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EFFICIENCY OF TERTIARY EDUCATION IN CROATIA: REVIEWING DEA APPLICATIONS

Abstract

Due to its impact on the quality of the human capital, and thus, the country's economic growth, education is considered a top priority and a strategic sector in every economy. This is the reason why education is in general publicly financed by governments throughout the world. Therefore, the efficiency of tertiary education needs to be consistently evaluated and measured.

The main goal of this article is to survey and present all the published studies investigating the efficiency of tertiary education in the Republic of Croatia with the application of the non-parametric methodology Data Envelopment Analysis (DEA). Moreover, other goals of the study are to explore their used DEA models, the selected inputs and outputs as well as their findings and recommendations.

The methodology used for this research is the extensive literature review of studies that employ the Data Envelopment Analysis (DEA) in the efficiency evaluation of higher education in Croatia. The research approach includes a survey of the most relevant scientific databases for this research (i.e. Scopus, Web of Science – SSCI and SCI papers and the Croatian Scientific Bibliography CROSBI). The terms "Data Envelopment Analysis", "Education" and "Croatia" were used for the data collection. After a total of 41 hits (5 in Scopus, 23 on WoS and 13 on CROSBI), a manual evaluation of the relevance and a selection has been made with the criterion of paper relevance. This ultimately led to 8 articles that investigate the relative efficiency of Croatian tertiary education. Thus, this article presents the findings of the most relevant published work regarding the efficiency of Croatian higher education and its findings are invaluable to the higher education institutions, the government, as well as academic members and the interested public.

Keywords: Croatia, Data envelopment analysis, education, efficiency.

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Introduction

Education and knowledge are the main drivers of economic growth and development, and thus, the public's awareness of the importance of higher education is growing, as is the number of students enrolling in higher education institutions (Mihaljević Kosor i Abramović, 2019). Moreover, the importance of investing in knowledge and education has been recognised by many governments and by the European Commission's 2020 strategy, which introduced education as one of the EU targets and most crucial areas (Malesević Perovic i Mihaljević Kosor, 2020). And even though the notion that a highly educated population in a country leads to its economic progress, prosperity, more innovation, social cohesion and lower unemployment rates is well known, the resources for the education sector are limited and therefore, should be used efficiently, which is highly stimulated by governments, especially as the interest for higher education has increased worldwide (Arbula, 2012). It is as a result of the more restrictive fiscal policies that more and more countries worldwide undertake, that the consistent evaluation of higher education efficiency has become an issue. Still, in most countries worldwide, higher education systems are financed from public funds (Malesević Perovic i Mihaljević Kosor, 2020). As Aristovnik (2012) states, "tight budgets and demanding citizens put governments under increasing pressure to show that they are providing good value for money". Moreover, expenditures on higher education "signify an important tax burden on taxpayers and the efficiency with which inputs produce the desired outputs is thus an important public policy issue" (Obadić i Aristovnik, 2011).

There are two approaches for measuring efficiency in the scholarly literature: parametric and non-parametric methodologies. Since the educational sector is a non-profit public sector that has goals that differ from the conventional commercial organisations, it is not suitable to be evaluated through regression analysis. The leading non-parametric methodology Data Envelopment Analysis (DEA) is the most appropriate methodology for the non-profit sectors, due to its possibility to include multiple input and multiple output variables (Obadić i Aristovnik, 2011). DEA today is one of the widely recognized mathematical linear programming techniques that is applied in many industries, but according to Emrouznejad i Yang (2018), it is mostly applied in banking, agriculture, supply chain,

transportation and public sector. A more thorough presentation of the DEA methodology is laid out in Section 3.

This paper aims to identify, present and analyse the relevant published papers that focus on efficiency evaluation of tertiary education in Croatia with an implementation of the Data Envelopment Analysis methodology. Other goals are to present the leading non-parametric methodology Data Envelopment Analysis (DEA), its strengths and limitations and its potential for wide use in many different industries.

The remainder of this paper is structured as follows. After the Introduction, in Section 2, theoretical background on both the efficiency of tertiary education and Data Envelopment Analysis (DEA) is presented. Section 3 reveals the research approach and the fourth section presents the results, i.e. the applications of Data Envelopment Analysis in tertiary education in Croatia. The fifth and last section opens a discussion and concludes the paper.

Theoretical background

Efficiency of tertiary education

Understandably, the efficiency of the public sector has been commonly examined, due to the pressure of the public. Moreover, the efficiency of the educational system is even more tempting, due to the crucial role of education in each economy's growth, prosperity, rate of unemployment and development. Since the introduction of the DEA methodology in 1978, "a considerable number of articles have been published on the educational sector, including primary and secondary education, and vocational and tertiary education" (Villano i Tran, 2019).

DEA's decision-making units in education can be national economies, higher education institutions, students, etc. Moreover, there are many different efficiencies to be examined in HEIs (higher education institutions), such as cost efficiency, research efficiency, teaching efficiency and the fee-paying enrolment efficiency (Ranjan i Singh, 2021). According to Mihaljević Kosor i Abramović (2019), the overall efficiency evaluation studies of higher education institutions are still rare and DEA has been mostly

applied in studies regarding the United States, Great Britain, Australia and Italy.

Abbott & Doucouliagos (2003) have investigated the efficiency of Australian universities in 1995 employing the DEA with four inputs (total number of academic staff – full-time equivalent, Non-academic staff, expenditure on all other inputs other than labor inputs and value of non-current assets) and four outputs (number of equivalent full-time students (EFTS), the number of post-graduate and undergraduate degrees enrolled, as well as the number of post-graduate degrees conferred and the number of under-graduate degrees conferred).

Perovic et al. (2017) focus on the educational efficiency of the biggest faculty in Serbia in 2013/2014. They have implemented the DEA methodology with the average secondary school grade and the number of scores earned on the entrance exam as inputs and the average grade achieved during the study and the length of study as outputs for their DEA model. Moreover, they included statistical variance analysis to expand and develop a model that would also assess the efficiency of the teaching process. Ranjan & Singh (2021) focused on the "impact of two-step categorical impact on the enrolment efficiency of 147 colleges in Bihar, one of the largest states of India". Thus, they have employed the DEA methodology with the use of two Categorical Variables (university and location). Their obtained results indicate that 12 out of 14 subcategories significantly influence the overall efficiency frontier.

Arbona et al. (2022) employed the metafrontier Malmquist-Luenberger productivity index to assess the efficiency and quality of education in Columbia in the period from 2014 to 2017. They found that both efficiency and quality in the Columbian universities has been decreased in the observed period.

Gebru et al. (2021) have analysed the efficiency of higher education in Pakistani HEIs from 2017 to 2018. They have implemented DEA methodology for measuring the overall efficiency of HEIs, and, thereafter eliminated "the sensitivity of efficiency scores using the bootstrap technique". Their results show that "12 out of 40 HEIs are efficient in their overall efficiency" and HEIs that note high efficiency in either teaching or research also note high efficiency in their overall performance.

Nader (2022) has applied the Multilevel frontier analysis to simultaneously analyse the efficiency scores of departments, faculties, colleges, and the university. However, he claims that the evaluation of efficiency is not so simple and their internal heterogeneities and complexities should be taken into consideration. He also found that "departments in comparison with faculties and colleges, play a more significant role in the overall performance of the university".

Many cross-country studies examine the educational efficiency of the European Union countries. For instance, Dinca et al. (2021) have conducted research on the educational efficiency of 28 EU countries every three years, starting with 2006. In their study, they give new insights and a "complete image of the education system, creating a ranking for the countries, based on efficiency scores". Yotova i Stefanova (2017) have measured the educational efficiency of nine EU member countries from Central and Eastern Europe (i.e. Bulgaria, the Czech Republic, Estonia, Latvia, Lithuania, Hungary, Poland, Romania, and Slovenia) in 2012. They have developed three models "due to the different character of output results of tertiary education that could be direct and indirect". Their findings show that Latvia is most efficient in tertiary education expenditure in all of the three developed models, whereas Lithuania has noted relative efficiency in the first and the second model. On the other hand, Hungary and Estonia are the least efficient.

Agasisti & Berbegal-Mirabent (2021) have employed the DEA methodology with an unbalanced panel from 2011 – 2013 with "761 observations coming from 307 universities located in 8 European countries (Belgium, Switzerland, Germany, Italy, Lithuania, Portugal, Sweden and UK)" to examine whether the "strategic choices regarding international positioning and scope determine how efficient universities are in the allocation of their internal resources". In their study, they identify three types of universities according to their internationalisation and scope as follows: world-class, flagship, and regional. Their findings reveal some new insights regarding the efficiency of higher education institutions (HEI) in Western Europe. Namely, they found UK and Belgium institutions to be most efficient, while Swiss and Portuguese institutions to be the least efficient.

Data envelopment analysis (dea)

DEA (hereafter Data Envelopment Analysis) is a methodology for measuring the relative efficiency of productive and non-productive units as decision-makers who use the same inputs and the same outputs but differ in the level of available resources and the type of activities in the process of their transformation (Cvetkoska, 2010). DEA is one of the leading and most popular "non-parametric, deterministic, linear programming technique that provides a piecewise frontier by enveloping the observed data points, and yields a convex production possibilities set" (Ahec Šonje et al., 2018). It has been extensively used in many industries since its introduction in 1957 by Farrell (Farrell, 1957) and its development in 1978 by Charnes, Cooper and Rhodes (1978).

DEA is a frontier method consisting of a series of optimizations (one for each entity included in the analysis). For each entity, the maximum measure of performance is calculated relative to the other entities in the observed sample. DEA is a non-parametric linear programming method used to measure best practices in technology and relative efficiency of units (called decision-making units or DMUs). What is crucial in data envelopment analysis is that the organisational units to be assessed should be relatively homogeneous (Fotova Čiković, 2021). "The focus in DEA is not on estimation on the average production function used by all units analysed but rather to identify the best practice units (DMUs), i.e. the relative efficient units, so that the best practice frontier is constructed and all analysed DMUs are related to the frontier" (Hartwich i Kyi, 1999). The "calculated frontier constitutes the model by which efficiency is measured" (Yotova i Stefanova, 2017).

The main advantage of the DEA methodology is the notion that, unlike regression analysis, a priori model specification is not required. Instead, DEA provides information on whether the analysed inputs and outputs of DMUs lie below or above the "efficient" limit (i.e. efficiency frontier). However, it should be borne in mind that this is a method that analyses the relative efficiency within the analysed sample of DMUs (Cvetkoska, 2010). Moreover, the DEA methodology is used for benchmarking and comparison of the relative efficiency of Decision- making units, by identifying the efficient DMUs that form the efficiency frontier and therefore,

the inefficiencies of the used inputs or outputs are measured concerning the efficiency frontier.

The limitations of this methodology are the "sensitivity to errors in the data and the fact that it evaluates relatively (by comparing DMUs only with the best in the observed set) and not absolutely" (Mihaljević Kosor i Abramović, 2019). DEA is nowadays extensively used in many industries and is widely applied by scholars, researchers, as well as analysts and managers.

Research approach

The research approach includes an extensive literature review that started with a survey of the most relevant scientific databases for this research (i.e. Scopus, Web of Science – SSCI and SCI papers and the Croatian Scientific Bibliography CROSBI).
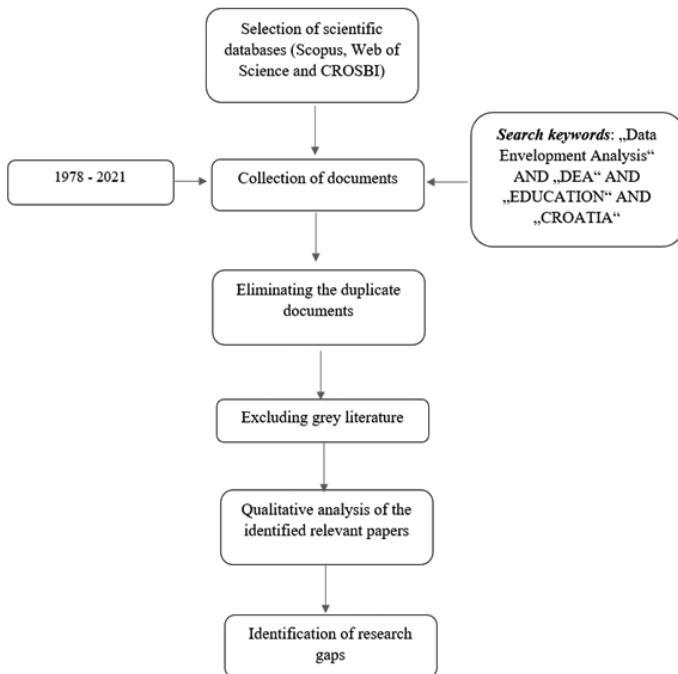

Figure 1. The research approach.
SOURCE: Author's creation.

The survey has been conducted with the keywords "DATA ENVELOP-MENT ANALYSIS", "EDUCATION" and "CROATIA" were used for the data collection. After a total of 41 hits (5 in Scopus, 23 on WoS and 13 on CROSBI), a manual evaluation of the relevance and a selection has been made with the criterion of paper relevance. This ultimately led to 8 articles that investigate the relative efficiency of Croatian tertiary education. The research approach and the steps that led to the analysis of 8 relevant published papers is shown in Figure 1.

Results: applications of data envelopment analysis in tertiary education in Croatia

Even though the efficiency of tertiary education has been empirically studied by a large number of papers, there are very few publications on a national Croatian level. The main goal of this paper was to survey, identify and present all of the relevant empirical papers that study the tertiary education efficiency in Croatia.

Therefore, in this paper, the author has explored three scientific databases: the Scopus, Web of Science (SSCI and SCI papers) and CROSBI (Croatian Scientific Bibliography) databases using the keywords "Data Envelopment Analysis" AND "Education" AND "Croatia", in the search for empirical studies that evaluate the efficiency of tertiary education in Croatia.

After a total of 41 hits (5 in Scopus, 23 on WoS and 13 on CROSBI), a manual survey and exclusion of grey literature and duplicate documents has been conducted (as shown in Figure 1). This led to 8 articles that investigate the relative efficiency of Croatian tertiary education.

A short tabular presentation of the DEA applications in tertiary education in Croatia is shown in Table 1, and a thorough analysis of their findings, used dataset and DEA models are elaborated thereafter.

Table 1. Applications of DEA in tertiary education in Croatia.

Author/s and year of publication	Paper	Time frame	Country
Obadić & Aristovnik (2011)	Relative efficiency of higher education in Croatia and Slovenia: an international comparison	1999 – 2007	37 OECD countries (focus on Croatia and Slovenia)
Arbula (2012)	Using Data Envelopment Analysis to evaluate the efficiency of higher education expenditure in Europe	2004 – 2008	23 European countries (including Croatia)
Aristovnik (2012)	The relative efficiency of education and R&D expenditures in the new EU member states	1999 – 2007	New EU member states (including Croatia)
Ahec Šonje, Deskar-Škrbić & Šonje (2018)	Efficiency of public expenditure on education: comparing Croatia with other NMS	2005 – 2013	New EU Member stated (including Croatia)
Nadoveza Jelić & Gardijan Kedžo (2018)	Efficiency vs effectiveness: an analysis of tertiary education across Europe	2004 – 2015	24 EU countries (including Croatia)
Mihaljević Kosor & Abramović (2019)	Measuring the relative efficiency of Croatian universities	2011./12. and 2016./17	Croatia
Malešević Perović & Mihaljević Kosor (2020)	The efficiency of universities in achieving sustainable development goals	2013 – 2017	25 European countries (including Croatia)
Arbula Blecich (2020)	Factors affecting relative efficiency of higher education institutions of economic orientation	academic year 2011 – 2012	Croatia, Slovenia and Bosnia and Herzegovina

SOURCE: Author's creation.

Obadić & Aristovnik (2011) have focused on the evaluation of the "relative efficiency of government spending on higher education in selected new EU member states (with special focus on Croatia and Slovenia) in comparison to selected 37 OECD countries". In their study, they have developed two output-oriented BCC DEA models. They selected one input (expenditure per student, tertiary as a % of GDP per capita) and three outputs (school enrolment, tertiary in % gross, labor force with a tertiary

education in % of total and the unemployed with a tertiary education in % of total unemployment). Their findings indicate that there is a "significant inefficiency of higher education spending in Croatia and therefore the considerable potential to reduce government expenditure and/or to increase the higher education output/outcome", whereas the higher education system in Slovenia is shown to have "a much higher level of efficiency compared to Croatia as well as many other comparable new EU member states and selected OECD countries".

Arbula (2012) focuses on the efficiency evaluation of education expenditure in 23 European countries. In this study, an output-oriented BCC DEA model with one input (the expenditure per student, tertiary as % of GDP per capita) and two outputs (the population that has attained tertiary education and employment rates-tertiary education) has been employed. The observed period is from 2004 to 2008. The findings indicate that only four out of 23 countries are relative efficient and these are: Iceland, Norway, Slovak Republic and the United Kingdom, whereas Hungary is the least efficient in education expenditure. Moreover, Italy, Spain, France and Croatia have been identified as the least efficient countries (together with Hungary) in higher education expenditure. The results of this research show that "higher education expenditure is inefficient in the majority of the observed countries". The author suggests increasing the outputs according to the existing input, as it could lead to future improvement in efficiency and their development.

Aristovnik (2012) focuses on the education expenditure efficiency and the R&D efficiency in 32 countries (which include EU-27, OECD and Croatia). In this study, the output-oriented BCC DEA methodology has been applied and its results indicate that "technical efficiency in education and the R&D (research and development) sectors differs significantly across the great majority of the EU (including new EU member states) and OECD countries". Moreover, Slovenia could be considered "a good benchmark country in the field of tertiary education". Interestingly, Cyprus and Hungary are most efficient in the field of R&D sector. The paper concludes that most new EU member states have shown relative high efficiency of tertiary education, but they "lag well behind in the R&D efficiency measures".

Ahec Šonje, Deskar-Škrbić i Šonje (2018) examine the efficiency of public expenditure on secondary and tertiary education in the eleven New Member States (NMS) in EU, which includes Croatia (together with Estonia, Lithuania, Poland, Slovenia, Latvia, Romania, Czechia, Bulgaria, Slovakia and Hungary). The observed period is 2005-2013. They have implemented the input-oriented DEA with variable returns to scale (VRS) with public expenditure on education per student and as % of total education expenditure as inputs and the share of unemployed with a tertiary education and Shanghai ranking of leading national universities as outputs for the model testing the efficiency of tertiary education. Their findings reveal "high inefficiency of public spending on education in Croatia", with the lowest efficiency score of 0.65. The Czech Republic, Latvia and Lithuania represent benchmarks and are the most efficient countries in tertiary education.

Nadoveza Jelić i Gardijan Kedžo (2018) have employed the DEA methodology to explore the tertiary education efficiency and effectiveness in 24 European Union countries in four sub-periods between 2004 and 2015 (i.e. 2004-2006, 2007-2009, 2010-2012, 2013-2015). Their DEA model considers and includes a broader set of inputs and outputs than previously published literature and it also includes quality indicators both on the side of the inputs and the outputs. Their paper highlights the importance of quality considerations regarding education and their findings indicate that "quality considerations affect the relative positions of countries regarding their efficiency scores".

Mihaljević Kosor i Abramović (2019) have measured the efficiency of 75 higher education institutions in Croatia in two periods (namely in 2011. /12. and 2016. /17). They have employed the output-oriented BCC DEA model with five inputs (total number of enrolled students, the number of students who enrolled in the 1st year of college, total number of teachers, number of teachers with the title of Doctor of Science and number of teachers with a master's degree) and one output (number of graduates). Their findings are rather concerning and indicate that "the relative efficiency of public higher education institutions in Croatia is low and only about 10% of institutions are fully efficient while the average efficiency of public higher education institutions is slightly higher than 50%". The average efficiency of higher education institutions for 2011/12 is 49.70%, and 58.40% for 2016/17. The most efficient universities are the University in Zagreb and the University in Rijeka.

Malešević Perović i Mihaljević Kosor (2020) have employed the DEA methodology to investigate the efficiency of universities in Europe in achieving Sustainable Development Goals (SDGs). They have employed the "newly published University Impact Rankings that account for SDGs" in their study for the period from 2013 to 2017. They adopt a dual approach for their research, i.e. they analyse the macro and the micro-level (country- and university-level) of efficiency in tertiary education. In their macroeconomic model, they employ two input variables (government expenditures on tertiary education as a percentage of GDP and the number of teachers in tertiary education per capita) and one output variable (the overall score in University Impact Rankings and the score in achieving SDG17) for each country. Their results indicate that "at a macro level, only three to four countries in the sample are fully efficient", meaning they could produce about 20% better score on University impact rankings without changing government tertiary expenditures on education, produce about 20% better score on University impact rankings. At a university level, "only about 16 percent of universities is efficient".

Arbula Blecich (2020) has explored the factors that impact the relative efficiency of higher education institutions of economic orientation with an empirical analysis carried out on 31 higher educational institutions of economic orientation in Croatia, Slovenia and Bosnia and Herzegovina in the academic year 2011-2012. This empirical study has been laid out in three phases. In the first phase, four DEA models have been developed in order to evaluate the relative efficiency of the higher education institutions "in three main activities: teaching, research and international activity", and a model for the overall activity. The second stage employs the cluster analysis, i.e. grouping the DMUs according to the achieved levels of relative efficiency in the area of teaching, research and international activity. In the last stage of the research, they employ logistic regression "to predict a probability of moving from one cluster to another in accordance with the change in the independent variable". The findings from this study show that the probability for placing "in the more efficient cluster are higher in public institutions than in private ones, in institutions with more published professional papers, in those with higher expenditures per faculty, the larger number of enrolled students per faculty, as well as in those with more visiting researchers". The proposed model could serve as a guideline for future empirical research, but also as a guideline for education policies.

There are many studies examining and focusing on the efficiency of education in the EU, which proves this is a relevant and contemporary subject. However, the research on the efficiency of education has been limited and this review paper is an attempt to bridge this literature gap.

Discussion and conclusion

The main goal of this paper was to survey, identify and present the relevant studies regarding Croatian tertiary education efficiency with the application of DEA. The other goal of this paper was to present the DEA as a mathematical programming methodology that is widely used to measure the relative efficiency of decision-making units and thus, to increase the interest of scholars to study and implement the DEA methodology more often in studies regarding the education industry as well as any other industry.

Only 1 of the total 8 surveyed papers focus on a single country (i.e. Croatia – Mihaljević Kosor i Abramović, 2019), whereas 7 studies are cross-country studies and include mostly EU countries.

Scholars Aristovnik, Mihaljević Kosor and Arbula Blecich are authors/co-authors of two of the surveyed papers on this subject.

Most of the surveyed papers (in particular, 6 out of 8) analyse the period after 2004. The shortest study is 1 academic year (Arbula Blecich, 2020), whereas the longest is 13 years – 2004-2015 (Nadoveza Jelić i Gardijan Kedžo, 2018).

In the final step of the study, as shown in Figure 1, the literature gap has been identified and it has revealed that papers and empirical studies regarding tertiary education efficiency in the SEE region are modest, papers and empirical studies regarding Croatian tertiary education with DEA are just a few, papers and empirical studies regarding tertiary education efficiency are mostly conducted for the EU countries (which is somewhat in line with the findings of Mihaljević Kosor i Abramović, 2019) and lastly, the application of DEA methodology in the evaluation of education efficiency has been thus far rather neglected by researchers.

This study is not without limitations. All the relevant and published empirical studies regarding the efficiency of higher education in Croatia have

been presented, to the best of the author's knowledge. There may be, however, papers and studies that have not been included in this review.

The scientific contribution of this review is threefold: first, it provides an in-depth extensive literature review on studies regarding efficiency of tertiary education in Croatia with the implementation of the non-parametric DEA methodology and focuses on 8 relevant studies; second, it introduces the DEA technique, its strengths and limitations; and finally, this article could represent a basis and an inspiration to future scholars in their future work and employment of DEA in education efficiency evaluation, and also in any other industry for that matter.

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UČINKOVITOST TERCIJARNOG OBRAZOVANJA U HRVATSKOJ: PREGLED APLIKACIJA AOMP

Sažetak

Zbog utjecaja na kvalitetu ljudskog kapitala, a time i na gospodarski rast zemlje, obrazovanje se smatra glavnim prioritetom i strateškim sektorom u svakom gospodarstvu. To je razlog zašto obrazovanje općenito javno financiraju vlade diljem svijeta. Stoga je potrebno dosljedno ocjenjivati i mjeriti učinkovitost tercijarnog obrazovanja.

Glavni cilj ovog članka je sagledati i prikazati sve objavljene studije koje istražuju učinkovitost tercijarnog obrazovanja u Republici Hrvatskoj uz primjenu neparametarske metodologije analiza omeđivanja podataka (AOMP). Štoviše, drugi ciljevi studije su istražiti korištene AOMP modele, odabrane ulazne i izlazne varijable kao i njihove rezultate i preporuke za buduće istraživače.

Metodologija korištena za ovo istraživanje je opsežan pregled literature empirijskih studija koje primjenjuju analizu omeđivanja podataka (AOMP – DEA) u evaluaciji učinkovitosti visokog obrazovanja u Hrvatskoj. Pristup istraživanja uključuje pregled najrelevantnijih znanstvenih baza za ovo istraživanje (tj. Scopus, Web of Science – SSCI i SCI radovi i Hrvatska znanstvena bibliografija CROSBI). Pojmovi "Analiza omeđivanje podataka", "Obrazovanje" i "Hrvatska" korišteni su za prikupljanje podataka. Nakon ukupno 41 učitavanja (5 u Scopusu, 23 na WoS-u i 13 na CRO-SBI-u), napravljena je ručna procjena relevantnosti i odabir prema kriteriju relevantnosti rada. To je u konačnici dovelo do 8 članci koji istražuju relativnu učinkovitost hrvatskog tercijarnog obrazovanja, pa stoga ovaj članak predstavlja najrelevantnije objavljene radove o učinkovitosti hrvatskog visokog obrazovanja i njegovi su nalazi neprocjenjivi za visokoškolske ustanove, vladu, ali i akademske članove i zainteresirane javnosti.

Ključne riječi: analiza omeđivanja podataka, Hrvatska, obrazovanje, učinkovitost.