CONTRIBUTIONS OF DATA ENVELOPMENT ANALYSIS IN STUDIES ON SCHOOL EFFECTIVENESS

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ABSTRACT

This article presents a systematic literature review conducted according to Prisma guidelines, using the descriptors 'Data Envelopment Analysis' AND 'School Effectiveness' in order to investigate how data envelopment analysis has been used in studies on school effectiveness. Searches were carried out in the Scopus and Web of Science databases for the period between 2010 and 2019, and 10 articles were selected. The findings were a predominance of the VRS output-oriented approach and a preference for two-stage procedures using statistical regression techniques to complement results. Furthermore, no uniformity was observed regarding the factors that most influence units' performance, which may reflect the diversity of realities, cultures and populations investigated in the mapped studies.

KEYWORDS DATA ANALYSIS • EFFECTIVENESS OF EDUCATION • QUALITY OF EDUCATION.

CONTRIBUIÇÕES DA ANÁLISE ENVOLTÓRIA DE DADOS EM ESTUDOS SOBRE EFICÁCIA ESCOLAR

RESUMO

Neste artigo foi realizada uma revisão sistemática da literatura utilizando os descritores *"Data Envelopment Analysis" AND "School Effectiveness"* para investigar como a Análise Envoltória de Dados tem sido empregada em estudos sobre eficácia escolar. Foram selecionados dez artigos, mediante buscas nas bases de dados Scopus e Web of Science, entre 2010 e 2019. Como resultados, observaram-se a predominância da abordagem *VRS output-oriented* e a opção pela realização de procedimentos em dois estágios, que utilizam técnicas de regressão para complementar os resultados obtidos. Ademais, não houve uma conclusão equânime acerca dos fatores de maior influência no desempenho das unidades, o que pode ser reflexo da diversidade de realidades, culturas e populações investigadas nos estudos mapeados.

PALAVRAS-CHAVE ANÁLISE DOS DADOS • EFICÁCIA DA EDUCAÇÃO • QUALIDADE DA EDUCAÇÃO.

CONTRIBUCIONES DEL ANÁLISIS ENVOLVENTE DE DATOS EN ESTUDIOS DE EFICACIA ESCOLAR

RESUMEN

En este artículo ha sido realizada una revisión sistemática de la literatura por medio de los descriptores *"Data Envelopment Analysis" AND "School Effectiveness"*, para investigar cómo el Análisis Envolvente de Datos ha sido utilizado en estudios de eficacia escolar. Se han seleccionado diez artículos por medio de búsquedas en las bases de datos Scopus y Web of Science, entre 2010 y 2019. Como resultado, se observó un predominio del enfoque *VRS output-oriented* y la opción de realizar procedimientos en dos etapas, utilizando técnicas de regresión para complementar los resultados obtenidos. Además, no hubo una conclusión equitativa sobre los factores que más influyen en el desempeño de las unidades, lo que puede ser un reflejo de la diversidad de realidades, culturas y poblaciones investigadas en los estudios mapeados.

PALABRAS CLAVE ANÁLISIS DE DATOS • EFICACIA DE LA EDUCACIÓN • CALIDAD DE LA EDUCACIÓN.

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INTRODUCTION

Data envelopment analysis (DEA) is a multivariable technique based on non--parametric mathematical models which seeks to evaluate the performance of decision-making units (DMU). This is done by comparing similar units which differ in the quantities of resources employed (inputs) and results achieved (outputs) (CORRÊA *et al.*, 2019; FERREIRA; GOMES, 2020).

According to Ferreira and Gomes (2020), DEA developed mainly from Michael James Farrell's article, "The Measurement of Productive Efficiency", published in 1957 in the *Journal of the Royal Statistical Society*, in which the author "[...] tried to develop better methods for evaluating productivity through concepts of activity analysis" (FERREIRA; GOMES, 2020, p. 17).

However, Charnes, Cooper and Rhodes (1978) say that, in fact, the history of DEA began with Edwardo Lao Rhodes' PhD thesis, supervised by William W. Cooper (RHODES, 1978). Briefly, Rhodes' research sought to develop a methodology that could compare the efficiency of American public schools, considering their participation in Follow Through, a federal program for the educational integration of vulnerable children (UNITED STATES, 1975; RHODES, 1978).

Since then, DEA-related concepts were extended and enhanced, consolidating it as a widely adopted methodological approach in school effectiveness studies (AGASISTI; BONOMI; SIBIANO, 2014), which, according to Johnes (2006), reflects the simplicity of its application to contexts with multiple inputs and outputs, as is typically the case with education. The theoretical foundation for these studies is that the school's inputs are key for achieving its educational outputs (BROOK; SOARES, 2008; LIMA, 2011).

DEA has two most popular approaches: the one which requires a constant return to scale (CRS), and the one which demands a variable return to scale (VRS). In practice, the main difference between these is related with the proportionality axiom. Contrary to the VRS model, the CRS model considers that any variation in the inputs implies a proportional variation in the outputs (SANTOS; FREITAS; FLACH, 2015; SOUZA; GOMES, 2016).[1]

For these approaches, in order to determine the efficient frontier, two radial orientations are possible: orientations to inputs (i.e., input-oriented approach) and orientations to output (i.e., output-oriented approach). The former deals with the amount of inputs that can be reduced, provided that outputs remain the same. The later deals with maximizing outputs, though without changing the amount of inputs.

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1   The CRS approach was initially formulated by Charnes, Cooper and Rhodes (1978) and is also known as CCR, which stands for the initials of its creators' last names. Likewise, the VRS approach proposed by Banker, Charnes and Cooper (1984) is also known as BCC.

However, these classic models have originated variations, like the ones that consider fuzzy coefficients (GUO; TANAKA, 2001; LERTWORASIRIKUL *et al.*, 2003), windows analysis (CHARNES *et al.*, 1984), cross-efficiency models (SEXTON; SILKMAN; HOGAN, 1986) and methods with stochastic variables, or chance--constrained programming (CCP) (SENGUPTA, 1987).

These variations seek to offset some disadvantages to the DEA model, like those arising from its non-parametric nature which prevent more robust statistical analyses. However, procedures with two or more stages have also been conducted using statistical inference techniques to complement results obtained via DEA.

In this strand, and considering DEA's dimension and importance in education research, the goal of this article is to investigate, by means of a systematic literature review, how this technique has been used in studies on school effectiveness. The idea is therefore to answer the following questions: which DEA approach and which input and output variables are most frequently used in the investigated studies? How have the authors of these studies overcome DEA's limitations, particularly those resulting from the non-supply of conventional measures of statistical significance and from the non-indication of strategies that might help to improve education quality?

To this end, besides this introduction, the text is divided into another four sections. In the first, the method used to select the articles that form this review is detailed. In the second, results are presented, providing a summarized description of the studies included in it. The third presents a discussion originating from the analysis of the mapped studies. Finally, in the fourth section, the final considerations are outlined.

METHOD

In order to select the scientific articles that make up this review, the preferred reporting items for systematic reviews and meta-analyses (Prisma)[2] model was followed. Prisma was developed by way of a checklist in order to provide authors with a guide on systematic reviews and meta-analyses that helps with the process of eligibility and analysis of sources (MOHER *et al.*, 2010; PAGE *et al.*, 2021).

The article selection process was carried out in March 2021 by searching in the Coordination for the Improvement of Higher Education Personnel's (Capes) Journal Portal, with expanded access to the Scopus and Web of Science (WoS) electronic databases, which were chosen for being the main indexing databases considered by the Qualis Journals rating system in education, according to a Capes

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2   The protocols pertaining to the Prisma model can be consulted at: https://prisma-statement.org//. Access on: Nov. 14, 2021.

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technical report[3] (COORDENAÇÃO DE APERFEIÇOAMENTO DE PESSOAL DE NÍVEL SUPERIOR – CAPES, 2019). Moreover, this study assumes that the importance of these bases for enhancing the dissemination and circulation of scientific publications is well established.

To this end, the descriptors 'Data Envelopment Analysis' AND 'School Effectiveness' were used, and the selection was limited to articles published between 2010 and 2019 in order to obtain recent studies related with the subject, and because this period was considered sufficient for all articles in this period to be indexed in the aforementioned databases. To be selected, articles had to be peer-reviewed, and their full texts had to be available on the internet at the Capes Journal Portal through the Federate Academic Community (CAFe).

The pre-selected articles were read by the authors, and studies whose focus was not directly related with school effectiveness or which did not address basic education specifically were excluded. For the other studies, the input and output variables were analyzed; the works were grouped through a procedure based on thematic analysis (BRAUN; CLARKE, 2006), considering also the employment of the DEA approach, and thus the selected studies were described.

PRESENTATION OF RESULTS

Initially, 28 scientific articles were identified, eight of which were indexed in at least two of the databases considered. By excluding those that repeated in different bases, there were 20 studies left for initial consultation. Of these, five were excluded, as their full texts were not available at the Capes Journal Portal through the CAFe, with the other 15 being considered as potentially available for inclusion in the review. However, after reading their full texts, another five works were excluded, as they did not address the proposed subject, leaving ten articles for the bibliographic research.

Figure 1 represents the flowchart of the selection of articles for analysis, based on Prisma guidelines. It should be noted the authors agreed 100% throughout this eligibility process, which adds to the credibility of the selection.

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3   The report containing this information is available at: http://capes.gov.br/images/Relatorio_qualis_periodicos_referencia_2019/Relatorio_qualis_educacao.pdf. Access on: Nov. 14, 2021.

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FIGURE 1 – Flowchart of the selection of articles based on Prisma guidelines
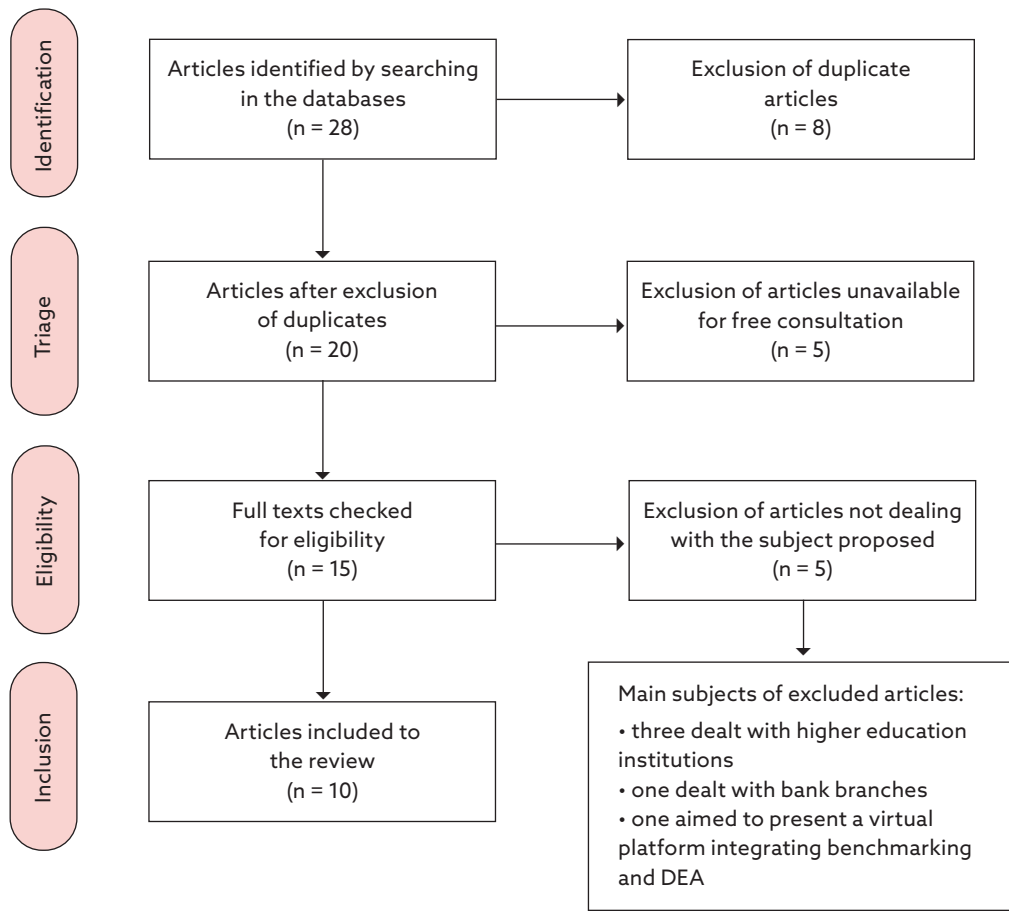
Source: The authors.

Chart 1 presents bibliographic information on these articles, i.e., their years, the journals in which they were published, their titles, authors, and DEA approach.

CHART 1 – Bibliographic information on the *corpus* of selected studies

Nº.	YEAR	JOURNAL	TITLE	AUTHOR(S)	APPROACH
1	2010	Quality Assurance in Education	The performance of Portuguese secondary schools: an exploratory study	C. S. Sarrico; M. J. Rosa; I. P. Coelho	output-oriented CRS
2	2012	International Journal of Educational Management	Benchmarking educational development efficiencies of the Indian states: a DEA approach	V. Gourishankar; P. S. Lokachari	cross-efficiency model
3	2013	Journal of Productivity Analysis	Assessing the evolution of school performance and value-added: trends over four years	M. C. Portela; A. S. Camanho; A. Keshvari	output-oriented VRS
4	2013	Education Economics	The efficiency of Italian secondary schools and the potential role of competition: a data envelopment analysis using OECD-PISA 2006 data	T. Agasisti	output-oriented VRS

(to be continued)

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(continuation)

NO.	YEAR	JOURNAL	TITLE	AUTHOR(S)	APPROACH
5	2014	Educational Sciences: Theory & Practice	The comparison of Turkish students' PISA achievement levels by year via data envelopment analysis	S. Yalçin; E. Tavşancil	output-oriented CRS
6	2014	International Journal of Educational Management	Measuring the "managerial" efficiency of public schools: a case study in Italy	T. Agasisti; F. Bonomi; P. Sibiano	output-oriented VRS
7	2015	International Journal of Educational Management	Determinants of school efficiency: the case of primary schools in the state of Geneva, Switzerland	J. Huguenin	input-oriented VRS
8	2016	Quality Assurance in Education	Assessing the efficiency of secondary schools in Chile: a data envelopment analysis	D. A. Munoz; J. P. Queupil	CRS*
9	2018	Educational Researcher	Comparing the efficiency of schools through international benchmarking: results from an empirical analysis of OECD PISA 2012 Data	T. Agasisti; P. Zoido	output-oriented VRS
10	2018	Education Sciences	The technical efficiency of high schools: the case of a Greek prefecture	D. Halkiotis; I. Konteles; V. Brinia	Not specified

Source: The authors.
* Radial orientation not specified.

As seen in Chart 1, while the selection does not comprise a massive output, at least one article was published per year (except for 2011 and 2017) for the 2010-2018 period. These works were published in seven different journals, with *Quality Assurance in Education* (QAE) and the *International Journal of Educational Management* (IJEM) being the only journals featuring more than representation – two and three articles, respectively.

As for the DEA approach used, three studies chose CRS, with two of these adopting orientations to output (SARRICO; ROSA; COELHO, 2010; YALÇIN; TAVŞANCIL, 2014) and one giving no information on this respect (MUNOZ; QUEUPIL, 2016). As to those using the VRS approach, five studies were found, four of which employ orientations to output (PORTELA; CAMANHO; KESHVARI, 2013; AGASISTI, 2013; AGASISTI; BONOMI; SIBIANO, 2014; AGASISTI; ZOIDO, 2018), and one to input (HUGENIN, 2015). In addition, one study uses the cross-efficiency model (GOURISHANKAR; LOKACHARI, 2012) and one does not specify the approach used (HALKIOTIS; KONTELES; BRINIA, 2018).

With a view to identifying the variables used as inputs in these studies for explaining school performance, Table 1 below was built.

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TABLE 1 – Variables used as inputs in the analyzed articles

VARIABLES USED AS INPUTS	ARTICLE(S)
Student-teacher ratio and/or number of teachers	1, 4, 6, 7, 8, 9, 10
Student socioeconomic and/or cultural status	1, 5, 8, 9
Faculty characteristics, training and/or work	1, 2, 8
Physical and/or digital infrastructure	2, 4, 9
Expenditure per student and/or school budget	6, 7, 10
Student performance in internal (*a priori*) assessments	1, 3
Parental education and/or occupational status	1, 4
Student number/average/proportion per class and/or school	8, 10
Gross school rate	2
Faculty and school managers' training	2
Student participation in classes	5
Outside-of-class study time	5
Number of technical-administrative staff	7
Proportion of male students	8
School hours	8
Specific educational indicators	8

Source: The authors.

As for outputs, five articles consider outcomes in national standardized exams with a focus on vernacular language and mathematics (PORTELA; CAMANHO; KESHVARI, 2013; AGASISTI; BONOMI; SIBIANO, 2014; HUGUENIN, 2015; MUNOZ; QUEUPIL, 2016; HALKIOTIS; KONTELES; BRINIA, 2018).

Another three articles appropriate outcomes in the Programme for International Student Assessment (PISA) (AGASISTI, 2013; YALÇIN; TAVŞANCIL, 2014; AGASISTI; ZOIDO, 2018). In common, these articles focus on outcomes in mathematics. Moreover, Agasisti (2013) and Yalçin and Tavşancil (2014) also consider the sciences assessment, and Yalçin e Tavşancil (2014) and Agasisti and Zoido (2018), the vernacular language assessment.

The other two articles analyzed consider as output information from internal exams. In addition, Sarrico, Rosa and Coelho (2010) include student flow indicators (dropout and completion), and Gourishankar e Lokachari (2012), gross enrollment rate and the percentage of students admitted to universities or technology institutes.

For a better description of these articles, the three subsections below describe briefly the analyses conducted in the mapped studies. To this end, and based on thematic analysis (BRAUN; CLARKE, 2006), groups were formed according to the DEA approach used in each work. The first two subsections describe the three and five articles that assume, respectively, constant and variable returns to scale, while the third addresses the other works.

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Studies that use the CRS approach to DEA

The article of Sarrico, Rosa and Coelho (2010) aims to develop a model to measure and compare the performance of secondary schools in Portugal's central region. The authors investigate to what extent the differences found are attributed to socioeconomic or managerial factors, and how schools have sought to adapt to national education policies.

To this end, they use data from the Regional Education Authority, in addition to complementary information collected through an electronic questionnaire sent to 103 secondary schools in the region. The questionnaire had questions on socioeconomic characteristics and other information about students, as well as school resources, and was responded by 33 schools, with complete data being obtained for 29 of them, which formed the sample used in the study (SARRICO; ROSA; COELHO, 2010).

CRS output-oriented DEA models were developed considering weight restriction techniques which sought to decrease distortions arising from the data collection process (THOMPSON *et al.*, 1986). As preliminary results, the authors indicated that the majority of schools has been following educational policy guidelines on decreasing dropout rates and increasing completion rates for the different school levels (SARRICO; ROSA; COELHO, 2010).

Moreover, the authors found no evidence for a relationship between school performance and geographic, typological and school-specific factors, but they believed this was due to good practices at the management level. However, they recognized the study's limitations, particularly its small, self-selected sample (SARRICO; ROSA; COELHO, 2010).

In turn, the article of Yalçin and Tavşancil (2014) aimed to determine the efficiency and effectiveness of the types of school that make up the Turkish secondary education system, namely Anatolian, Anatolian vocational, vocational schools, science high schools, primary schools and schools in general. In addition, the authors conduct a comparative analysis considering information from PISA questionnaires and assessments for 2003, 2006 and 2009, based on samples of 4,637, 4,952 and 4,412 students respectively, selected at random and ignoring discrepant values, encompassing Turkey's seven regions (YALÇIN; TAVŞANCIL, 2014).

To this end, besides applying the CRS output-oriented DEA model, the authors used windows analysis (AL-ERAQI *et al.*, 2008) to examine school performance variations over time, considering each type of school as a distinct unit (YALÇIN; TAVŞANCIL, 2014).

The authors found that school type affects student success, with science schools being the most efficient, followed by Anatolian schools, which were considered efficient in PISA 2006 and 2009, though not in the 2003 edition, which can be

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explained by the low participation and performance rates in the mathematics assessment that year (YALÇIN; TAVŞANCIL, 2014).

In addition, the authors found that primary schools were the least efficient type for all evaluated periods, which can be explained by the lower socioeconomic and cultural status of students attending these schools. Thus, they conclude that equal opportunities are not a reality in the country. To solve this problem, Yalçin and Tavşancil (2014) suggest a curriculum reform towards reduction and standardization, and that the Turkish education system be restructured with a view to equal opportunities.

The article of Munoz and Queupil (2016) is similar to the others in this category in that it uses a longitudinal analysis to compare the performances of different types of school, considering secondary education in Chile. The study examines the effect of student socioeconomic status on schools' estimated efficiency. To this end, two models are developed using the CRS approach to DEA, though without specifying the radial orientation: a longitudinal model (model 1) and vulnerability model (model 2) (MUNOZ; QUEUPIL, 2016).

Model 1 used data for 2,686 schools, considering the performance of students in two standardized tests, namely the Sistema de Medición de la Calidad de la Educación (Simce) 2012 test and the Prueba de Selección Universitaria (PSU) 2014, a Chilean higher education entrance exam. Thus, the same group of students was analyzed in different grades of secondary education in order to examine performance consistency for different types of school over time (MUNOZ; QUEUPIL, 2016).

The authors found that private schools on average are more efficient than other types of school and tend to be more consistent over time. In addition, urban schools were found to be more efficient than rural ones based on their performances in both standardized assessments considered in the study (MUNOZ; QUEUPIL, 2016).

In turn, model 2 used data for 2,205 public and subsidized schools, incorporating the vulnerability index (Vulindex) as an input in efficiency estimates. This index comprises information on students' socioeconomic characteristics. This model considered performances for 2014 only (MUNOZ; QUEUPIL, 2016).

Results indicated that subsidized schools were more efficient than public ones, and that public schools with delegated management were the most efficient. Finally, in contrast with Sarrico, Rosa and Coelho (2010), the authors attribute the low efficiency of certain schools to the socioeconomically vulnerable condition of most of their students (MUNOZ; QUEUPIL, 2016).

Studies that use the VRS approach to DEA

The article of Huguenin (2015) aimed to evaluate the efficiency of 90 public primary schools in the Canton of Geneva, in Switzerland, correlating it with

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contextual variables in order to identify which of them are critical to good school performance (HUGUENIN, 2015).

To this end, the author used a VRS input-oriented DEA approach – this is the only study using this radial characteristic in the category. Moreover, in a second-stage analysis, an ordinary least squares regression was performed, with estimated efficiency as the dependent variable and with contextual variables as independent (HUGENIN, 2015).

The empirical study includes all primary schools in the region and uses cross-sectional data for the school year 2010-2011 obtained from the government of the Canton of Geneva. As initial results, the author indicates that the average for the analyzed schools' efficiencies is 93%, therefore, it can be increased by 7% to maximum efficiency, which would result in savings of 17 million Swiss francs in 2010 (HUGUENIN, 2015).

As for the regression analysis, it showed that four contextual variables would have an effect in terms of making schools less efficient: functioning in different locations; serving more vulnerable students; offering special education; and the reduced number of students. The author finishes by stressing the importance of the findings for improving units' management (HUGUENIN, 2015).

The article of Portela, Camanho and Keshvari (2013) aimed to analyze evolution in school performance and added value (AV) for 27 Portuguese secondary schools which participate in the Evaluation of Schools with Secondary Education (AVES), an evaluation program run by the Manuel Leão Foundation. It is the only article in this category with longitudinal analysis characteristics. The study assesses the performance of 4,863 students for the 2005-2008 period, comparing their performances in the beginning and in the end of secondary education in order to examine school effect through AV (PORTELA; CAMANHO; KESHVARI, 2013).

To this end, in addition to a VRS output-oriented DEA model, developed in order to obtain an efficiency frontier, the authors propose the use of an adapted Malmquist index to evaluate the evolution of schools' performance over the years. According to the authors, this index can be broken down into a component that reflects AV change and another that reflects the reach of the efficiency frontier (PORTELA; CAMANHO; KESHVARI, 2013).

They found that the performance of the analyzed schools had an inconstant behavior over time. Moreover, some schools showed improvements in school frontier in analyses that considered different periods of time. However, they say this is not evidence enough to indicate a possible improvement in the quality of these schools, and further analyses are necessary about the subject (PORTELA; CAMANHO; KESHVARI, 2013).

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The other articles in this category (AGASISTI, 2013; AGASISTI; BONOMI; SIBIANO, 2014; AGASISTI; ZOIDO, 2018) have some characteristics in common. Initially, all of them were written by Professor Tommaso Agasisti, whether individually or in partnership with other authors. Methodologically, the studies use bootstrapping with the VRS DEA approach in order to make statistical inferences as a complement to the results obtained through efficiency estimates. Besides, all of them present a second-stage analysis in which the factors with a possible influence on school efficiency are investigated using a Tobit regression.

Tobit regression, initially developed by James Tobin (1958), has a similar theoretical base to OLS regression models, with the difference that it can consider censored data for a particular dependent variable, i.e., a variable whose information about it is available only for a part of the observations. This makes it an effective instrument in cases where the dependent variable belongs to specific intervals or is concentrated on points equal to a limiting value (GUJARATI; PORTER, 2011; KHOSHROO *et al.*, 2013).

Agasisti's (2013) article aimed to achieve two general goals. Initially, it sought to analyze the efficiency of 651 Italian secondary schools based on their outcomes in PISA 2006, comparing the performances of different units. Then, the main determinants of efficiency were detected, particularly considering the potential role of the competition (AGASISTI, 2013).

Results indicated that the poorest-performing schools are located in islands and that schools in southern Italy performed worse than those in the country's north. Moreover, on average, schools of the liceu type (of a more theoretical nature) performed better than vocational ones. The author also indicates that, on average, schools located in cities perform worse than those in villages, and that public schools tend to be more efficient than private ones (AGASISTI, 2013).

As for the second-stage analysis, contrary to Huguenin's (2015) results, no statistically significant differences were found that signaled an influence of class size on school effectiveness. However, the author observes that this may be due to the use of student-teacher ratio as an input in the efficiency estimates (AGASISTI, 2013).

The author also manifests surprise in finding that the proportion of girls and parental pressure are associated with poorer performances, but he explains that the latter may be justified, considering that a greater pressure by parents for results reflects on insufficient school performance (AGASISTI, 2013).

The article of Agasisti, Bonomi and Sibiano (2014), like that of Agasisti (2013), had Italian schools as its object of analysis. However, it is more specific as it considers just one Italian region (Lombardia) in measuring "managerial" efficiency. Thus, the authors analyzed 583 primary and 479 secondary schools, all of which were public, using data from standardized tests administered in 2010 for 5th and

6th grade students. These tests were run by the Istituto Nazionale per la Valutazione del Sistema Educativo di Istruzione e di Formazione (Invalsi) (AGASISTI; BONOMI; SIBIANO, 2014).

Results showed that, in general, the Lombardia region has highly efficient schools, with an average value of 80%. Thus, performance scores could be raised by up to 20% using the same inputs, or potential savings are possible for the same outputs. However, such savings were not calculated, since a VRS output-oriented DEA approach was adopted (AGASISTI; BONOMI; SIBIANO, 2014).

Moreover, the study revealed that efficiency and equity are complementary in primary education, i.e., schools with a smaller dispersion regarding student performance tend to be more efficient. The regression analysis also indicated that the number of non-tenured teachers is negatively related with school performance in mathematics in primary schools. However, these results were not found for secondary education, which suggests that education policy makers should take into account the specificity of each school level (AGASISTI; BONOMI; SIBIANO, 2014).

Finally, the authors stress that studies of this type should include external (non-controllable) variables in order to obtain more reliable results, which constitute the so-called "managerial" efficiency, achieved after the inclusion of such variables in the analyses. Otherwise, results could be misleading, indicating efficiency in cases where schools enjoy better contextual conditions (AGASISTI; BONOMI; SIBIANO, 2014).

The article of Agasisti and Zoido (2018) aimed to compare the efficiency scores for about 8,500 schools in 30 countries using data from PISA student and principal questionnaires for 2012, as well as schools' performances in the assessment for the same year. It is the only article in this review that analyzes the performances of school units located in different countries (AGASISTI; ZOIDO, 2018).

These countries were chosen based on two conditions: being an OECD member; and having a cumulative expenditure per student of more than $50,000 PPPs (purchasing power parities). Singapore was the only non-OECD member included in the study (AGASISTI; ZOIDO, 2018).

Results indicated that schools' performance can be raised by up to 27%, considering the same inputs. Besides, efficiency scores were found to vary considerably between and within countries. The country with the best average efficiency was Singapore (84.7%), and the worst average was that of Slovenia (68.3%). Besides, on average, Asian countries were found to be the most efficient (AGASISTI; ZOIDO, 2018).

As for the regression analysis, it was observed that schools which serve students with more diversified socioeconomic status tend to be less efficient, but this effect is smaller in units that serve a greater number of immigrant students. The same holds for schools with small classes, as also indicated by Huguenin (2015). Moreover,

contrary to Agasisti (2013), it was concluded that a greater proportion of female students is positively associated with school effectiveness, just like the number of hours that students dedicated to school assignments (AGASISTI; ZOIDO, 2018).

With regard to school practices and processes, the relationship between students and teachers and the participation of the latter in governance and decision making were found to be factors directly related with units' efficiency. Finally, the authors indicated that the better the schools' infrastructure, and the better their teachers' education, the more efficient they tend to be (AGASISTI; ZOIDO, 2018).

Other studies that compose this literature review

The article of Gourishankar and Lokachari (2012) aimed to propose a model for evaluating education development programs launched in Indian schools, providing a cross-comparison between the results obtained by India's 28 states and seven Union territories, and exploring the possible factors for these results (GOURISHANKAR; LOKACHARI, 2012).

To this end, a cross-efficiency model was used in the DEA method. This model, proposed by Sexton, Silkman and Hogan (1986) and developed by Doyle and Green (1994), is meant for set evaluations, rather the individual evaluations performed through classic DEA models.

Thus, in the cross-efficiency model, each unit's efficiency is evaluated according to the others' optimal weight schemes, and the average of all these efficiencies is the cross-efficiency of the analyzed unit. Thus, based on the peer appraisal principle, the discriminatory power of DEA can be increased, providing a better distribution of variables' weights (REZENDE; PESSANHA; AMARAL, 2014).

Further, the authors also used factor analysis to determine possible interrelations between the variables and the OLS regression analysis, in order to evaluate the impact of the variables on the estimated educational efficiency (GOURISHANKAR; LOKACHARI, 2012).

The factor analysis indicated four important components for analyzing educational development in India: financial adequacy; school resources, regarding teacher education and school infrastructure; quality; and educational access. In addition, using regression analysis, the authors identified three factors with a more significant impact on states' efficiency (GOURISHANKAR; LOKACHARI, 2012). The first regards gross enrollment rate, indicating that the state which concentrates on increasing school enrollments will not only contribute to the country's educational development, but it can also become more efficient. The second concerns student performance, confirming the hypothesis that this factor is a key measure of education quality. The third, albeit counterintuitive, indicates that infrastructure negatively impacts efficiency (GOURISHANKAR; LOKACHARI, 2012).

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In turn, the article of Halkiotis, Konteles and Brinia (2018) aimed to measure the technical efficiency of 23 secondary schools for the school year 2014-2015. The authors' specific goal was to determine whether it was advantageous for the state to invest in schools of the liceu type (of a generalist nature). However, unlike the study of Gourishankar and Lokachari (2012), the units considered were located in a single municipality: Phthiotis, in Greece (HALKIOTIS; KONTELES; BRINIA, 2018).

Though they did not specify the DEA approach used in the analysis, the authors consider that both radial orientations (to input and to output) are included. Besides, as in Gourishankar and Lokachari (2012), using an OLS regression allowed exploring the factors that might be related with efficiency (HALKIOTIS; KONTELES; BRINIA, 2018).

Results indicated that only eight of the 23 analyzed units (34.8%) showed maximum efficiency. Decentralized schools, which serve a small number of students and have high average costs per student, were the least efficient. Besides, the regression analysis indicated as optimal the total of 238 students per school and 15 school units, instead of the existing 23. Otherwise, these units would tend to involve waste of resources (HALKIOTIS; KONTELES; BRINIA, 2018).

Finally, the authors propose three measures that could maximize units' efficiency. The first is to merge the schools that serve a small number of students, since these schools were the least efficient in the analysis, a result also found and discussed by Gourishankar and Lokachari (2012). The second deals with the need for better management of teaching, since a significant number of teachers has not been working the minimum hours established by the state. The third is a new geographic distribution of the generalist schools of the liceu type in the region (HALKIOTIS; KONTELES; BRINIA, 2018).

DISCUSSION

In the mapped studies, no consensus was found between authors regarding the choice of variables to be used as inputs in the application of DEA models, which can be explained by the diversity of realities, cultures and populations investigated. In this respect, it is noteworthy that two articles analyze schools located in Portugal (SARRICO; ROSA; COELHO, 2010; PORTELA; CAMANHO; KESHVARI, 2013) and two in Italy (AGASISTI, 2013; AGASISTI; BONOMI; SIBIANO, 2014). Another five approached data for India (GOURISHANKAR; LOKACHARI, 2012), Turkey (YALÇIN; TAVŞANCIL, 2014), Switzerland (HUGUENIN, 2015), Chile (MUNOZ; QUEUPIL, 2016) and Greece (HALKIOTIS; KONTELES; BRINIA, 2018). The work of Agasisti and Zoido (2018) was the only one that considered a comparative study between countries.

As indicated in Table 1, most of these variables were used in a single study. On the other hand, there is a predominance of classic factors, widely discussed in

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the specialist literature because of their significant impacts on education quality, which assume conditions intrinsic to the classroom, to the school context and to students' lives.

As for the variables used as outputs in the application of DEA models, the massive majority of studies (*n* = 8) considered outcomes in standardized exams (national or international), with priority to some contents – vernacular language and mathematics –, which reinforces the hypothesis of hierarchization of these curriculum components at the international level for purposes of measuring or monitoring basic education quality.

It should be noted that the use of DEA in studies on school effectiveness has technical and practical advantages in relation to parametric analyses, particularly because it does not impose a particular functional form on the link between inputs and outputs for comparing schools. In addition, no relation between them is required, and its application does not demand a specific distribution of data in the population.

However, due to its non-parametric nature, DEA is not able to explain the effects of the analyzed factors, for purposes of school effectiveness, which is a major limitation of this technique. Because of this characteristic, no conventional measures of statistical significance can be provided, which prevents inferences for the target-population that might widen the scope of results.

To bypass this problem, most of the mapped articles (*n* = 6) perform a regression analysis as a second-stage procedure, complementing the results from DEA. Of these, three use Tobit regression (AGASISTI, 2013; AGASISTI; BONOMI; SIBIANO, 2014; AGASISTI; ZOIDO, 2018) and another three, OLS regression (GOURISHANKAR; LOKACHARI, 2012; HUGUENIN, 2015; HALKIOTIS; KONTELES; BRINIA, 2018) in order to investigate the factors affecting schools' efficiency. This made it possible to examine how the different outputs of school units can be attributed to environmental and managerial factors.

Thus, it was found that when students' socioeconomic status was used as an independent variable in the regression model, results indicated that schools that served a greater proportion of vulnerable students were more inefficient. Indeed, this factor has become almost unanimous in terms of impact on school outcomes in standardized assessments, considering studies conducted for that purpose at the international level, whose initial milestone was the release of the Coleman Report[4] (COLEMAN, 1966). In addition, factors related with units' management also showed statistical significance in the analyses conducted in the mapped studies.

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4   The Coleman report sought to identify the possible causes for the discrepancies in American schools' outcomes in standardized assessments, signaling that students' socioeconomic differences were the main factor for that (COLEMAN, 1966).

On the other hand, the analyses that considered units' infrastructure, geographic factors, class size and the proportion of female students did not present results in a single direction, which indicates that the effects of these variables on school efficiency can take different courses for studies developed in different places. Thus, no uniformity was found in conclusions about the influence of these factors on units' estimated performance.

It should also be noted that bootstrapping was applied to DEA in three studies developed from a sample of the analyzed target-population (AGASISTI, 2013; AGASISTI; BONOMI; SIBIANO, 2014; AGASISTI; ZOIDO, 2018), which allowed to correct the estimated efficiency values, considering the random errors in the sampling process. This allowed estimating, for each analyzed unit, the confidence interval and bias, in addition to the corrected efficiency, thus making it possible for statistical inferences to be made from results.

As for the DEA approaches, VRS was most used, as it was employed in five studies (HUGUENIN, 2015; PORTELA; CAMANHO; KESHVARI, 2013; AGASISTI, 2013; AGASISTI; BONOMI; SIBIANO, 2014; AGASISTI; ZOIDO, 2018). These results are in line with Faria, Jannuzzi and Silva (2008, p. 164), who found that "[...] in general, the relations established in the field of public policy do not suppose constant returns to scale".

With regard to radial orientation, six studies chose output-oriented models (SARRICO; ROSA; COELHO, 2010; PORTELA; CAMANHO; KESHVARI, 2013; AGASISTI, 2013; AGASISTI; BONOMI; SIBIANO, 2014; YALÇIN; TAVŞANCIL, 2014; AGASISTI; ZOIDO, 2018), one, an input-oriented model (HUGUENIN, 2015), and one considered both orientations (HALKIOTIS; KONTELES; BRINIA, 2018). Indeed, still according to Faria, Jannuzzi and Silva (2008), those relations established in the field of public policy require maximizing outputs from the same inputs (output--oriented), assuming limited budget funds for the area, which must be used in the most efficient way possible.

The studies that propose a longitudinal analysis also use complements to DEA methodology in order to achieve their goals, whether by adapting the Malmquist index (PORTELA; CAMANHO; KESHVARI, 2013) or through windows analysis (YALÇIN; TAVŞANCIL, 2014). While they are few in this mapping, studies of this type are very important for monitoring education quality and preventing unfavorable alterations in schools' efficiency.

It is also necessary to highlight a limitation found in all mapped articles which regards their methodological structure. The authors are concerned with estimating units' efficiency through their outcomes in standardized tests, school performance and quality indicators, disregarding the existence of the multiple processes occurring within schools which are not measurable.

These processes constitute practices and subjectivities that can only be understood by going into these units' daily life, which is not done by any of the mapped studies, although two of them (SARRICO; ROSA; COELHO, 2010; GOURISHANKAR; LOKACHARI, 2012) consulted the analyzed units. According to Alves and Garcia (2002, p. 261), in order to understand these processes, it is necessary to feel the school, and not just look at it "[...] in a superior attitude, from a distance", which might have been done through in loco studies, interacting with the school community, thus leading to more significant, adequate results.

FINAL CONSIDERATIONS

This article aimed to investigate how DEA has been used in studies on school effectiveness. To this end, a systematic literature review was carried out following Prisma guidelines (MOHER *et al.*, 2010; PAGE, 2021) and using thematic analysis (BRAUN; CLARKE, 2006). Studies of this type, which analyze a body of research, not only enable the dissemination of research already conducted, but can also be used as tools to assist researchers with regard to research trends on a particular subject.

In the case of this article, the review focused on education research, thinking the school as the object of analyses in the mapped articles. While the reviewed output is not massive, considering the evaluated period (2010-2019), it allowed identifying potentials and limitations to the application of methodology involving DEA in these studies.

Regarding the potentials, it is noteworthy that the application of DEA does not require the existence of functional relations between the output and input variables, nor is it necessary to pre-assign weights to them. Besides, the ease of application and interpretation of the techniques involving it, particularly given the extensive development of specialist computer software, makes its use attractive in contexts that require a practical study, though without disregarding scientific rigor.

As for the limitations found, it is noteworthy that they stem from DEA's non--parametric nature, due to which no statistical inferences can be made for the study's target population, nor can the scope of results be widened. However, bootstrapping was found to be useful in some of the mapped studies, and can be adopted as a way of bypassing this limitation.

It should also be noted, as a major limitation of its use, that DEA only identifies peer/benchmark units through comparison with units with similar characteristics to theirs, without even indicating the determinant factors for improving education quality. However, second-stage procedures, which encompass correlation and regression analyses, have proved of great relevance to bypassing this problem.

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On the other hand, no consensus was found about which type of regression to use, since part of the mapped studies use Tobit regression, while others use OLS regression.

In future studies, it seems interesting to investigate how Brazilian research about school effectiveness is being conducted, with a view to identifying the place of DEA as a methodological approach, since no studies carried out in the national context were mapped in this review. Finally, it is expected that this article serves as an instrument to assist and guide researchers of education who intend to incorporate DEA in their empirical analyses.

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