Society*, Vol. 68, No. 4, pp.331–338. Doi: 10.1057/s41274-016-0109-z.

Kadilar, G.Ö. (2015) 'Efficiency analysis of foundation universities in Turkey', *Education and Science*, Vol. 40, No. 177, pp.31–41. Doi: 10.15390/EB.2015.1813.

Khurizan, N.S.N., Mustafa, A. and Abd Hamid, H. (2018) 'An efficiency analysis of grant awarded research projects: a case study of a Malaysian public university', *International Journal of Public Sector Performance Management*, Vol. 4, No. 1, pp.80–97. Doi: 10.1504/IJPSPM.2018.088696.

Klumpp, M. (2018) 'The index number problem with DEA: insights from European university efficiency data', *Education Sciences*, Vol. 8, No. 2. Doi: 10.3390/educsci8020079.

Kosor, M.M., Perovic, L.M. and Golem, S. (2019) 'Efficiency of public spending on higher education: a data envelopment analysis for Eu-28', *Problems of Education in the 21st Century*, Vol. 77, No. 3, pp.396–409. Doi: 10.33225/pec/19.77.396.

Lehmann, E.E., Meoli, M., Paleari, S. and Stockinger, S.A.E. (2018) 'Approaching effects of the economic crisis on university efficiency: a comparative study of Germany and Italy', *Eurasian Business Review*, Vol. 8, No. 1, pp.37–54. Doi: 10.1007/s40821-017-0091-7.

Li, Y. (2022) 'Evaluation of learning efficiency of massive open online courses learners', *International Journal of Emerging Technologies in Learning*, Vol. 17, No. 17, pp.50–61. Doi: 10.3991/ijet.v17i17.33849.

Lita, I. (2018) 'Data envelopment analysis techniques – dea and malmquist indicators, in CRS mode, for measuring the efficiency of Romanian public higher education institutions', *Economic Computation and Economic Cybernetics Studies and Research*, Vol. 52, No. 3, pp.249–264. Doi: 10.24818/18423264/52.3.18.17.

Lozano, S. and Contreras, I. (2022) 'Centralised resource allocation using lexicographic goal programming: application to the Spanish public university system', *Socio-Economic Planning Sciences*, Vol. 84. Doi: 10.1016/j.seps.2022.101419.

Luo, Q. (2021) 'Research on the dynamic evolution of scientific and technological innovation efficiency in universities and identification of influencing factors – based on Markov chain estimation and GMM model', *Mathematical Problems in Engineering*. Doi: 10.1155/2021/9831124.

Ma, D. and Li, X. (2021) 'Allocation efficiency of higher education resources in China', *International Journal of Emerging Technologies in Learning*, Vol. 16, No. 11, pp.59–71. Doi: 10.3991/ijet.v16i11.23315.

Macedo, P., Moutinho, V. and Madaleno, M. (2023) *Advanced Mathematical Methods for Economic Efficiency Analysis*, Springer. Doi: 10.1007/978-3-031-29583-6.

Madaleno, M. and Moutinho, V. (2023) 'Stochastic frontier analysis: a review and synthesis', *Advanced Mathematical Methods for Economic Efficiency Analysis*, Springer, pp.55–78.

Mayring, P. (2014) *Qualitative Content Analysis: Theoretical Foundation, Basic Procedures and Software Solution*, Sage publications.

Meireles, M. (2023) 'Production economics and economic efficiency', Macedo, P., Moutinho, V. and Madaleno, M. (Eds): *Advanced Mathematical Methods for Economic Efficiency Analysis: Theory and Empirical Applications*, Springer International Publishing, pp.17–32. Doi: 10.1007/978-3-031-29583-6_2.

Mergoni, A. and De Witte, K. (2022) 'Policy evaluation and efficiency: a systematic literature review', *International Transactions in Operational Research*, Vol. 29, No. 3, pp.1337–1359. Doi: 10.1111/itor.13012.

Moreno-Gómez, J., Calleja-Blanco, J. and Moreno-Gómez, G. (2020) 'Measuring the efficiency of the Colombian higher education system: a two-stage approach', *International Journal of Educational Management*, Vol. 34, No. 4, pp.794–804. Doi: 10.1108/IJEM-07-2019-0236.

Mousa, W. and Ghulam, Y. (2019) 'Exploring efficiency differentials between Saudi higher education institutions', *Managerial and Decision Economics*, Vol. 40, No. 2, pp.180–199. Doi: 10.1002/mde.2995.

Navickas, V., Grenčíková, A. and Krajčo, K. (2021) 'DEA model and efficiency of universities – case study in Slovak Republic', *Entrepreneurship and Sustainability Issues*, Vol. 9, No. 1, pp.348–362. Doi: 10.9770/jesi.2021.9.1(21).

Nazli, N., Ahmad, N., Ismail, S. and Siraj, S.A. (2019) 'Financial sustainability of Malaysian public universities: officers' perceptions', *International Journal of Educational Management*, Vol. 33, No. 2, pp.317–334. Doi: 10.1108/IJEM-06-2017-0140.

Nepomuceno, T.C.C., Agasisti, T., Bertoletti, A. and Daraio, C. (2024) 'Multicriteria panel-data directional distances and the efficiency measurement of multidimensional higher education systems', *Omega (United Kingdom)*, Vol. 125. Doi: 10.1016/j.omega.2024.103044.

Neto, E.L.G.R., Galkin, S., Samanta, G.P., Yi, K. and Maluleke, R. (2022) *BRICS – Joint Statistical Publication*. Available inline at: https://brics.ibge.gov.br/downloads/BRICS_Joint_Statistical_Publication_2022.pdf

Nkohla, T.V., Munacinga, S., Marwa, N. and Ncwadi, R. (2021) 'A non-parametric assessment of efficiency of South African public universities', *South African Journal of Higher Education*, Vol. 35, No. 2, pp.158–187. Doi: 10.20853/35-2-3950.

OECD (2020) *The Allocation of Public Funding to Higher Education Institutions*, Resourcing Higher Education: Challenges, Choices and Consequences.

OECD (2022) *Education at a Glance 2022: OECD Indicators*. Doi: 10.1787/3197152b-en.

Olariu, G.V. and Brad, S. (2022) 'Preventive risk management of resource allocation in romanian higher education by assessing relative performance of study programs with DEA method', *Sustainability (Switzerland)*, Vol. 14, No. 19. Doi: 10.3390/su141912527.

Papadimitriou, M. and Johnes, J. (2019) 'Does merging improve efficiency? A study of English universities', *Studies in Higher Education*, Vol. 44, No. 8, pp.1454–1474. Doi: 10.1080/03075079.2018.1450851.

Perović, L.M. and Kosor, M.M. (2020) 'The efficiency of universities in achieving sustainable development goals. *Amfiteatru Economic*, Vol. 22, No. 54, pp.516–532. Doi: 10.24818/EA/2020/54/516.

Perovic, V., Bojanic, R. and Nerandzic, B. (2017) 'Measuring efficiency of teaching process and faculty in transition states using DEA analysis', *Tehnicki Vjesnik – Technical Gazette*, Vol. 24, No. 5, pp.1509–1517. Doi: 10.17559/tv-20151228131035.

Ranjan, P. and Singh, S. (2021) 'Efficiency analysis of higher education institutions: use of categorical variables', *International Journal of Mathematical, Engineering and Management Sciences*, Vol. 6, No. 6, pp.1518–1532. Doi: 10.33889/IJMEMS.2021.6.6.090.

Rodionov, D. and Velichenkova, D. (2020) 'Relation between Russian universities and regional innovation development', *Journal of Open Innovation: Technology, Market, and Complexity*, Vol. 6, No. 4, pp.1–26. Doi: 10.3390/joitmc6040118.

Shariatmadari Serkani, E., Hosseinzadeh Lot, F., Naja, E. and Ahadzadeh Namin, M. (2022) 'Efficiency measurement for hierarchical network systems using network DEA and intuitionistic fuzzy ANP', *Scientia Iranica*, Vol. 29, No. 4, pp.2252–2269. Doi: 10.24200/sci.2020.54619.3836.

Sing, D. and Imen, H. (2022) 'Is government funding critical to the operating performance of technology universities ? A case study of Taiwan', *Asia Pacific Education Review*. Doi: 10.1007/s12564-022-09753-w.

Smith, P.C. and Street, A. (2005) 'Measuring the efficiency of public services: the limits of analysis', *Journal of the Royal Statistical Society. Series A: Statistics in Society*, Vol. 168, No. 2, pp.401–417. Doi: 10.1111/j.1467-985X.2005.00355.x.

Thanassoulis, E., De Witte, K., Johnes, J., Johnes, G., Karagiannis, G. and Portela, C.S. (2016) 'Applications of data envelopment analysis in education', in Zhu, J. (Ed.): *Data Envelopment Analysis: A Handbook of Empirical Studies and Applications*, Springer US, pp.367–438. Doi: 10.1007/978-1-4899-7684-0_12.

Turwelis, A.K., Rykova, I., Shestakov, D., Hasan, M., Kurniady, D.A., Grebennikova, V., Shcherbatykh, L., Kosov, M. and Dudnik, O. (2022) 'Assessing the quality and efficiency of education in rural schools through the models of integration and the cooperation of educational institutions: a case study of Russia and Indonesia', *Sustainability (Switzerland)*, Vol. 14, No. 14, pp.1–17. Doi: 10.3390/su14148442.

Wolszczak-Derlacz, J. (2017) 'An evaluation and explanation of (in)efficiency in higher education institutions in Europe and the U.S. with the application of two-stage semi-parametric DEA', *Research Policy*, Vol. 46, No. 9, pp.1595–1605. Doi: 10.1016/j.respol.2017.07.010.

Wolszczak-Derlacz, J. (2018) 'Assessment of TFP in European and American higher education institutions – application of malmquist indices', *Technological and Economic Development of Economy*, Vol. 24, No. 2, pp.467–488. Doi: 10.3846/20294913.2016.1213197.

WorldData (2023) *Members of the BRICS Countries*. https://www.worlddata.info/alliances/brics.php#:~:text=A total of 3.27 billion,all global gross domestic products.

Zhang, G., Wu, J. and Zhu, Q. (2020) 'Performance evaluation and enrollment quota allocation for higher education institutions in China', *Evaluation and Program Planning*, Vol. 81. Doi: 10.1016/j.evalprogplan.2020.101821.

Zhao, H.H., Liu, Y., Li, J., Guo, X.G. and Gui, H.J. (2022) 'Chinese provincial difference in the efficiency of universities' scientific and technological activities based on DEA with shared input', *Mathematical Problems in Engineering*. Doi: 10.1155/2022/8319498.

Zimmer, L. (2006) 'Qualitative meta-synthesis: a question of dialoguing with texts', *Journal of Advanced Nursing*, Vol. 53, No. 3, pp.311–318. Doi: 10.1111/j.1365-2648.2006.03721.x.

Appendix 1 Protocol for Systematic Literature Review – SLR

Research Protocol		
Título da pesquisa: EFFICIENCY IN HIGHER EDUCATION INSTITUTIONS: AN ANALYSIS OF DATA ENVELOPMENT ANALYSIS APPLICATIONS.		
Research Team:		
Stakeholders: Higher Education Institutions, Managers and Researchers.		
Review:	Date: 2022/2023	Reviewed by:

1. Research Questions:

(1) How can the DEA technique be used to evaluate efficiency in HEIs? (2) What are the methodological approaches of the DEA technique (type, orientation, one-stage or two-stage analysis)? (3) What are the main input and output variables? (4) What are the main types of efficiency? (5) What are the main motivators and results of using the DEA technique when evaluating efficiency in HEIs?

2. Research Objective:

To provide a comprehensive and robust overview of academic publications on efficiency evaluation in Higher Education Institutions using the Data Envelopment Analysis (DEA) technique, identifying the type, orientation and main input and output variables of the DEA models used in the studies, as well as their main motivators and results.

3. Assess the Scope:

3.1 Width:	☐ narrow	☒ wide
3.2 Depth:	☐ superficial	☒ deep
3.3 Type of Review:	☐ aggregative	☒ configurative

4. Conceptual Framework:

The benefits of education accrue to both society and individuals and, as such, the provision of education in general in many countries is paid for, at least in part, by the public purse (Johnes, 2006; Johnes et al., 2017). Governments have generally allocated considerable portions of public resources to education, including higher education (Frio et al., 2018). These resources compete with other areas, such as health, security and the cost of the public structure (Henriques and Marcenaro-Gutierrez, 2021). According to Psacharopoulos (1996), it is essential to know the level of efficiency in relation to the use of these inputs, so that new allocations of resources can subsequently be justified.

Evaluating the efficiency of education spending in general has challenged researchers over the decades. The allocation of public resources and their efficient use are two closely related factors that force educational researchers to focus on evaluating the efficiency of institutions (Visbal-Cadavid et al., 2017). The education sector, especially higher education, is often characterized by being non-profit, the absence of product and input prices and the production of multiple outputs from multiple inputs, which makes it difficult to assess the efficiency of institutions (J. Johnes, 2006; Kristof de Witte and López-Torres, 2017).

Statistical methods are used to measure the level of efficiency of the higher education system. The options for frontier techniques to study the efficiency of this system include non-parametric methods based on mathematical optimization models - Data Envelopment Analysis - DEA and parametric methods - Stochastic Frontier Analysis - SFA (Kristof de Witte and López-Torres, 2017). Considering these techniques, it is important to highlight the application of DEA in education, as it is one of the five main areas of application of this methodological approach (Emrouznejad and Yang, 2018; Liu et al., 2013).

In this sense, the general objective of this study is to provide a comprehensive and robust overview of academic publications on the evaluation of efficiency in Higher Education Institutions (HEIs) using the DEA technique.

5. Time Horizon:

No time limit

6. *String* de pesquisa:

*TITLE-ABS-KEY (('efficiency' **OR** 'economic efficiency' **OR** 'performance measurement') **AND** ('universities' **OR** 'higher education') **AND** ('data envelopment analysis' **OR** 'DEA')) **AND** SUBJAREA ('BUSI' OR 'ECON' OR 'ENG' OR 'MULT') **AND** LIMIT-TO (DOCTYPE, 'ar')*

7. Research Sources:

Scopus and Web of Science

8. Research Approach:

☒ Direct Search ☐ Contact Experts ☐ Snowball ☐ Other

9. Eligibility Criteria:

9.1 Inclusion Criteria:	Documents dealing with the DEA technique. Documents on efficiency evaluation in HEIs. Documents that present the results of implementing the DEA technique to evaluate efficiency in HEIs.
9.2 Exclusion Criteria:	Documents that do not meet the inclusion criteria.

10. Data Analysis:

10.1 Cintometric Analysis: ☒ Scientific Development

10.2 Bibliometric analysis: ☐ Research Performance ☒ Scientific Mapping

10.3 Content Analysis: ☒ Aggregative ☐ Thematic Analysis ☐ Structural Analysis

11. Data Synthesis:

11.1 Aggregative Synthesis: ☐ Quantitative Meta-Analysis ☐ Qualitative Meta-Analysis

11.2 Configurative Synthesis: ☒ Meta-Synthesis ☐ Other

Source: Adapted from Cardoso Ermel et al. (2021).

Appendix 2 Primary Studies Included in the Review

Cód.	*Title*	*Author(s), Year*
I1	A Study on the Spatial–Temporal Evolution of Innovation Efficiency in Chinese Universities in the Context of the Digital Economy	Gao; Wang, 2023
I2	Benchmarking of academic departments using data envelopment analysis (DEA)	Alam; González; Raman, 2023
I3	Centralised resource allocation using Lexicographic Goal Programming. Application to the Spanish public university system	Lozano; Contreras, 2022
I4	Preventive Risk Management of Resource Allocation in Romanian Higher Education by Assessing Relative Performance of Study Programs with DEA Method	Olariu; Brad, 2022
I5	Effects of Local Government Behavior on University–Enterprise Knowledge Flow: Evidence from China	Zhang; Wang, 2022
I6	A Comparative Study on the Efficiency of R&D Activities of Universities in China by Region Using DEA–Malmquist	Du; Seo, 2022
I7	Efficiency measurement for hierarchical network systems using network DEA and intuitionistic fuzzy ANP	Shariatmadari Serkani et al., 2022
I8	Assessment of Research Efficiency in China's Universities Based on Data Envelopment Method	Qi; Dou; Li, 2022
I9	Evaluation of Learning Efficiency of Massive Open Online Courses Learners	Li, 2022
I10	Efficiency of the Education System (Primary, Secondary and Tertiary) in Particular Voivodeships of Poland	Brzezicki; Pietrzak; Cieciora, 2022
I11	Academic efficiency of engineering university degrees and its driving factors. A PLS-DEA approach	Zuluaga-Ortiz; Delahoz-Dominguez; Camelo-Guarín, 2022
I12	Analysis of regional differences in government funding performance in higher education – A case study of China	Fu; Heenko, 2022
I13	Chinese Provincial Difference in the Efficiency of Universities' Scientific and Technological Activities Based on DEA with Shared Input	Zhao et al., 2022
I14	Do socially responsible higher education institutions contribute to sustainable regional growth and innovation?	Pedro; Leitão; Alves, 2022
I15	Is There Complementarity between Teaching and Research? Evidence from Pakistani Higher Education Institutions	Gebru; Khan; Raza, 2022
I16	Operating efficiency in Chinese universities: An extended two-stage network DEA approach	Chen et al., 2021
I17	Research performance evaluation of Chinese university: A non-homogeneous network DEA approach	Ding et al., 2021

Appendix 2 Primary Studies Included in the Review (continued)

Cód.	*Title*	*Author(s), Year*
I18	Quality assessment of scientific papers: Excellence or legitimization of research practices?	De Almeida Vilela et al., 2021
I19	Efficiency of European universities: A comparison of peers	Herberholz; Wigger, 2021
I20	Measuring the Efficiency of Turkish State Universities Based on a Two-Stage DEA Model	Kocak; Orkcu, 2021
I21	Efficiency Analysis of Higher Education Institutions: Use of Categorical Variables	Ranjan; Singh, 2021
I22	The Scientific and Technological Innovation Performance of Chinese World-Class Universities and its Influencing Factors	Chen; Shu, 2021
I23	Allocation Efficiency of Higher Education Resources in China	Ma; Li, 2021
I24	Research on the Dynamic Evolution of Scientific and Technological Innovation Efficiency in Universities and Identification of Influencing factors - Based on Markov Chain Estimation and GMM Model	Luo, 2021
I25	The Construction and Empirical Research on the Dynamic Evaluation Model of University Science and Technology Output	Sun; Yuan; Chen, 2021
I26	Evaluation of expenditure efficiency of the Federal Institutions of Brazilian Higher Education	Rolim et al., 2020
I27	Assessing and classification of academic efficiency in engineering teaching programs	Hoz; Zuluaga; Mendoza, 2021
I28	DEA model and efficiency of universities - case study in Slovak Republic	Navickas; Grenčíková; Krajčo, 2021
I29	Efficiency of the teaching-industry linkage in the Australian vocational education and training	Tran, 2021
I30	A non-parametric assessment of efficiency of South African public universities	Nkohla et al., 2021
I31	An Empirical Study on Scientific Research Performance of Universities in Different Regions of China Based on PCA and Malmquist Index Method	Xia et al., 2021
I32	Incubator efficiency vs survival of start-ups	Zapata-Guerrero et al., 2020
I33	Relation between Russian universities and regional innovation development	Rodionov; Velichenkova, 2020
I34	Social media advertising efficiency on higher education programs	Cordero-Gutiérrez; Lahuerta-Otero, 2020
I35	A model for sector restructuring through genetic algorithm and inverse DEA	Guijarro; Martínez-Gómez; Visbal-Cadavid, 2020
I36	Factors affecting relative efficiency of higher education institutions of economic orientation	Blecich, 2020
I37	A DEA approach towards exploring the sustainability of funding in higher education. Empirical evidence from Romanian public universities	Dumitrescu et al., 2020

Appendix 2 Primary Studies Included in the Review (continued)

Cód.	*Title*	*Author(s), Year*
I38	The efficiency of universities in achieving sustainable development goals	Perović; Kosor, 2020
I39	Measuring the efficiency of the Colombian higher education system: a two-stage approach	Moreno-Gómez; Calleja-Blanco; Moreno-Gómez, 2020
I40	The Efficiency of Public Higher Education Institutions: A Meta-Analysis	Mikušová, 2020
I41	Measurement of efficiency of didactic activities of public universities of technology in Poland: Directional distance function with undesirable output approach	Brzezicki; Rusielik, 2020
I42	A Nonradial Super Efficiency DEA Framework Using a MCDM to Measure the Research Efficiency of Disciplines at Chinese Universities	Su et al., 2020
I43	The Total Efficiency of Teaching Activity of Polish Higher Education Institutions	Brzezicki; Pietrzak; Cieciora, 2020
I44	The Efficiency of Public and Private Higher Education Institutions in Poland	Brzezicki, 2020
I45	Accelerating a technology commercialization; with a discussion on the relation between technology transfer efficiency and open innovation	Sutopo; Astuti; Suryandari, 2019
I46	Technical efficiency heterogeneity of tertiary institutions in Vietnam: A metafrontier directional technology approach	Villano; Tran, 2019
I47	Efficiency and productivity in transfer units of scientific research results in Mexico	Juárez; Sánchez, 2019
I48	Measuring the efficiency of higher education: Case of Bosnia and Herzegovina	Figurek et al., 2019
I49	How efficiently do elite US universities produce highly cited papers?	Wohlrabe; Anegon; Bornmann, 2019
I50	Efficiency evaluation of parallel interdependent processes systems: an application to Chinese 985 Project universities	An et al., 2019
I51	Assessing the performance of UK universities in the field of chemical engineering using data envelopment analysis	González-Garay et al., 2019
I52	Efficiency of public spending on higher education: A data envelopment analysis for Eu-28	Kosor; Perovic; Golem, 2019
I53	Efficiency assessment of public universities in South Africa, 2009–2013: Panel data evidence	Myeki; Temoso, 2019
I54	Does merging improve efficiency? A study of English universities	Papadimitriou; Johnes, 2019
I55	How to measure research efficiency in higher education? Research grants vs. publication output	Gralka; Wohlrabe; Bornmann, 2019
I56	University Brand as a key factor of Graduates Employment	Blanco; Bares; Hrynevych, 2019
I57	Exploring efficiency differentials between Saudi higher education institutions	Mousa; Ghulam, 2019

Appendix 2 Primary Studies Included in the Review (continued)

Cód.	*Title*	*Author(s), Year*
I58	Efficiency in public higher education on Argentina 2004–2013: institutional decisions and university-specific effects	Quiroga-Martínez; Fernández-Vázquez; Alberto, 2018
I59	Shapley value-based multi-objective data envelopment analysis application for assessing academic efficiency of university departments	Abing et al., 2018
I60	Approaching effects of the economic crisis on university efficiency: a comparative study of Germany and Italy	Lehmann et al., 2018
I61	Measuring the Efficiency of Colleges at the University of Al-Qadisiyah-Iraq: A Data Envelopment Analysis Approach	Drebee; Razak, 2018
I62	Data envelopment analysis techniques – DEA and Malmquist indicators, in CRS mode, for measuring the efficiency of Romanian public higher education institutions	Lita, 2018
I63	A research framework for data envelopment analysis with upper bound on output to measure efficiency performance of higher learning institution in Aceh province	Abdullah et al., 2018
I64	The influence of regulatory frameworks on research and knowledge transfer outputs: An efficiency analysis of Spanish public universities	Berbegal-Mirabent, 2018
I65	An efficiency analysis of grant awarded research projects: A case study of a Malaysian public university	Khurizan; Mustafa; Abd Hamid, 2018
I66	The Index Number Problem with DEA: Insights from European University Efficiency Data	Klumpp, 2018
I67	Assessment of TFP in European and American higher education institutions – Application of Malmquist indices	Wolszczak-Derlacz, 2018
I68	Transfer Benefit Evaluation on University S&T Achievements based on Bootstrap-DEA	Di, 2018
I69	Measuring efficiency of teaching process and faculty in transition states using DEA analysis	Perovic; Bojanic; Nerandzic, 2017
I70	The efficiency of higher education institutions in England revisited: comparing alternative measures	Johnes; Tone, 2017
I71	Exploring the efficiency of Mexican universities: Integrating Data Envelopment Analysis and Multidimensional Scaling	Sagarra; Mar-Molinero; Agasisti, 2017
I72	Efficiency of state universities in Turkey during the 2014–2015 academic year and determination of factors affecting efficiency	Türkan; Özel, 2017
I73	Productivity development of Norwegian institutions of higher education 2004–2013	Edvardsen; Førsund; Kittelsen, 2017
I74	Quality of teaching and research in public higher education in Poland: Relationship with financial indicators and efficiency	Kudła; Stachowiak-Kudła; Figurski, 2016

Appendix 2 Primary Studies Included in the Review (continued)

Cód.	*Title*	*Author(s), Year*
I75	A three-stage DEA model to evaluate learning-teaching technical efficiency: Key performance indicators and contextual variables	Fuentes; Fuster; Lillo-Bañuls, 2016
I76	A network DEA quantity and services model: An application to Australian university research services	Lee; Worthington, 2016
I77	Comparing the Efficiency of Italian Public and Private Universities (2007–2011): An Empirical Analysis	Agasisti; Ricca, 2016
I78	Parametric and non-parametric methods for efficiency assessment of state higher vocational schools in 2009-2011	Rządziński; Sworowska, 2016
I79	How efficient are Malaysian public universities? A comparative analysis using data envelopment analysis	Hock-Eam et al., 2016
I80	The efficiency of regional higher education systems and competition in Russia	Leshukov; Platonova; Semyonov, 2016
I81	The relative efficiencies of research universities of science and technology in China: Based on the data envelopment analysis and stochastic frontier analysis	Chuanyi; Xiaohong; Shikui, 2016
I82	Exploring efficiency differentials between Italian and Polish universities, 2001–2011	Agasisti; Wolszczak-Derlacz, 2016
I83	Do the autonomous region financial models influence the efficiency of Spanish national universities?	Larrán-Jorge; García-Correas, 2015
I84	Efficiency Analysis of Foundation Universities in Turkey	Kadilar, 2015
I85	Efficiency and mergers in English higher education 1996/97 to 2008/9: Parametric and non-parametric estimation of the multi-input multi-output distance function	Johnes, 2014
I86	Evaluating the performance of university course units using data envelopment analysis	El-Mahgary et al., 2014
I87	Performance Efficiency Measurement in the Nigerian Public Sector: The Federal Universities Dilemma	Inua; Maduabum, 2014
I88	Efficiency in Foundation Provisioning in a Selected University	Nkonki; Ntlabathi; Ncanywa, 2014
I89	Application of DEA method in efficiency evaluation of public higher education institutions	Nazarko; Šaparauskas, 2014
I90	An investigation of technical and scale efficiency of public universities in Saudi Arabia	Al Kahtani; Malik, 2014
I91	Measuring the institutional efficiency using DEA and AHP: The case of a Mexican university	Altamirano-Corro; Peniche-Vera, 2014
I92	Network DEA: an application to analysis of academic performance	Saniee Monfared; SAFI, 2013
I93	Accounting for economies of scope in performance evaluations of university professors	De Witte et al., 2013
I94	The Relative Efficiency of Education and R&D Expenditures in the New EU Member States	Aristovnik, 2012

Appendix 2 Primary Studies Included in the Review (continued)

Cód.	*Title*	*Author(s), Year*
I95	University Technology Transfer: How (in-)efficient are French universities?	Curi; Daraio; Llerena, 2012
I96	Efficiency and Performance in Higher Education: A Frontier Analysis of the Educational Productivity of the Brazilian Federal Institutes of Higher Education	Costa et al., 2012
I97	Performance of the Different Methods of Study Financing: A Measurement through the Data Envelopment Analysis Method	Vierstraete; Yergeau, 2012
I98	Identifying the Best Buys in U.S. Higher Education	Eff; Klein; Kyle, 2012
I99	Assessment of Academic Departments Efficiency using Data Envelopment Analysis	Agha et al., 2011
I100	Efficiency of Research Performance of Australian Universities: A Reappraisal using a Bootstrap Truncated Regression Approach	Lee, 2011
I101	Costs and efficiency of higher education institutions in England: A DEA analysis	Thanassoulis et al., 2011
I102	The efficiency of German universities - some evidence from nonparametric and parametric methods	Kempkes; Pohl, 2010
I103	Comparing efficiency in a cross-country perspective: The case of Italian and Spanish state universities	Agasisti; Pérez-Esparrells, 2010
I104	Is the new ECTS system better than the traditional one? An application to the ECTS pilot-project at the University Pablo de Olavide	Herrero; Algarrada, 2010
I105	Beyond frontiers: Comparing the efficiency of higher education decision-making units across more than one country	Agasisti; Johnes, 2009
I106	An evaluation of the dynamics of the plan to develop first-class universities and top-level research centers in Taiwan	Chang et al., 2009
I107	Measuring the research performance of Chinese higher education institutions using Data Envelopment Analysis	Johnes, 2008
I108	Does expansion cause congestion? The case of the older British universities, 1994-2004	Flegg; Allen, 2007
I109	Measuring productivity of research in economics: A cross-country study using DEA	Kocher; Luptacik; Sutter, 2006
I110	Data Envelopment Analysis and its application to the measurement of efficiency in Higher Education	Johnes, 2006
I111	Is government funding critical to the operating performance of technology universities? A case study of Taiwan	Sing; Imen, 2022
I112	Does econometric methodology matter to rank universities? Na analysis of Italian higher education system	Barra; Lagravinese; Zotti, 2018
I113	Technical efficiency in Chile's higher education system: A comparison of rankings and accreditation	Cossani et al., 2022

Source: Prepared by the authors.