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ASSESSING CIRCULAR ECONOMY PERFORMANCE OF EUROPEAN COUNTRIES AND SERBIA USING DATA ENVELOPMENT ANALYSIS

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Abstract:

The circular economic system concentrates on closing the loop for resource flows by imitating the function of natural ecosystems in order to achieve sustainability. The aim of the paper is to introduce a comprehensive approach to assessing countries' performance in municipal waste management and utilization. The change in the efficiency of circular economy in the period from 2016 to 2019 has been analyzed using Data Envelopment Analysis model. Furthermore, Tobit regression model examined the influence of macroeconomic factors on achieved efficiency scores. Results indicate that the performance of the circular economy has an admirable level of efficiency level, as the average score is above 70%. Belgium, Lithuania, Poland and Sweden obtained the highest efficiency levels, while Greece and Cyprus experienced the lowest efficiency scores. The positive observation is that countries efficiency mainly has an ascending trend. Furthermore, the second stage analysis showed that resource productivity, private investments, jobs and gross value added related to the circular economy sector and GDP per capita significantly influence the efficiency of circular economy performance.

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INTRODUCTION

According to projections of the UN environment program, global resource demand will increase three times by 2050, *ceteris paribus*. However, a 70% acceleration is plausible due to ever present increase in demand for food and fiber. Under the "business as usual" scenario, putting it bluntly, we consume annually over 1.5 Earth's worth of all resources. That means we shall need our four planets just to meet ends with the current demand until 2050. According to a Eurobarometer survey, Europe's near-complete reliance on energy import as well as the import of ore results in the following: Imports vary from 40% up to a staggering 70% for certain strategic resources. Furthermore, 9 out of 10 European companies anticipate a sharp rise in input costs in the near future.

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Resources are limited, but not our appetites for them (Fan and Fang, 2020). Therefore, in order to offer solutions to figures from the previous passage, a circular economic system concentrates on forming the resource flow loop in order to achieve sustainability (van Capelleveen *et al*., 2021). Circular economy offers a paradigm change from a linear economy which highly depends on the consumption of resources that end up in landfills after being used, that is not economically, ecologically and socially sustainable in the long run (Busu, 2019). The alternative to the linear economy, embodied in the "take-make-dispose" model to one that aims to reduce waste and maximizes the utilization of resources. The waste management will be very important as well in the tranformation into a circular economy (CE), with an aim to keep and use products and materials economically , minimizing waste and resource use (Busu, 2019). Waste management is a crucial for a circular economy, which targets to reduce material use and waste by ensuring that resources are kept and use as much time as possible (Giannakitsidou *et al*., 2020). In our current linear economy, we extract resources from the Earth, use them to make products, and then dispose of them as waste. However, in a circular economy, we aim to create closed-loop systems where waste is treated as a valuable resource and reused, recycled, or repurposed. This requires a shift towards circular waste management systems that prioritize the reuse and recycling of materials (van Capelleveen *et al*., 2021). Circular waste management involves several strategies, including reducing waste generation and designing products for reusability and recyclability. Recycling and composting are also essential aspects of circular waste management, as they allow materials to be used again instead of ending up in landfills or incinerators.

There are wide social and economic differences between European countries, and no less difference can be expected when it comes to waste generation and management performance. Furthermore, the results in practice indicate a constant struggle between economic growth, environmental protection and resource recycling (Sun *et al*., 2019, Lacko *et al*., 2021).

There are various indicators that can be used to measure progress towards a circular economy, broadly divided into 5 groups based on the Bellagio Principles: Environmental and Governance related indicators, Economy and business kind, Infrastructure and technology and Societal indicators. Waste management indicators as a subgroup of Environmental related indicators include total waste generation, municipal waste generation, various recycling and disposal shares. All in all 474 indicators were collected and drew from based on Chapter 5 of the OECD 2020 report: The Circular Economy in Cities and Regions.

The transition towards a circular economy is closely linked with sustainable production, waste management, and recycling. Conceptual analysis has shown that there is a strong linkage between the circular economy and these factors, indicating that improving waste management and recycling practices is a key step toward achieving a circular economy. Current research show that there is a positive trend in the improvement of implemetnation and evaluation of the effects of Circular Economy, but it is still deficient (Popović *et al*., 2022).

The aim of this paper is to illuminate the performance in municipal waste management of European member states. The investigation can be separated into two parts: the first stage applies DEA methodology on one input and two output variables. The second stage utilizes Tobit model on the efficiency of each country as a dependent variable and provides further explanation through the use of macroeconomic variables. Furthermore, Section 2 focuses on the literature review of solid waste management in the European Union. Section 3 includes the methodology and presentation of the data used. Section 4 summarizes the findings and provides a discussion. Section five concludes.

LITERATURE REVIEW

In the case of an evident circular economy, the main intention is to minimize or even avoid wate production as much as possible (de Leonardis, 2011). Concerning the accomplishment of such aspirations, local policymakers must lead residents to more responsible behavior toward waste management and recycling procedure (Agovino *et al.*, 2018). Also, to shrink the waste generation level, it is assumed that the manufacturing process and the use of products are approached in a more careful, efficient, and culpable way (Corvellec *et al.*, 2018). Furthermore, the competitiveness of European economies is increasingly affected by competition for limited resources and high prices of raw materials (Giannakitsidou *et al.*, 2020).

Data envelopment analysis (DEA) is known for its usable value and adaptability to a diversity of problems, mainly in fields of energy, transportation, agriculture, finance, industry and public policy (Emrouznejad and Yang, 2018). However, its application is limited to scientific papers coping with waste management and circular economy overall.

Chen (2010) assessed the integrated cost efficiency scores of waste management by using generated quantities of collected and sorted municipal solid waste. Halkos and Papageorgiou (2016) measured the efficiency of the environment of 116 European regions examining the generation of waste just as an unwanted output. Their findings point to the need to adopt unified policies in the field of waste management. Giannakitsidou *et al.* (2020) argue that only combining recycling material use rate with the waste generation level can lead to a proper estimation of countries` performance. Their research conducted on a sample of 26 European Union countries shows large disparities among observed countries, where the lines between West and East have fallen, but not between North and South. The same authors noticed that solid waste production has a driving part in waste management performance and it is mostly neglected by scholars applying DEA methodology. Also, when it comes to the concept of circular economy, various researchers encounter difficulties in the selection and measurement of efficiency indicators (Winans *et al.*, 2017).

Earlier applied examinations have focused thoughtfully on increasing outputs and reducing inputs. Hence, only a few have referred to potential sources of waste production improvement (Sun *et al.*, 2019). Waste materials and energy through decomposition and readjustment become inputs again in the circular economy (Korhonen *et al.*, 2018). In this regard, the essence of the concept of the circular economy becomes the minimization of resource consumption and environmental costs while gaining maximum sustainable benefits (Garcia Barragan *et al.*, 2019).

In the last couple of years, there are numerous studies conducted on the circular economy. Mainly, mentioned researches can be categorized as follows: the connotation of circular economy, the implementation of circular economy and the selection of evaluation indicators in the circular economy (Ghisellini *et al.*, 2016). Therefore, the research gaps in the circular economy primarily lie in the following areas (Sun *et al.*, 2019). Van Fan *et al.* (2019) introduce an interdisciplinary method involving consensus building among stakeholders, data availability, cost of investment and waste recovery framework to encourage the further development of a circular economy. Jakobi *et al.* (2018) evaluated the circular economy development process in Austria based on multiple flows related to inputs of resources with outputs of waste production and environmental policies. Fan and Fang (2020) created the DEA model where energy, water and capital are indicated as inputs and GDP and utilization rate of wastes as outputs. Mentioned authors consider that research findings may help in evaluating the level of circular economy development.

DATA AND METHODOLOGY

Data Envelopment Analysis (DEA) is a commonly used nonparametric method for efficiency analysis of selected Decision Making Units (DMU), and can be applied successfully in different fields on micro and macroeconomic levels, as well (Milenković *et al.*, 2022). A DMU is observed as the entity responsible for converting inputs into outputs and whose performances are to be evaluated (William *et al.*, 2007). In our specific case, the DMUs are independent countries, hence they fit the definition of the DMU. DEA method is a non-parametric method that orders DMU efficiencies in comparison to the highest efficiency score in the set. Various parametric approaches, on the other hand, use the mean instead of the maximal value. DEA utilizes a linear programming model, exploring the relationship between chosen output and input data. A different selection of variables results in different relative efficiency scores. So, the correct selection of adequate inputs and outputs is among the most important and most difficult pace in creating an adequate empirical model for assessing the relative performance of countries (Cooper *et al.*, 2007)

The DEA model with a variable return to scale has been used to explore the efficiency of circular economy performance for selected European countries. Whether we shall opt for input or output DEA model, is based primarily on which variables we would like to ameliorate – input or output ones, therefore the applied model is output oriented. The output-oriented model makes effort to determine the maximum possible proportional increase of outputs while maintaining the levels of used inputs constant (Milenković *et al.*, 2022). This study conducts the analysis in the following manner (Banker *et al.*, 1984) stating for each DMU and each time period the linear programming:

$$\begin{aligned} &\max \phi \\ &s.t.\sum_{j=1}^{n} x_{ij}\lambda_j \le x_{i0} \quad i=1,2,\ldots,m; \\ &\sum_{j=1}^{n} y_{rj}\lambda_j \ge \phi y_{r0} \quad r=1,2,\ldots,s; \\ &\sum_{j=1}^{n} \lambda_j = 1 \\ &\lambda_j \ge 0 \end{aligned} \tag{1}$$

In our particular case, n represents number of countries. Assume that s is the number of output variables, while m denotes number of inputs. According to Banker *et al.* (1984), output and input values are y_r and x_i. Furthermore, e y_{r0} is the amount of output r used by DMU$_o$, while x_{i0} is the amount of input i used by DMU$_o$. λ is the DMU's weight and the efficiency score is ϕ.

In the second part of the data examination, the results of the countries' efficiencies as a dependent variable will be regressed against certain independent variables (scores). The scores, were only nonnegative and also right censored, with an upper limit of 1. In this case, the choice is to apply the Tobit model, which is suitable to deal with truncated data. In other words, the study shall estimate the adjusted productivity by regressing it on the set of explanatory variables. Following Green (2003), the method used was maximum likelihood under the assumption of homoscedastic normal disturbances. The formulation of Tobit model can be found in various literature (see eg. Green, 2003, or Cameron & Trivedi, 2005) and in this study adopted notation form is presented as follows (Greene, 2003):

$$\begin{gathered} y_i^* = x_{ij}^{'}\beta + \varepsilon_i, \\ y_i = 0 \;\text{ if }\; y_i^* \leq 0 \\ y_i = y_i^* \;\text{ if }\; y_i^* \geq 0 \end{gathered} \tag{2}$$

Where y_i^* denotes the so-called latent dependent variable of the technical efficiency result, which corresponds to ith country, $x_i^{'}$ represents the regressors vector and ε_i is the standard error.

Our research assessed technical efficiency change in of circular economy performance in European countries during the four year period 2016-2019. The source of data is the Eurostat database and the countries were selected by the availability of data. Our analysis utilizes one input variable and two output variables. The input variable is Generation of municipal waste per capita. Formal definition states (taken from OECD) that it measures the waste collected by or on behalf of municipal authorities and disposed of through the waste management system. The measurement unit is kilogram per capita. When it comes to the other two variables, the formal definition of Recycling rate of municipal waste is, again according to OECD, the share of recycled municipal waste in the total municipal waste collection, while the same organization defines the share of energy from renewable sources as percentage of final consumption of energy that is derived from renewable resources. The last variable was chosen as a proxy for a country's progress towards the set targets of the European Union Sustainable Development Strategy.

RESULTS AND DISCUSSION

Descriptive statistics are shown in the Table 1, and consist of data for 2016 and 2019 respectively.

Table 1. Input and Output Variables – descriptive statistics

	Generation of municipal waste	Recycling rate of municipal waste	Share of energy from renewable resources
2016			
Mean	477.68	35.57	23.46
St. Dev.	143.49	16.48	15.06
Min.	261.00	0.30	5.85
Max.	830.00	67.10	69.24
2019			
Mean	498.41	38.55	25.52
St. Dev.	134.82	16.20	15.58
Min.	280.00	0.20	8.89
Max.	844.00	66.70	74.41

Source: *Author's calculations*

Since the DEA study observe only one input variable, it is possible to show grafically the efficient frontier by dividing both output variables with the input variable and plotting dots for each country (O1 stands for Recycling rate of municipal waste, while O2 is Share of energy from renewable sources). Figure 1a and 1b present the situation for the first and the last observed year.

Figure 1a. Efficient frontier 2016

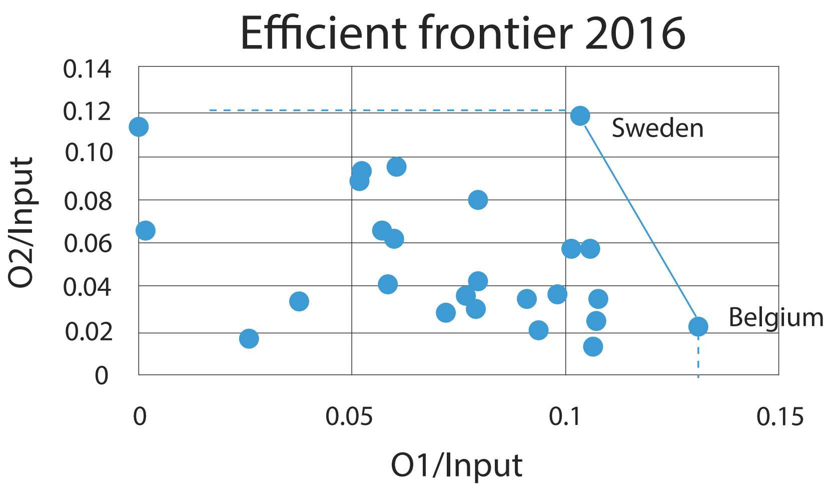
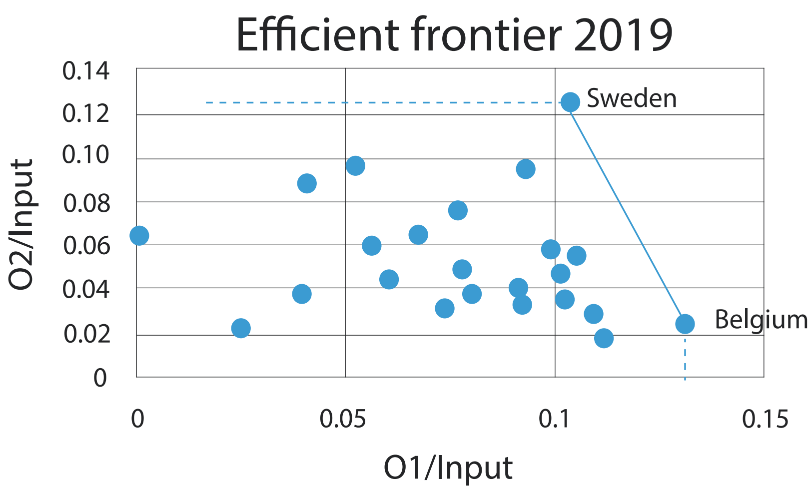


Figure 1b. Efficient frontier 2019



The results of the abovementioned DEA model (1) are presented in Table 2. The values of efficiency scores are between 0 and 1. From the DEA results it can be concluded that performance of circular economy has relatively high efficiency, because the average score is higher than 70%. Belgium, Lithuania, Poland and Sweden are the most efficient countries in sample since the efficiency score is above 90% during the entire period. Greece and Cyprus are with the lowest efficiency scores (less than 35%). The positive conclusion is that countries efficiency mainly has an ascending trend, which is also confirmed by the fact that the highest average efficiency belongs to the last year in the sample (80%). The findings of this paper are consistent with recent studies (Giannakitsidou *et al.,* 2020) which also showed large disparities among European countries in their circular economy performance. Similarly to our research countries with the lowest efficiency scores were Cyprus and Greece, while Belgium, Germany, Lithuania and Poland attained the circular economy performance. Therefore, the authors conclude (Giannakitsidou *et al.*, 2020) that there exist significant disparities in the development of a circular economy and its performance between North and South European countries.

Our research also confirms this conclusion and enriches the previous research by adding Serbia as European Union membership candidate country and Tobit regression in the analysis. Compared to the other efficiency scores Serbia is somewhere in between with an efficiency score of about 60%.

Table 2. Efficiency Scores

DMU	2016	2017	2018	2019	Average efficiency per country
Belgium	100%	100%	100%	100%	100%
Bulgaria	67%	67%	65%	67%	67%
Denmark	50%	51%	52%	92%	61%
Germany	84%	83%	85%	100%	88%
Greece	31%	34%	35%	41%	35%
Spain	61%	63%	60%	69%	63%
France	59%	58%	58%	67%	61%
Croatia	60%	56%	55%	62%	58%
Italy	75%	79%	79%	88%	80%
Cyprus	22%	22%	23%	31%	24%
Latvia	77%	80%	79%	87%	81%
Lithuania	91%	89%	92%	91%	91%
Hungary	75%	73%	77%	78%	76%
Netherlands	81%	81%	82%	94%	85%
Austria	86%	86%	83%	100%	89%
Poland	92%	85%	84%	100%	90%
Portugal	59%	57%	53%	59%	57%
Romania	82%	76%	71%	100%	82%
Slovakia	55%	64%	69%	75%	66%
Sweden	100%	100%	100%	100%	100%
Norway	78%	79%	78%	100%	84%
Serbia	67%	56%	51%	61%	59%
Average efficiency per year	70%	70%	70%	80%	

Source: *Author's calculations*

Moreover, the following stage in the efficiency assessment is conducted in order to notice the main influence of the technical efficiency analysis scores. Considering possible drivers of technical efficiency from previous studies and accessible data sets in the case of EU countries and Serbia, this paper introduces three independent variables:

- Resource productivity is the division of the gross domestic product by the consumption of materials in the observed country
- Private investments, jobs and gross value added related to the circular economy sector
- Gross domestic product (GDP) per capita

Table 3. Results of the Tobit model

Variable	Parameter	z-Statistic
Intercept	0.6206***	15.4353
Resource productivity	0.0414**	2.2208
Private investments, jobs and gross value added related to the circular economy sector	0.0004***	3.3771
GDP per capita	0.000004***	3.1698

*Note: *** and ** demonstrate the statistical significance at the level of 1% and 5%*
***Source:** Author's estimations*

The results, presented in Table 3, indicate the significance of resource productivity, private investments, jobs and gross value added related to the circular economy sector and GDP per capita. Also, all previously mentioned independent variables are kept in the model and reflect the positive effect on the efficiency score level.

Growth in resource productivity leads to growth in the circular economy efficiency level. To rephrase it, the reduced use of raw materials per unit of realized gross domestic product causes a more efficient implementation of the principles of the circular economy. Witnessing the results of the formed sample of EU states and Serbia, it is expected that the growth of private investments, jobs and value added at factor costs in the recycling, repair and reuse sectors explains better efficiency scores in the case of the circular economy. Decisively, the results demonstrate that a higher level of development in the country, looking at GDP per capita, is expected to cause an increase in the efficiency scores of the circular economy.

CONCLUSION

The intention of the paper is to demonstrate a comprehensive way to assess the performance of observed country set in municipal waste management and utilization. In the first stage, the above mentioned DEA model approach has been applied with two output and one input variable. In the second stage, the Tobit regression model used each country's technical efficiency scores as a dependent variable and provided further explanation through macroeconomic variables. Results show great differences between the values of efficiency scores in the observed countries and support the previous findings of other authors (Giannakitsidou *et al.*, 2020) that mainly North European countries achieved higher performance in the circular economy than South European countries. Thus, the results of efficiency analysis point the position of Serbia within the European framework. Furthermore, the analysis showed that resource productivity, private investments, jobs and gross value added related to the circular economy sector and GDP per capita significantly influence the efficiency of circular economy performance. At the same time, through this research, options were offered to decision-makers, primarily at the statal level, with an aim to improve and further encourage the development of the circular economy.

The leading limitation of the analysis is the accessibility of data since the circular economy is a relatively new topic. Taking into account main constraints of the applied methodology, limitations are also associated with the results of DEA and Tobit models, since the results are heavily determined by the selection of the DMU units included in the sample and the selection of input and output variables (Marcikić Horvat *et al.*, 2022). Therefore, further research should include more variables in DEA and Tobit model and observe a wider time frame. In the meantime, policymakers and researchers may benefit from the current study since this paper contributes to the new and attractive research area and provides relevant conclusions for future drivers of circular economy performances.

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https://www.oecd.org/cfe/cities/InventoryCircularEconomyIndicators.pdf

PROCENA PERFORMANSI CIRKULARNE EKONOMIJE EVROPSKIH ZEMALJA I SRBIJE PRIMENOM DVOSTEPENE ANALIZE OBAVIJANJA PODATAKA

Rezime:

Osnovni cilj ovog rada je da predstavi sveobuhvatniji pristup proceni učinka evropskih zemalja u upravljanju i korišćenju komunalnog otpada. U ovom radu je analizirana promena tehničke efikasnosti performansi cirkularne ekonomije u evropskim zemljama u četvorogodišnjem periodu, od 2016. do 2019. U prvoj fazi je primenjen izlazno orijentisan DEA model sa varijabilnim prinosom na obim, dok je u drugoj fazi primenjen Tobit regresioni model za ispitivanje uticaja izabranih makroekonomskih faktora na postignute rezultate efikasnosti. Rezultati pokazuju da performanse cirkularne ekonomijeu evropskim zemljama ostvaruju zavidan nivo efikasnosti, budući da je prosečna efikasnost iznad 70%. Belgija, Litvanija, Poljska i Švedska su ostvarile izuzetno visok nivo efikasnosti (iznad 90%) tokom posmatranog vremenskog perioda. Zemlje sa najnižim rezultatima efikasnosti su Grčka i Kipar (manje od 35%). Pozitivan zaključak je da efikasnost zemalja uglavnom ima uzlazni trend, što potvrđuje i činjenica da najveća prosečna efikasnost pripada poslednjoj godini u uzorku (80%). Rezultati Tobit regresionog modela pokazuju da produktivnost resursa, privatne investicije i bruto dodata vrednost u vezi sa sektorom cirkularne ekonomije i BDP po glavi stanovnika statuistički značajno utiču na efikasnost cirkularne ekonomije.

Ključne reči:
cirkularna ekonomija,
analiza obavijanja podataka,
Tobit regresioni model,
analiza efikasnosti,
održivi razvoj.