HOW EFFICIENT ARE COUNTIES IN THE CROATIAN RIVER DRAVA BASIN REGION? REVIEWING DATA ENVELOPMENT ANALYSIS APPLICATIONS

KOLIKO SU EFIKASNE ŽUPANIJE UZ RIJEKU DRAVU? PREGLED APLIKACIJA ANALIZE OMEĐIVANJA PODATAKA (AOMP)

Katerina FOTOVA ČIKOVIĆ
University North, Croatia
E-mail address: kcikovic@unin.hr

Mario TOMIŠA
University North, Croatia
E-mail address: mtomisa@unin.hr

Joško LOZIĆ
University North, Croatia
E-mail address: jlozic@unin.hr

ABSTRACT

This paper surveys and presents the applications of the mathematical programming methodology, the Data Envelopment Analysis (hereafter DEA) in the evaluation and measurement of the efficiency and performance of Croatian counties. The aim of this article is to present and analyse the findings regarding the efficiency and performance of counties in the Croatian river Drava basin region (which are Koprivnica – Križevci, Virovitica – Podravina and Međimurje County) and to provide conclusions regarding this region and its regional efficiency. Other goals of this article are to introduce and provide a theoretical background to the DEA methodology as one of the most popular non-parametric methods in efficiency evaluation since its introduction in the revolutionary paper by Charnes, Cooper and Rhodes in 1978. This article conducts an in-depth extensive literature review of studies employing the DEA methodology in efficiency evaluation of Croatian counties. The authors have surveyed the Scopus, Web of Science (SSCI and SCI papers) and CROSBI (Croatian Scientific Bibliography) databases using "CROATIA", "COUNTY" and "DATA ENVELOPMENT ANALYSIS" as keywords for the survey. This has resulted in 7 hits in Scopus, 15 on Web of Science and 11 on CROSBI, which ultimately led to a total of 12 papers. This study furthermore reveals the previous work regarding the efficiency of counties in the river Drava basin region as well as an in-depth analysis of their used models, the variable set and their findings.

The findings reveal different aspects of efficiency evaluation of Croatian counties with a special focus on counties in the river Drava basin region. Koprivnica – Križevci and Virovitica – Podravina counties have shown high environmental and total-factor energy efficiency, but were least efficient in entrepreneurship and social services for the elderly, respectively. According to the obtained results, Međimurje County is the least efficient county in the analysed region. Moreover, the three analysed Drava basin region counties in most studies show technical inefficiency and efficiency scores below the average. In this sense, counties need to take into consideration these findings and benchmark and copy the best practices from the highly efficient Croatian counties.

Keywords: County, Northern Croatia, River Drava basin region, Relative Efficiency, Data Envelopment Analysis, Regional Efficiency

Ključne riječi: DEA model analize podataka, Analiza omeđivanja podataka (AOMP), Rijeka Drava, regionalna efikasnost, relativna učinkovitost, Sjeverna Hrvatska, županija.

INTRODUCTION

Efficiency is a vital principle in any business, profit and non-profit, private and public. It is measured to compare the performance of an entity with its peers and competitors and with itself. This brings new insights into the performance of the entity in relation to other peers and its performance in time. There are three forms of business efficiency, which are technical efficiency (productivity), economic efficiency (cost-effectiveness) and financial efficiency (profitability) (Marković et al., 2015). This study explores the technical efficiency, i.e. "the ability of a firm to produce as much output as possible with a specified level of inputs, given the existing technology" (Erena et al., 2021), which is represented by the ratio between the produced quantities or units of products or services and the production factors used (number of employees, working hours, resources etc.).

To measure and assess efficiency, there are two possible methodologies: parametric and non-parametric. As Wang (2003) has put it, "there have been two competing paradigms on efficiency analysis for private and public organizations, one of which is the data envelopment analysis (DEA) which is based on a mathematical programming approach, and the other is the estimation of stochastic frontier functions (SFF) which is based on the econometric regression theory". The parametric methodologies (regression) "focus on the average tendencies and deviations from it" (Cvetkoska & Fotova Čiković, 2021). Moreover, they require a prior assumption for the production function and they only employ one output variable. The non-parametric methodologies, on the other hand, can handle the inclusion of multiple input and output variables and do not require a prior assumption for the production function, which are their biggest advantages.

Interestingly, in the beginning, DEA has been mostly employed in the empirical studies of non-profit organisations, due to the difficulty to assess them based on traditional economic and financial indicators that are commonly used for commercial organizations (Santos et al., 2013). However, DEA today is the most popular and implemented non-parametric methodology which has been extensively used in the evaluation of efficiency in many industries, but mostly in agriculture, banking, supply chain, transportation, education and public policy (Emrouznejad & Yang, 2018).

In the past few decades, DEA has been implemented in measuring the efficiency and performance of countries, local governments and regions (counties). The evaluation of the performance of the public sector has become crucial after "a significant increase in the public expenditures of the most developed countries and the question of economic and social effects of using such large resources" (Slijepčević, 2019). Furthermore, "regional and economic efficiency and the prospects of their improvement have become one of the leading imperatives of all world economies" (Rabar, 2013b). Moreover, "efficient management and utilization of public resources improve the general well-being of a community, and benefits especially the users of municipal services" (Šegota et al., 2017). Interestingly, Rabar & Grbin (2019) claim that "the uneven economic growth of Croatian counties indicates the need to analyse their comparative (relative) efficiency", which is in line with the statements of Škare & Rabar (2014) that the uneven development of counties shows a "regional disparity". This is, however, due to the vanishing of the traditional industries and the insufficient growth of the primary sectors (such as agriculture and forestry) and additionally, the poorly executed privatization which all led to a major "gap in the economic equality of the regions in Croatia" (Šebalj et al., 2017).

The Republic of Croatia consists of 21 counties (i.e. 20 counties plus the City of Zagreb), which are perceived as "Croatia's primary administrative subdivisions" (Borozan & Borozan, 2018). The river Drava basin region consists of three counties as follows: Koprivnica – Križevci, Virovitica – Podravina and Medjimurje County. According to the NUTS-2 (Nomenclature of Territorial Units for Statistics), these counties are positioned in Northern Croatia (Fotova Čiković et al., 2021a). In this study, the

170 Podravina

PODRAVINA Volumen 21, broj 41, Str. 168 – 179 Koprivnica 2022.

emphasis will be put on the findings regarding these three counties. Thus, this study will be valuable to both regional governments and academic members.

In this paper, we have surveyed, introduced and analysed all the DEA applications which measure the relative efficiency of counties in the Republic of Croatia. This paper aims to explore the results obtained regarding the efficiency and performance of the three river Drava basin region counties. Other goals are to introduce the DEA methodology, its basic concept and provide a theoretical background to this methodology as one of the leading frontier techniques in efficiency measurement.

This paper is organized as follows. The next section introduces the DEA methodology, its basic concept and models. The research methodology has been laid out in Section 3. Section 4 reveals the surveyed studies and presents the different applications of DEA in efficiency measurement of Croatia's (and more specifically, the river Drava basin region) counties. The fifth section unveils the results of this study and all the findings from the literature review. The sixth (and last) section opens up a discussion regarding the extensive literature review and the findings and gives recommendations and guidance for future work, which is followed by a conclusion.

DATA ENVELOPMENT ANALYSIS (DEA): THEORETICAL BACKGROUND

The Data Envelopment Analysis Methodology has been developed and introduced by Charnes, Cooper and Rhodes in 1978, building on the foundation, concept and computation of efficiency made by Farrell (1957). Ever since its introduction, DEA has become a vital part of Operations Research (OR) and the Multi-Criteria Decision Aid methods. DEA is a mathematical linear programming technique that belongs to the frontier methods and is extensively used in the efficiency measurement of complex homogeneous entities (so-called Decision-Making Units, i.e. DMUs). As Lukač & Neralić (2012) put it, a mathematical programming problem is solved for each DMU in the sample and the efficiency results identify the efficient and inefficient DMUs.

Furthermore, DEA is a data-oriented non-parametric methodology. Gökşen et al. (2015) refer to DEA as an "efficiency measurement technique without parameters". It is also referred to as an econometric frontier approach since it uses an efficiency frontier in order to classify the various DMUs included in the sample. "The efficiency frontier is based on real observations and only the cases of best practices belong to it. All DMUs that are not on the frontier are considered inefficient " (Jorda et al., 2012).

The efficiency scores with DEA are expressed as either a number between 0-1 or a percentage 0-100%. Therefore, a DMU with a score less than 100% is considered relative inefficient (i.e. relative to the other units in the sample).

The DEA methodology has two basic models, which are the CCR and the BCC model. The CCR model is named after Charnes, Cooper and Rhodes, who introduced the CCR model and the DEA methodology altogether in 1978. The BCC model is named after Banker, Charnes and Cooper, who developed the BCC model in their study in 1984. The main distinction of the basic DEA models is in the built-in assumption of return to scale. Namely, the CCR DEA model is built on the assumption of constant returns to scale (CRS) of activities, i.e. it assumes a proportional change in inputs and outputs, whereas the BCC model assumes variable (either increasing or decreasing) return to scale (VRS), i.e. a change in the inputs does not necessarily result in a proportional change in the outputs. Additionally, the DEA model, depending on the orientation, can be input-oriented, output-oriented model or non-oriented (Cooper et al., 2007).

DEA has become a compelling analytical methodology that is widely applied in the evaluation of different entities and industries, such as banks, hospitals, police stations, tax offices, defence bases, schools, insurance companies, libraries, university departments etc.

DEA has many strengths and advantages when compared to parametric methodologies. Most importantly, it does not require assumptions regarding "the functional form other than the concavity of the frontier functions" (Wang, 2003). Furthermore, its greatest advantage is that it can handle and include multiple inputs and outputs. As Toci (2009) stated, "it performs very well with small samples; does not suffer from the possibility of misspecification error of the production function and simultaneous equa-

tion bias; it can identify the sources of inefficiency". This allows for the DMU that has output deficiency, that uses excessive inputs or has scale problems to identify and address these problems, and thus, improve its performance and efficiency. Moreover, the inefficient DMUs are evaluated and compared with the most favourable set of weights, which is "compelling proof that inefficient DMUs are operating badly" (Radojicic et al., 2018).

Even though its advantages are numerous, DEA has some limitations. First and foremost, unlike parametric methodologies, the DEA is based on the "extreme observations comparing each decision-maker only with the best ones" (Rabar & Blažević, 2011), and thus, the frontier is "sensitive to extreme observations and measurement errors", due to the "basic assumption that random errors do not exist and that all deviations from the frontier indicate inefficiency" (Jemrić & Vujčić, 2002). Furthermore, the frontier calculated by DEA could be "warped if the data are contaminated by statistical noise" (Wang, 2003).

However, despite its limitations, DEA should be perceived as "a significant diagnostic tool" that could help analysts, policymakers, management and the public to gain new insights concerning entities' performance and efficiency (Fotova Čiković & Lozić, 2022).

RESEARCH METHODOLOGY

In this study, an in-depth extensive literature review has been conducted in order to summarize past findings regarding the efficiency of Croatian counties, with the application of Data Envelopment Analysis methodology. The conducted research started by exploring three scientific databases: Scopus, Web of Science (SSCI and SCI papers) and CROSBI (Croatian Scientific Bibliography) using the keywords "*Croatia*", "*County*" and "*Data Envelopment Analysis*". The CROSBI database has been vital for such a review, due to the fact this research concerns Croatia and Croatian counties in particular.

Figure 1. The selection process of the papers for the literature review
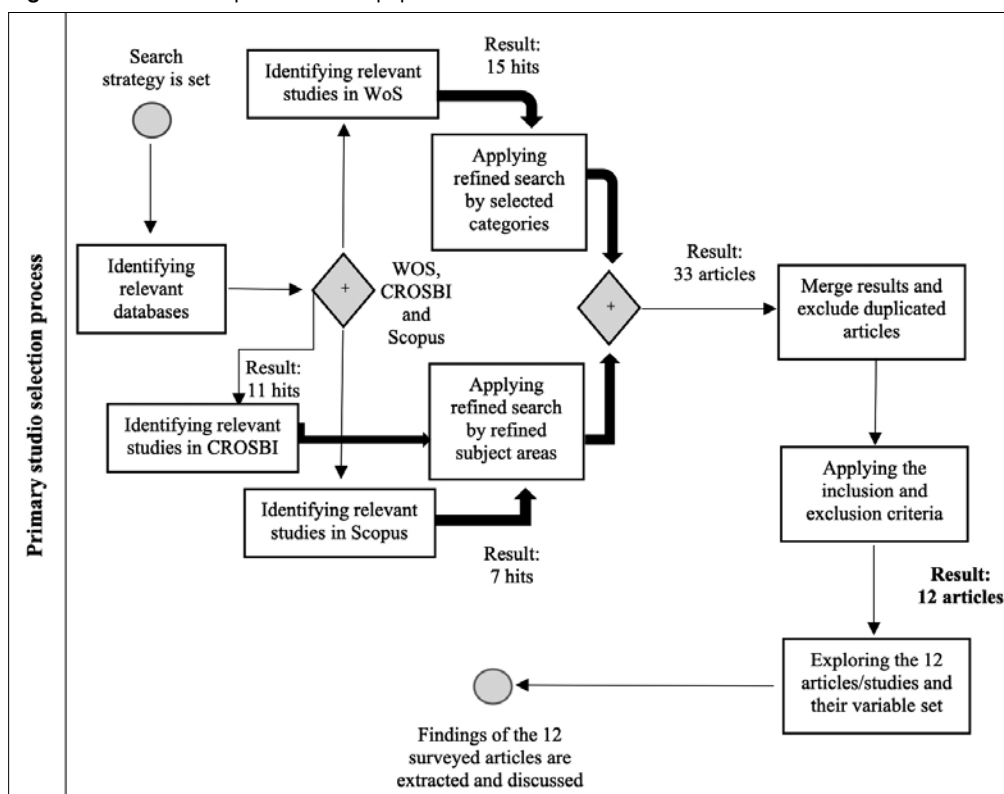
Source: Authors' work

In our study, we focus on 12 papers. Even though we surveyed a total of 33 papers (15 in Web of Science, 7 in Scopus and 11 CROSBI), after merging the papers, we have excluded the papers that were duplicated (indexed in more than one of the three surveyed databases). Furthermore, after reviewing the abstracts and keywords, 12 papers remained for further analysis. The criterion of the relevance of the paper and its findings was used in the final selection of the surveyed papers. These papers (together with their used DEA models and variable set) are presented in detail in Section 4.

APPLICATIONS OF DEA IN EFFICIENCY EVALUATION OF CROATIA'S (AND RIVER DRAVA BASIN REGION) COUNTIES

This study has explored all the relevant databases in search for all the previous work regarding the efficiency of Croatia's counties (and thereafter, the counties in the river Drava basin region) and it provides an introduction of the surveyed studies, their used DEA models, the selected variable set and their findings. The focus is put on the three counties in the river Drava basin region (Koprivnica – Križevci, Virovitica – Podravina and Međimurje County). A short overview of the applications of DEA in Croatia's counties is presented in Table 1, and a thorough presentation and analysis of the findings and used models are presented thereafter.

Škuflić, Rabar & Šokčević (2010) focus on measuring the regional efficiency of Croatia, by employing the CCR DEA output-oriented model. They have selected 5 inputs (the number of graduated students, active legal entities, the amounts of foreign direct investment (FDI), equipment investment and exports) and 2 outputs (gross domestic product (GDP) and gross wages) for their DEA model. The observed period is 2000 – 2006.

The obtained results show that the least efficient county in Croatia is Vukovar – Sirmium county (0.5057), while the average efficiency score for the whole sample is 0.8492. They found seven counties

Table 1. Applications of DEA in the efficiency evaluation of Croatia's counties

Author/s and year of publication	Application	Time frame	Applied DEA model
Škuflić, Rabar & Šokčević (2010)	*Assessment of the efficiency of Croatian counties*	2000 – 2006	Output-oriented CCR DEA model
Rabar & Blažević (2011)	*Evaluation of the touristical efficiency of Croatian counites*	2008 2004 – 2008	Output-oriented BCC DEA model
Rabar (2013a)	*Decomposing Regional Efficiency: The Case of Croatian Counties*	2005 – 2010	Both BCC and CCR DEA window models
Rabar (2013b)	*Assessment of regional efficiency in Croatia*	2005 – 2007	Both input-oriented and output-oriented window BCC DEA model
Škare & Rabar (2014)	*Regional efficiency measurement*	2005 – 2007	DEA Window analysis
Korent, Detelj & Vuković (2015)	*Evaluating the efficiency of Croatian counties in entrepreneurship*	2009	Output-oriented BCC and CCR DEA models
Škrinjarić (2018)	*Assessment of the efficiency of environmentally conscious tourism industry*	2011 – 2015	Output-oriented DEA model with VRS
Borozan & Borozan (2018)	*Evaluation of the total-factor energy efficiency in Croatian counties*	2001 – 2013	CCR and BCC DEA methodology
Hodžić & Muharemović (2019)	*Fiscal Decentralization and Efficiency of Regional Government in Croatia*	2009 – 2016	DEA methodology + Tobit regression
Rabar & Grbin (2019)	*Analysis of regional efficiency in Croatia using fiscal indicators*	2002 – 2015	DEA BCC model (window technique)
Slijepčević (2019)	*Measuring Efficiency at the Regional Level: A Data Envelopment Analysis Approach*	2015 – 2017	DEA methodology with six sub-indicators
Rabar (2020)	*Efficiency of regions: Environmental vs. Economic point of view*	2016	Output-oriented DEA BCC model

Source: Authors' construction

to be less-than-averagely efficient, and among them is one of the river Drava basin region's counties: Virovitica – Podravina county with an efficiency result of 0.7906.

Rabar & Blažević (2011) employ the CCR, the BCC output-oriented models together with the DEA window technique approach in the time-frame from 2004 – 2008 and for the year 2008, in order to investigate the touristic efficiency of the counties in Croatia. They used three inputs (number of beds, number of seats and number of employees) and four outputs (number of arrivals, number of stays, number of nights, revenue in thousands HRK) for their DEA model.

They found 13 and 10 efficient, 8 and 11 inefficient counties in their BCC and CCR model, respectively. The window DEA model was run with one and five windows. The results from the DEA methodology with one window show that the number of efficient counties has increased from zero efficient counties in 2004 to 11 efficient counties in 2008 and has decreased in the 5-windows model (from 16 efficient counties in 2004 to 13 in 2008).

Rabar (2013a) compares the regional efficiencies of Croatian counties and "identifies efficient counties as benchmark members" in the period 2005 – 2010 by employing both the BCC and CCR DEA methodology based on seven socio-economic indicators as follows: registered unemployment rate, number of support allowance users as inputs and the share of the secondary sector in gross value added (GVA), gross fixed capital formation in fixed assets (by headquarter of investor), level of import coverage by export, number of graduated students (by residence) and gross domestic product (GDP) as outputs. The findings show quite a contrast depending on the chosen DEA model. Thus, the CCR model shows lower efficiency than the BCC model.

Interestingly, the obtained results from the BCC model show that Koprivnica – Križevci, Virovitica – Podravina and Međimurje counties were BCC-efficient during the entire analysed period, whereas the window DEA technique shows that Međimurje County is the most efficient river Drava basin county (0.6106), followed by Koprivnica – Križevci (0.5462) and Virovitica – Podravina (0.4867).

Rabar (2013b) has applied the DEA methodology with a variable return to scale (VRS) and the window technique for the evaluation of the Croatian counties in the period 2005 – 2007. In her DEA models, she has selected seven socioeconomic indicators for the variable set, such as the registered unemployment rate and number of support allowance users are selected as inputs, the share of the secondary sector in gross value added (GVA), gross fixed capital formation in fixed assets (by headquarter of investor), level of import coverage by export, number of graduated students (by residence) and gross domestic product (GDP) as outputs. According to the obtained results, Vukovar – Sirmium county is the least efficient, and Požega – Slavonia county is the most efficient Croatian county.

Škare & Rabar (2014) analyse the period 2005 – 2007 to evaluate the efficiency of Croatian counties by employing the window DEA model with the variable return to scale. In their DEA model, they use two inputs (registered unemployment rate and number of support allowance users) and eight outputs (the share of secondary sector in gross value added (GVA), gross fixed capital formation in fixed assets (by headquarter of investor), level of import coverage by export, number of graduated students (by residence), gross domestic product (GDP), level of emigrants coverage by immigrants, number of active legal entities and number of medical doctors). They find that the output-oriented window DEA model (with an average total efficiency score of 0.964310) notes higher efficiency scores than the input-oriented (with an average total efficiency score of 0.821179).

Korent, Detelj & Vuković (2015) employ the BCC and CCR DEA models with an output orientation for the assessment of Croatian counties in entrepreneurship in the year 2009. They selected two input variables (Total expenses of entrepreneurs and Investments of entrepreneurs in fixed assets) and two output variables (Total income of entrepreneurs and Patents granted) for their models.

According to the obtained results, the average efficiency of the whole sample is 97.03% and 94.95% for the BCC and CCR models, respectively. However, no county from the river Drava basin region has been identified as relative efficient, neither in the BCC nor in the CCR DEA model. They claim the results suggest that entrepreneurial activity positively influences the economic growth and regional development of Croatian counties.

Borozan & Borozan (2018) investigate the total-factor energy efficiency of Croatian counties in a period of 14 years (2001 – 2013). Thus, this is the longest surveyed study. They employ the DEA methodology with both constant return to scale (CRS) and variable return to scale (VRS), with three inputs (labor employment, final electricity consumption and gross fixed capital formation) and one output (GDP).

According to the results from the DEA models, only eight counties noted total-factor energy efficiency of 1.00. The findings indicate that Koprivnica – Križevci (0.9563) and Virovitica – Podravina County (0.9551), which belong to the river Drava basin region, show rather high overall technical efficiency results. On the other hand, Međimurje county is classified as an inefficient county, with an efficiency score of 0.8833.

Škrinjarić (2018) focused her research on the efficiency of Croatian counties in terms of their environmental consciousness in tourism. The analysed period is 2011 – 2015. In this study, four different DEA models have been developed with the following variables: number of beds, number of rooms, municipal waste in tourism (in tons), current expenditures on environment protection (in thousands of HRK), total investments in environment protection (in thousands of HRK), number of tourist arrivals, number of overnight stays, total GDP (in thousands of HRK) and the surface of each county (in square kilometres), tourism pressure, reciprocal value of municipal waste, percentage of current expenditures in, percentage of total investments in GDP and undesirable output municipal waste. The obtained results suggest greater investment in environmental protection for greater efficiency of Croatian counties. More importantly, the findings indicate that "it is possible to obtain satisfactory economic and environmental results simultaneously".

Slijepčević (2019) has employed the DEA methodology with "six dimensions of performance of local government units at the regional level" (so-called sub-indicators, i.e. outputs), which are Education, General administration services, Social services for elderly, Environmental protection, Infrastructure and Culture and the total expenses of local government units in the county per capita as output. The obtained results and the ranking shows that Međimurje county has been ranked 7th, with an efficiency score of 0.78, Koprivnica – Križevci county has been ranked 12th (with an efficiency score of 0.66) and Virovitica – Podravina with 0.57 has been ranked 14th.

Hodžić & Muharemović (2019) focus on the efficiency and performance of the regional and local government by employing the DEA methodology and Tobit regression analysis in the period from 2009 to 2016. They chose Gross earnings of employed people in counties, Material expenses and Borrowing costs as inputs and Number of businesses in counties, Number of schools (basic and secondary education) and Number of individuals in counties as outputs in the DEA model. The obtained results from both their DEA models indicate that Virovitica – Podravina and Međimurje County "operate at maximum score".

Rabar & Grbin (2019) have analysed the efficiency of Croatian counties with the inclusion of six indicators related to fiscal policy measures. They selected Tax revenues, Current expenses, Capital expenditures, Number of employees in local and regional self-government, and the Total number of employees fewer employees in local and regional self-government bodies and with budget users as inputs, and GDP as an output for their BCC DEA window model. They have employed the DEA model with one and with 14 windows, and the results show that Slavonski Brod – Posavina County had obtained the highest efficiency score (0.992), whereas Virovitica – Podravina as the least efficient county with a 0.910 score. The obtained results confirm the hypothesis that there is a huge "inter-county disparity".

Rabar (2020) has developed two DEA models to assess both the economic and environmental efficiency of Croatian counties in 2016. Both the developed DEA models are output-oriented DEA models with variable return to scale. The model investigating the economic efficiency of counties is based on six indicators: population size, GDP, number of graduated students by residence, level of import coverage by export, the total number of persons in employment and number of medical doctors, whereas the model investigating the environmental efficiency of counties is based on five indicators: recovery rate of municipal waste collected by local government units, CO_2 emission in kg per capita, the share of treated water in total municipal wastewater discharge, environmental protection expenditure and invest-

PODRAVINA Volumen 21, broj 41, Str. 168 – 179 Koprivnica 2022.

Podravina 175

ments as a percentage of GDP and ratio of production and installed capacity of renewable energy plants. The results from the model investigating the economic efficiency show that the average efficiency score of the whole sample is 0.8350, with only Lika – Senj and the City of Zagreb being relatively fully efficient in 2016, while Šibenik – Knin was the least efficient county. Moreover, Međimurje county noted lower-than-average efficiency (0.7902). The second DEA model, on the other hand, has shown that the average environmental of the whole sample of counties in 2016 is 0.9793. In this model, only one of the river Drava basin counties has noted below-average efficiency, and that is Virovitica – Podravina (0.9618).

RESULTS

The results of the extensive literature review and the summary of these studies' findings regarding the river Drava basin region are presented in Table 2.

Table 2. Findings regarding the counties in the river Drava basin region.

Author/s and year of publication	Findings regarding the river Drava basin region		
	Koprivnica- Križevci County	Virovitica-Podravina County	Međimurje County
Škuflić, Rabar & Šokčević (2010)	Koprivnica – Križevci is considered the most efficient Croatian county and as reference for twelve inefficient counties.	The results indicate an average efficiency below average (0.8492).	
Rabar & Blažević (2011)	According to the one window results (2004 –2008), the efficiency score is 0.937, whereas the five windows model show a relative efficiency score of 1.	In this research, Virovitica – Podravina county noted efficiency scores of 0.834 and 0.950 in the one- and five-window models, respectively.	Međimurje County is the least efficient river Drava basin region county, with 0.814 and 0.893 scores.
Rabar (2013a)	The three river Drava basin region counties were CCR inefficient, but BCC-efficient (scores of 1) in the whole observed period 2005-2010.		
	The window analysis results show an efficiency of 0.5462.	The window analysis results show the lowest efficiency of 0.4867.	The window analysis results show the highest efficiency out of the analysed sample (0.6106).
Rabar (2013b)	Obtained efficiency scores of 0.825 and 0.973 in the input-oriented and output-oriented one window DEA model, respectively and 0.827 and 0.976 in the input-oriented and output-oriented BCC DEA combined model.	The DEA window model shows 0.857 and 0.966 scores for the input- and output-oriented model, respectively. The results from the combined BCC model are 0.871 and 0.971 for the input- and output-oriented model, respectively.	Međimurje is the least efficient river Drava basin region county in this study, with scores of 0.778 and 0.944 (input- and output-oriented window DEA model) and 0.778 and 0.945 (combined BCC DEA model).
Škare & Rabar (2014)	Efficiency scores of 0.825 and 0.974 in the input-oriented and output-oriented one window DEA model, respectively and 0.827 and 0.978 in the input-oriented and output-oriented BCC DEA combined model.	Most efficient river Drava basin region county in this study. Efficiency scores of 0.875 and 0.956 in the input-oriented and output-oriented one window DEA model, respectively and 0.934 and 0.988 in the input-oriented and output-oriented BCC DEA combined model.	Least efficient river Drava basin region county in this study. Efficiency scores of 0.779 and 0.976 in the input- and output-oriented one window DEA model, respectively and 0.803 and 0.966 in the input- and output-oriented BCC DEA combined model.
Korent, Detelj & Vuković (2015)	According to the results from the BCC-O DEA model, all of the observed river Drava basin region counties were relative inefficient.		
	Koprivnica – Križevci County proved to be the least efficient in total expenditures in entrepreneurship, but solid in the number of patents.	Least invested in long-term assets.	Solid in the number of registered patents

Author/s and year of publication	Findings regarding the river Drava basin region		
	Koprivnica- Križevci County	Virovitica-Podravina County	Međimurje County
Škrinjarić (2018)	The results from the BCC-O window model shows a decrease in efficiency (from 0.8436 to 0.7165). It is ranked 7th. The efficiency score for models with undesirable outputs is 0.842.	The lowest efficiency scores from the river Drava basin region - ranked 15th, with a decreasing efficiency and an efficiency score for models with an undesirable output of 0.621	Increase in efficiency according to the BCC-O model (from 0.821 to 0.925). This county is ranked 12th and its efficiency score for models with undesirable outputs is 0.738.
Borozan & Borozan (2018)	According to the overall technical efficiency scores, Koprivnica – Krizevci is a highly efficient county with Zagreb County. As for the total-factor energy efficiency, it is highly efficient with a score of 1.	The overall technical efficiency score is 0.9551, whereas the total-factor energy efficiency score is 1.	The Međimurje County is the least efficient in the river Drava basin region, with an overall efficiency score of 0.8833 and a total-factor energy efficiency score of 0.9988.
Hodžić & Muharemović (2019)	Koprivnica – Križevci County is relative inefficient in both Model 1 and Model 2 of the research.	The results from scale efficiency indicate that both Virovitica – Podravina and Međimurje County operate at the maximum score in both Model 1 and 2, meaning they are highly efficient.	
Rabar & Grbin (2019)	The efficiency score of 0.954 (ranked 14th) and 0.855 (ranked 11th) in the 14-windows and 1-window DEA model.	In this study, it is the least efficient river Drava basin county, ranked 19th (with a score of 0.910) and 16th (0.812) in the 14-windows and 1-window DEA model.	The most efficient river Drava basin county in both 14-window DEA (ranked 1st with a score 1,00) and 1-window DEA (ranked 2nd with a score 0.963 and highly efficient in 5 years out of the observed 14).
Slijepčević (2019)	The performance of sub-indicators at the regional level shows that this county has the highest scores in education and environment, but the lowest in culture. It has been ranked 12th with an efficiency score of 0.66.	It is ranked 14th, with an efficiency score of 0.57. Regarding the sub-indicators, it received highest score for the environment, whereas lowest for social services for the elderly.	Međimurje county is best ranked (7th) river Drava basin county in this study, with an efficiency score of 0.78. It received the highest scores for infrastructure and culture and the lowest for social services for the elderly.
Rabar (2020)	The relative economic efficiency results show a result of 0.8702 and a rank as the sixth county. The environmental efficiency results show high efficiency and a score of 1.	Ranked 10. in economic efficiency (score 0.8379) and 17th in environmental efficiency (score 0.9618).	Međimurje County is the least efficient river Drava basin region country in economic efficiency (ranked 15th with an efficiency score of 0.7902), whereas a highly environmentally efficient county (score of 1).

Source: Authors' construction

DISCUSSION AND CONCLUSION

This article implements an in-depth extensive literature review of studies employing the DEA methodology in measuring the efficiency of Croatian counties, with an accent on the three river Drava basin region counties, which are Koprivnica – Križevci, Virovitica – Podravina and Međimurje County. The conducted literature review has surveyed the Scopus, WoS (SSCI and SCI papers) and CROSBI (Croatian Scientific Bibliography) databases using "Croatia", "County" and "Data Envelopment Analysis" as keywords for the search. This research approach resulted in 7 hits in Scopus, 15 on WoS and 11 on CROSBI, which eventually (after the exclusion of duplicated papers and after reviewing the abstracts and keywords), resulted in analysis and a survey of a total of 12 papers. The criterion of the relevance of the paper and its findings was also crucial in the final selection of the surveyed papers.

This paper aimed to identify all the previous work regarding the efficiency of Croatia's counties as well as to provide an in-depth analysis of the used models, the variable set and their findings.

The surveyed papers include various aspects of regional efficiency. Namely, Rabar & Blažević (2011) and Škrinjarić (2018) focused on the touristic efficiency of Croatian counties; Škuflić, Rabar & Šokčević (2010), Rabar (2013a; 2013b) and Škare & Rabar (2014) have assessed the regional efficiency of counties; Rabar & Grbin (2019) and Hodžić & Muharemović (2019) have assessed the regional efficiency in Croatia with the use of fiscal indicators and fiscal decentralization, respectively; Slijepčević (2019) focused on regional efficiency with consideration of six dimensions of performance of counties; Borozan & Borozan (2018) have explored the "total-factor energy efficiency" of counties; and Rabar (2020) investigated the economic and environmental efficiency of Croatian counties.

The findings reveal rather inconsistent results, depending on the analysed period, DEA model, the variable set and the perspective of efficiency analysed. However, in most of the surveyed studies Koprivnica – Križevci and Virovitica – Podravina counties have shown high environmental and total-factor energy efficiency, but were least efficient in entrepreneurship and social services for the elderly, respectively. Moreover, Međimurje County seems to note the lowest efficiency scores in the river Drava basin region in the majority of these studies (Rabar & Blažević, 2011; Rabar, 2013b; Škare & Rabar, 2014; Borozan & Borozan, 2018; Rabar, 2020). Additionally, the three analysed river Drava basin region counties in most studies show technical inefficiency and efficiency scores below the average. In this sense, counties need to take into consideration these findings and benchmark and copy the best practices from the highly efficient Croatian counties (and especially the City of Zagreb). These findings could serve as a compass and guide to the local authorities to reveal their blind spots and areas for potential improvements as well as their ranking relative to the other Croatian counties, and thus, to undertake preventive and corrective measures.

The surveyed studies have been published from 2001 to 2020 but cover the period 2000 – 2016. They have employed both BCC and CCR DEA models, and, interestingly, the window DEA technique (used in four out of the twelve studies). The longest study covers 14 years (2002-2015 – the study of Rabar & Grbin, 2019), and the shortest study covers the year 2016 (Rabar, 2020).

This study represents an incentive for even greater use of the DEA methodology as the leading non-parametric mathematical programming technique for efficiency and performance evaluation, and thus, largely contributes to scholarly literature, the policymakers and the interested public. In future work, the efficiency of Croatian counties in a longer time-frame will be empirically evaluated with the window DEA methodology.

REFERENCES

1. Banker, R.D., Charnes, A., Cooper, W.W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management Science*, 30(9), pp. 1078-1092.

2. Borozan, Đ. & Borozan, L. (2018). Analyzing total-factor energy efficiency in Croatian counties: evidence from a non-parametric approach. *Central European journal of operations research*, 26 (3), pp. 673-694 doi:10.1007/s10100-017-0493-8.

3. Charnes, A., Cooper, W. W., Rhodes, E. L. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, 3(4), pp. 429–444.

4. Cooper, W., Seiford, L., Tone, K. (2007). *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software*. 10.1007/978-0-387-45283-8.

5. Cvetkoska, V. (2010). The Quantitative Basis on The DEA Methodology - Its Models and Areas of Application. *Annu. Fac. Econ. 45*. pp. 629-641

6. Cvetkoska, V. (2011). Data Envelopment Analysis Approach and Its Application in Information and Communication Technologies. In: M. Salampasis, A. Matopoulos (eds.): *Proceedings of the International Conference on Information and Communication Technologies for Sustainable Agriproduction and Environment (HAICTA 2011)*, Skiathos, 8-11 September, 2011. pp. 421-430

7. Cvetkoska, V., Fotova Čiković, K. (2021). Efficiency Analysis of Macedonian and Croatian Banking Sectors with DEA. *Economy, Business & Development*, 2(2), pp. 1-19. doi:10.47063/ebd.00003.

178 Podravina

PODRAVINA Volumen 21, broj 41, Str. 168 – 179 Koprivnica 2022.

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

9. Erena, O.T., Kalko, M.M. & Debele, S.A. (2021). Technical efficiency, technological progress and productivity growth of large and medium manufacturing industries in Ethiopia: A data envelopment analysis. *Cogent Economics & Finance*, 9:1, 1997160, DOI: 10.1080/23322039.2021.1997160

10. Farrell, M. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society, Series A (General),* 120 (3), pp. 253-290. https://doi.org/10.2307/2343100

11. Fidanoski, F., Simeonovski, K., Cvetkoska, V., (2021). Energy Efficiency in OECD Countries: A DEA Approach. *Energies*, 14, 1185. https://doi.org/10.3390/en14041185

12. Fotova Ciković, K., Cvetkoska, V. (2017). Efficiency of the Macedonian banking sector: A nonparametric approach. *CEA Journal of Economics*, 12(2), pp. 17–26.

13. Fotova Čikovič, K., Lozić, J. & Smoljić, M. (2021a). Efficiency of banks in Northern Croatia. *Podravina: časopis za multidisciplinarna istraživanja*, 20 (40), 128-140.

14. Fotova Čikovič, K., Lozić, J. (2022). Application of Data Envelopment Analysis (DEA) in Information and Communication Technologies. *Tehnički Glasnik* 16(1), pp. 129-134.

15. Fotova Čikovič, K., Smoljić, M. & Lozić, J., (2021b). The Application of The Non-Parametric Methodology DEA in the Croatian Banking Sector. In *Book of Proceedings - 71st International Scientific Conference on Economic and Social Development*, online, pp. 113-127

16. Gökşen, Y., Doğan, O., Özkarabacak, B. (2015). A Data Envelopment Analysis Application for Measuring Efficiency of University Departments. *Procedia Economics and Finance*, 19, pp. 226-237, https://doi.org/10.1016/S2212-5671(15)00024-6.

17. Hodžić, S., Muharemović, A., (2019). Fiscal Decentralization and Efficiency of Regional Government in Croatia: A Data Envelopment Analysis. *Lex Localis - Journal of Local Self-Government* 17(3), pp. 453 – 470.

18. Jemrić, I., Vujčić, B. (2002). Efficiency of Banks in Croatia: A DEA Approach, *Comparative Economic Studies*, 44 (2-3), pp. 169-193, 10.1057/ces.2002.13.

19. Jorda, P., Cascajo, R., Monzón, A. (2012). Analysis of the Technical Efficiency of Urban Bus Services in Spain Based on SBM Models. *ISRN Civil Engineering*. 12. 10.5402/2012/984758.

20. Korent, D., Detelj, K. & Vuković, K. (2015). Ocjenjivanje efikasnosti hrvatskih županija u poduzetništvu primjenom analize omeđivanja podataka. In: Vuković, K., Brčić, R. & Klačmer Čalopa, M. (eds.) *Entrepreneurial Society: Current Trends and Future Prospects in Entrepreneurship, Organization and Management, Book of Abstracts*.

21. Lukač, Z., Neralić, L. (2012). *Operacijska istraživanja*, Element, Zagreb

22. Marković, M., Knežević, S., Brown, A., Dmitrović, V. (2015). Measuring the productivity of Serbian banks using Malmquist index. *Manag. J. Sustain. Bus. Manag. Solut. Emerg. Econ.*, 20, pp. 1–10.

23. Marošević, K. (2020). Lagging regions: The case of Eastern Croatia. *Ekonomski vjesnik*, 33(1), pp. 255-270

24. Paradi, J.C., Sherman, D.H., Fai Keung Tam, F.K. (2018). *Data Envelopment Analysis in the Financial Services Industry, International Series in Operations Research & Management Science*. Springer International Publishing AG, 266, https://doi.org/10.1007/978-3-319-69725-3_1

25. Rabar, D. & Grbin, A. (2019). Analiza regionalne efikasnosti u Hrvatskoj korištenjem fiskalnih pokazatelja – neparametarski pristup. *Ekonomski pregled: mjesečnik Hrvatskog društva ekonomista Zagreb*, 70(4), 627-649 doi:10.32910/ep.70.4.3.

26. Rabar, D. (2013a). Decomposing regional efficiency: The case of Croatian counties. In: Blažević, S., Sinković, D., Černe, K. & Stjepanović, S. (eds.) *Conference Proceedings of The 6th International Conference "The Changing Economic Landscape: Issues, Implications and Policy Options".*

27. Rabar, D. (2013b). Assessment of regional efficiency in Croatia using data envelopment analysis. *Croatian Operational Research Review,* 4(1); 76-88.

28. Rabar, D. (2020). Efficiency of regions: Environmental vs. economic point of view. *Interdisciplinary management research*, 1, 1757-1777.

29. Rabar, D., Blažević, S. (2011). Ocjenjivanje efikasnosti hrvatskih županija u turizmu primjenom analize omeđivanja podataka. *Privredna kretanja i ekonomska politika*, 21, 127; pp. 25-55.

30. Radojicic, M., Savic, G., Jeremic, V. (2018). Measuring the Efficiency of Banks: The Bootstrapped I-Distance GAR DEA Approach. *Technological and Economic Development of Economy*, 24(4), DOI: https://doi.org/10.3846/tede.2018.3699

31. Santos, J., Negas, E.R., Santos, L.C. (2013). Introduction to Data Envelopment Analysis. In Mendes et al. (eds.), *Efficiency Measures in the Agricultural Sector: With Applications*, DOI 10.1007/978-94-007-5739-4 3

32. Šebalj, D., Mesarić, J. & Franjković, J. (2017). Research of development and growth perspectives of the local ICT sector. In: Jurcic, A., Oreski, D. & Mikic, M. (eds.) *21st International Scientific Conference on Economic and Social Development.* pp. 29-38

33. Šegota, A., Cerović, L. & Maradin, D. (2017). Efficiency of municipal service providers in the Republic of Croatia. *Croatian operational research review*, 8 (2), pp. 537-562 doi:10.17535/crorr.2017.0035.

34. Škare, M. & Rabar, D. (2014). Regional efficiency assessment using DEA window analysis. *Journal of Economic Computation and Economic Cybernetics Studies and Research,* 48 (4), pp. 39-61.

35. Škrinjarić, T. (2018). Evaluation of environmentally conscious tourism industry: case of Croatian counties. *Tourism: an international interdisciplinary journal*, 66 (3); pp. 254-268.

36. Škuflić, L., Rabar, D., Šokčević, S. (2010). Assessment of the efficiency of Croatian counties using data envelopment analysis. *Ekonomska istraživanja,* 23(2); pp.88-101

37. Slijepčević, S. (2019). Measuring efficiency at the regional level: a data envelopment analysis approach. *Lex localis - Journal of Local Self-Government*, 17 (3), pp. 679-696 doi:10.4335/17.3.679-696.

38. Stancheva, N., Angelova, V. (2008). Measuring the efficiency of University libraries using Data Envelopment Analysis. In Mantri, J.K., *Research Methodology on Data Envelopment Analysis (DEA).*

39. Thanassoulis, E., (2001). *Introduction to the Theory and Application of Data Envelopment Analysis: A Foundation Text with Integrated Software.* Springer-Verlag New York, LLC.

40. Toci, V.Z. (2009). Efficiency of Banks in South-East Europe: with Special Reference to Kosovo. *CBK Working paper*, No. 4.

41. Wang, S. (2003). Adaptive non-parametric efficiency frontier analysis: a neural-network-based model. *Computers & Operations Research*, 30(2), pp. 279-295, https://doi.org/10.1016/S0305-0548(01)00095-8.

SAŽETAK

U radu je primijenjena metodologija matematičkog programiranja AOMP (analiza omeđivanje podataka) modela analize u evaluaciji i mjerenju efikasnosti i uspješnosti hrvatskih županija. Temeljni je cilj ovog članka prikazati i analizirati efikasnost i uspješnost županija uz rijeku Dravu (Koprivničko-križevačke, Virovitičko-podravske i Međimurske županije) te dati zaključke o ovoj regiji i njezinoj regionalnoj efikasnosti. Ostali se ciljevi referiraju na korištenje i tumačenje teoretske pozadine AOMP metodologije. Riječ je o jednoj od najpopularnijih ne parametarskih metoda u evaluaciji efikasnosti od njenog uvođenja u revolucionarni rad Charnesa, Coopera i Rhodesa 1978. godine. U radu se koristi opsežni pregled literature o studijama primjene AOMP metodologije te dubinska evaluacija učinkovitosti hrvatskih županija. Autori su pregledali baze podataka Scopus, Web of Science (SSCI i SCI radovi) i CROSBI (Hrvatska znanstvena bibliografija) koristeći ključne riječi »CROATIA«, »COUNTY« i »DATA ENVELOPMENT ANALYSIS« kao ključne riječi za istraživanje. Pronađeno je sedam radova u Scopusu, petnaest na Web of Science i jedanaest na CROSBI-u, što je u konačnici rezultiralo pronalaskom dvanaest relevantnih radova za ovu analizu. Nadalje, ova studija analizira dosadašnji rad na području učinkovitosti županija u podravskoj regiji, kao i dubinsku analizu korištenih modela, skupa varijabli i njihovih nalaza. Rezultati analize otkrivaju različite aspekte evaluacije efikasnosti hrvatskih županija s posebnim naglaskom na županije uz rijeku Dravu. Koprivničko-križevačka i Virovitičko-podravska županija pokazale su visoku ekološku i ukupnu energetsku učinkovitost, ali su bile najmanje učinkovite u poduzetništvu i socijalnim uslugama za starije osobe, sukladno. Prema dobivenim rezultatima, Međimurska županija je najneučinkovitija županija u analiziranoj regiji. Štoviše, tri analizirane podravske županije u većini studija pokazuju tehničku neučinkovitost te ispodprosječnu učinkovitost. U tom kontekstu, županije trebaju uzeti u obzir dobivene rezultate te usporediti i primijeniti najbolje prakse iz visoko učinkovitih hrvatskih županija. Ovaj bi rad mogao poslužiti kao poticaj za veću upotrebu AOMP metodologije kao vrlo relevantne tehnike za ocjenu učinkovitosti i izvedbe, kao i alata za usporedbu u različitim regijama.