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EU COUNTRIES HIERARCHICAL CLUSTERING TOWARDS CIRCULAR ECONOMY PERFORMANCE INDICATORS

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Abstract. *Circular economy indicators can be used for ranking countries and their hierarchical clustering. It shows the differences and similarities in the progress between individual countries, made toward the realization of the principles of the circular economy (CE). CE is a modern concept and the aspiration to preserve resources and protect the environment. The paper presents a cluster analysis at the level of the European Union (EU27) countries, based on the data of CE composite indicators, which is managed by the statistical office of the European Union (Eurostat). SPSS IBM 26.0 statistics software was used for cluster analysis, while the ANOVA method was applied to check the statistical significance of the obtained results. The most important results achieved in the paper are the classification into 6 clusters within the EU27 countries, with similar policies in the area of the circular economy. The best-ranked cluster is cluster 6 which consists of only 1 country, the Netherlands, the European leader in the circular economy. Accordingly, this paper aims to determine the similarities and differences between the EU member states in the implementation of circular economy postulates by dividing them into clusters. In this way, the highest mean values of the indicators within the cluster will be determined, and thus the circular economy model that other clusters should follow.*

Key words: *circular economy, indicators, EU countries, cluster analysis*

1. INTRODUCTION

European Union has a growing interest in legislation and policies related to CE and developed CE indicators as guidelines for their countries. The European Commission launched the Circular Economy Action Plan in 2015 and highlighted the importance of CE. It has introduced monitoring its performance across countries to understand and benchmark the level of success of policy initiatives [1]. Without measuring, researchers cannot manage any

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system, and for that reason, many indicators are being presented in the area of CE. Some authors reviewed tools and methodologies of CE indicators that are already in use and their disadvantages: none of the indicators and methodologies alone was capable of monitoring all the CE characteristics (Elia et al.,2017) and none of the methods alone could account for the retention of value in waste resources (Iacovidou et al., 2017) [2,3].

The composite indicator aims to prioritize measurement progress to CE and uniformity to drive the development to create an innovative and prosperous environment, zero-waste [4,5,6]. In 2018, a Monitoring Framework for the CE was presented by the statistical office of the European Union (Eurostat), the Joint Research Centre, and the European Patent Office. The CE indicators are classified into four thematic areas: Production and Consumption, Waste Management, Secondary Raw Material, and Competitiveness and Innovation. CE indicators related to the generation of different types of waste are within the theme of rea Production and Consumption. The indicators included in the thematic area of Waste Management are the recycling rates of different products. Indicators such as material use rates and trade of recyclable raw materials are within the thematic area of Secondary raw material. Indicators such as patents in CE, gross investment in tangible goods, persons employed, and value-added are within the thematic area of Competitiveness and Innovation. The framework illustration shows that most of the indicators focus on the preservation of materials, with strategies such as recycling, reuse, and generally on environmental protection [7].

As follows, the authors selected Eurostat indicators in order to perform a cluster analysis on EU27 countries and grouped them into similar circular economy "ecosystems" [8].

2. METHODOLOGY

The methodology applied in this research is based mainly on cluster analysis. The application of cluster analysis aims to group the European Union member states based on selected indicators for the circular economy. Grouping the member states of the European Union based on the value of the indicators should contribute to the perception of similarities between the countries in certain clusters in the matter of conducting the circular economy policy. Also, by determining descriptive statistics for each cluster individually, the cluster with the best conditions for implementing the circular economy is determined, which provides guidelines for other member countries to advance in this area. In doing so, authors use indicators value for EU27 from the last available year Eurostat data set for CE (Circular Economy) indicators, as follows:

- *Resource productivity* - The indicator is defined as the gross domestic product (GDP) divided by domestic material consumption (DMC). DMC measures the total amount of materials directly used by an economy. It is defined as the annual quantity of raw materials extracted from the domestic territory of the local economy, plus all physical imports minus all physical exports. It is important to note that the term 'consumption', as used in DMC, denotes apparent consumption and not final consumption. DMC does not include upstream flows related to imports and exports of raw materials and products originating outside of the local economy [13].
- *Recycling rate of municipal waste*–measures the share of recycled municipal waste in the total municipal waste generation. Recycling includes material recycling, composting, and anaerobic digestion. The ratio is expressed in percent (%) as both terms are measured in the same unit, namely tones [13].

- *Circular material use rate*–measures the contribution of recycled materials to overall materials demand. The indicator measures the share of material recycled and fed back into the economy - thus saving extraction of primary raw materials - in overall material use. The circular material use, also known as the circularity rate is defined as the ratio of the circular use of materials to the overall material use [13].
- *Recycling rate of all waste excluding major mineral waste*- The indicator is calculated as recycled waste divided by total waste treated excluding major mineral wastes, multiplied by 100 [13].

Cluster analysis as a multivariate technique was carried out using statistical software SPSS IBM 26.0, using an agglomerative hierarchical approach. First of all, the authors have conducted a hierarchical agglomerative procedure based on Euclidean squared distance. The obtained agglomeration scheme (Table 1) as an output result of SPSS cluster analysis, involves bottom-up analysis and then combines objects and groups until each of them is in a group or cluster [11]. The last smallest bottom-up change in cluster formation indicates the number of future clusters. Ward's method applied in the agglomerative procedure is based on the analysis of variance to estimate the distance between clusters and thus differs from the others [9, 10].

Table 1 Hierarchical agglomerative approach for circular economy indicators

Stage	Agglomeration Schedule					
	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	13	21	.012	0	0	6
2	7	27	.026	0	0	7
3	9	16	.044	0	0	5
4	10	15	.071	0	0	17
5	9	22	.100	3	0	8
6	13	17	.130	1	0	18
7	2	7	.172	0	2	21
8	9	24	.231	5	0	9
9	5	9	.310	0	8	19
10	11	26	.394	0	0	15
11	14	18	.490	0	0	23
12	3	23	.589	0	0	18
13	6	8	.720	0	0	22
14	12	19	.890	0	0	16
15	1	11	1.062	0	10	17
16	12	25	1.306	14	0	21
17	1	10	1.605	15	4	23
18	3	13	1.935	12	6	20
19	4	5	2.499	0	9	20
20	3	4	3.355	18	19	22
21	2	12	4.345	7	16	24
22	3	6	6.242	20	13	26
23	1	14	8.817	17	11	24
24	1	2	13.427	23	21	25
25	1	20	23.495	24	0	26
26	1	3	48.460	25	22	0

Source: Author's visualization based on the SPSS IBM 26.0 cluster output

3. RESULTS AND DISCUSSION

Descriptive statistics among the formed clusters represent the second output results of the conducted cluster analysis (Table 2). From Table 2, it can be concluded that there are a total of six clusters of EU member states, which is also confirmed in the previously mentioned agglomeration scheme with the last biggest change in the Coefficients column. Also, Table 2 shows the mean value of the analyzed indicators between the clusters. Country-cluster Netherlands has the highest values for all indicators except for indicator C1- Resource productivity, which has the maximum value in the third cluster. Therefore, countries that want to achieve higher values of the indicators should strive for the country cluster which represents Cluster 6.

Table 2 Descriptive statistics within clusters

CLU	No.	Countries	Mean within the clusters			
			C1	C2	C3	C4/6
1	5	Belgium, France, Germany, Italy, and Spain	.980	.124	.501	2.877
2	6	Austria, Denmark, Greece, Malta, Slovenia, Sweden	.507	.016	.358	1.969
3	11	Bulgaria, Croatia, Cyprus, Finland, Hungary, Latvia, Lithuania, Poland, Portugal, Romania, and Slovakia	**1.05 (max)**	.014	.327	.936
4	2	Czechia and Estonia	.000	.016	.372	.898
5	2	Ireland and Luxembourg	.000	.014	.466	3.788
6	1	Netherlands	.820	**.072 (max)**	**.569 (max)**	**5.88 (max)**

Source: Author's elaboration based on the SPSS IBM 26.0 cluster output

The hierarchical agglomerative approach as well as the descriptive statistics between the existing clusters show that based on the analyzed indicators of the circular economy, six clusters of European Union countries have been identified, which are represented by a map diagram (Figure 1). Based on the European map chart, it can be seen that in the third cluster there are as many as 11 member states of the European Union with a similar circular economy policy.

Table 3 ANOVA procedure

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
C1	Between Groups	3.913	5	.783	8.787	.000
	Within Groups	1.870	21	.089		
	Total	5.783	26			
C2	Between Groups	.050	5	.010	4.509	.006
	Within Groups	.046	21	.002		
	Total	.096	26			
C3	Between Groups	.155	5	.031	1.271	.033
	Within Groups	.513	21	.024		
	Total	.668	26			
C4	Between Groups	39.997	5	7.999	87.685	.000
	Within Groups	1.916	21	.091		
	Total	41.913	26			

Source: Author's visualization based on the SPSS IBM 26.0 cluster output

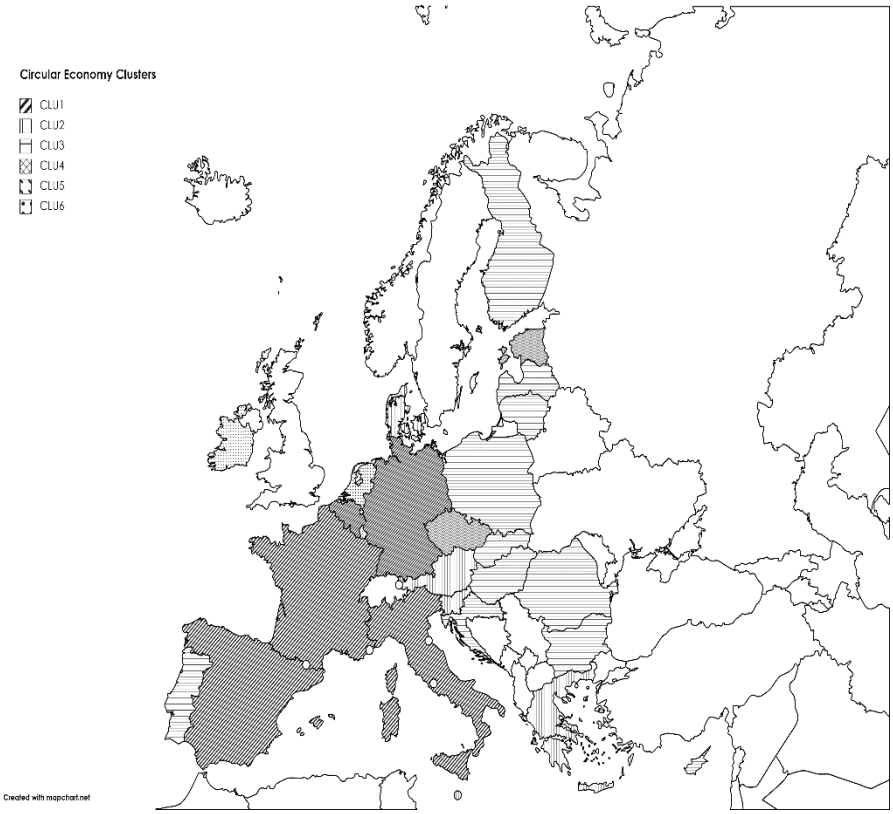

Fig. 1 European map chart for circular economy clusters
Source: Author's visualization based on the SPSS IBM 26.0 cluster output

The authors used the ANOVA procedure to check the statistical significance of differences in the average values of indicators among clusters. Based on the conducted ANOVA procedure (Table 3), statistically significant differences in average values can be stated for the indicators as can be seen in the Sig. a column where $P < 0.05$ for all CE indicators.

4. CONCLUSION

The paper presents issues related to circular economy indicators and cluster analysis in EU 27 countries and the disparities in performance which are largely the result of different starting positions of countries' development [12]. The authors used selected CE indicators from the Eurostat database, as follows: Resource productivity, the Recycling rate of municipal waste, Circular material use rate, and the Recycling rate of all waste excluding major mineral waste. The statistical software SPSS IBM 26.0 was used for cluster analysis, while the ANOVA method was used to check the statistical significance of the obtained results. Within the paper, EU27 countries are classified into six clusters and the top-ranked is country-cluster Netherlands with the highest values for the most

indicators. It is interesting that Czechia and Estonia joined the EU in the same year (2004) and also constitute the fourth cluster which means those countries have similar circular economy politics requirements. Moreover, further research should provide specific recommendations for improving the circular economy environment in the cluster of the EU countries with the weakest progress in agricultural performance, especially for the countries from the third and fourth clusters. Circular economy policymakers should provide a more effective CE strategy for countries from mentioned clusters to eliminate limitations from their economic transition period before the joining EU. The optimal model of circular economy politics is the Netherlands. This country- cluster has long- a term government-wide framework for raw materials in all industries until 2030. year. The mentioned framework has main priorities in biomass and food, plastics, the manufacturing industry, the construction sector, and consumer goods.

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HIJERARHIJSKO GRUPISANJE ZEMALJA EU PREMA INDIKATORIMA CIRKULARNE EKONOMIJE

Indikatori cirkularne ekonomije mogu se primeniti za rangiranje zemalja, kao i njihovo hijerargijsko grupisanje. To pokazuje razlike i sličnosti u napretku između pojedinih zemalja, ostvarenog ka realizaciji principa cirkularne ekonomije. Cirkularna ekonomija, je savremeni koncept sa težnjom ka očuvanju resursa i zaštiti životne sredine. U okviru rada prikazana je klaster analiza, na nivou zemalja Evropske unije (EU27) bazirana na podacima kompozitnih indikatora cirkularne ekonomije, koje vodi Evropska služba za statistiku (Eurostat). Softver za statistiku SPSS IBM 26.0 je korišćen za klaster analizu, dok je ANOVA metod primenjen za proveru statističke značajnosti dobijenih rezultata. Najvažniji rezultati do kojih se došlo u radu su klasifikacija na 6 klastera u okviru EU27 zemalja, sa sličnim politikama u oblasti cirkularne ekonomije. Najbolje rangirani klaster je klaster 6 koji čini samo 1 zemlja, Holandija, evropski lider u oblasti cirkularne ekonomije. Shodno tome, cilj ovog rada je utvrđivanje sličnosti i razlika između zemalja članica EU u implementaciji postulata cirkularne ekonomije njihovim deljenjem u klastere. Na ovaj način, biće utvrđene najviše srednje vrednosti indikatora u okviru klastera a samim tim i model cirkularne ekonomije koji bi ostali klasteri trebalo da slede.

Ključne reči*: cirkularna ekonomija, indikatori, zemlje EU, klaster analiza*