

TARGETING ECO-INNOVATION PERFORMANCE AMONG EU COUNTRIES: CLUSTER OUTCOME

Žarko Radenović^{1*}, Ivana Janjić¹, Miljana Talić¹

¹Innovation Centre, University of Niš, Serbia,
e-mail: z_radjenovic89@outlook.com, ivana.janjić@junis.ni.ac.rs, miljanatalic@gmail.com



Abstract: An indispensable tool for enhancing economic growth and protecting the environment is eco-innovation, which integrates innovation and sustainable development. By utilizing innovation to address social, economic, and environmental issues, eco-innovation is essential to achieving sustainable development goals. One significant strategy for addressing environmental issues and promoting economic expansion is eco-innovation. Optimizing resource use and promoting efficiency across various sectors, eco-innovation holds significant importance in modern conditions. Eco-innovation represents a proactive approach and leads to positive environmental outcomes. The performance of eco-innovation is a key determinant of its effectiveness in achieving sustainable development goals. Undoubtedly, the European Union's (EU) policy plan of the past few decades strongly emphasizes eco-innovation. Through initiatives such as the Eco-Innovation Scoreboard, which provides a comprehensive evaluation of eco-innovation performances across EU member states, the EU has been at the forefront of fostering eco-innovation. Eco-Innovation Scoreboards consist of indicators designed to measure various aspects of eco-innovation, used to assess the overall eco-innovation performance of EU member states and to track progress over time. This study examines the average value of eco-innovation performances across EU member states using data from the Eco-innovation Scoreboard. It also presents a comparative analysis of eco-innovation performances across EU member states over two different periods, 2013-2017 and 2018-2022, using indicators including eco-innovation input, eco-innovation activities, eco-innovation output, resource efficiency outcomes, and socio-economic outcomes. Cluster analysis groups EU member states based on their eco-innovation performances, allowing for a comparative assessment of different clusters. The examination evaluates the effectiveness of EU member states in combining innovative practices with sustainable development by focusing on cluster outcomes. The results of the analysis show dynamic changes in eco-innovation performance among EU countries, indicating migration between clusters over time. The observed trends suggest an evolution of priorities and strategies in eco-innovation, which requires adaptive policy responses. Policymakers are advised to adopt flexible and adaptive strategies that take into account the changing performance landscape of eco-innovation and that capitalize on the strengths recognized within each cluster while overcoming identified weaknesses.

Keywords: Eco-innovation Index, green economy, resource efficiency, cluster analysis.

Field: Social sciences

1. INTRODUCTION

Eco-innovations play an important role in the transition to sustainable and circular business models. Their goal is to find new opportunities and prevent further risks to the environment through green growth (OECD, 2011). Eco-innovation catalyzes transitioning societies towards sustainability by integrating environmentally friendly practices with economic growth and societal progress (Piwowar-Sulej & Podsiadly, 2022). The emphasis on eco-innovation and green technologies reflects a forward-looking approach by the European Union (EU). By staying at the forefront of innovation in this field, the EU is poised to lead the way towards a greener, more prosperous future for its citizens and the global community (Castellacci et al., 2020). The European Commission (EC) defines eco-innovation as "innovation that reduces impacts on the environment, enhances resilience to environmental pressures, or achieves a more efficient and responsible use of natural resources" (EC, 2011). Because of the potential they offer, they have become one of the main priorities of EU policy. In December 2011, the European Commission created the Eco-Innovation Action Plan (EcoAP), which represents an important element of the European policy framework for sustainable consumption and production, intending to transition to a more competitive economy that uses resources more efficiently, creates jobs, encourages growth and competitiveness, and also aims to protect the environment (EC, 2011).

Due to the growing importance of eco-innovation since the 1990s, interest in measuring eco-innovation has also increased (Kemp & Pearson, 2007; Arundel & Kemp, 2009). It is important to understand the ecological, economic, and social dimensions of eco-innovation, as well as to find a way to measure them. Measuring eco-innovation helps in understanding general eco-innovation trends, identifying drivers

*Corresponding author: z_radjenovic89@outlook.com



and barriers to eco-innovation, and creating effective policies (Arundel & Kemp, 2009). A systematic approach to measuring eco-innovation is provided in the Scoreboard developed by the Eco-Innovation Observatory. The Eco-Innovation Scoreboard (Eco-IS) (EC, n.d.) shows the strengths, weaknesses, and overall performance of EU member states in the field of eco-innovations, compared to the EU average. The index shows the general situation of eco-innovation in a certain country by combining input-output models, and based on this, information is obtained about the national contexts of eco-innovation. The eco-innovation index is a composite indicator based on five dimensions: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency outcomes, and socio-economic outcomes (EEA, 2023). Relevant indicators are used to measure performance in each of these dimensions. Eco-IS shows, on an annual basis, how EU member states perform in various dimensions of eco-innovation compared to the EU average. This allows the measured values of the respective indicators to be compared and to monitor changes over time.

The aim of the paper is to analyze the eco-innovation performance of EU countries using the eco-innovation index as a measuring instrument in order to identify changes in performance. Therefore, a comparative overview of the value of the eco-innovation index of 27 EU countries in two different periods will be given. Using the methods of cluster analysis, countries will be classified into four groups according to their performance, and changes in the groups will be monitored over the proposed time intervals.

2. MATERIALS AND METHODS

The cluster analysis allows to assessment of the position of countries within the values achieved by eco-innovation. Cluster analysis, also known as CLA, encompasses a set of algorithms utilized to categorize various entities, including countries, species, and individuals, based on their resemblance to different individual indicators. This classification endeavor seeks to condense the complexity of a dataset by leveraging the shared traits and distinctions among the entities. Kula & Ünlü (2019) employed cluster and discriminant analysis to assess the relative levels of eco-innovation efforts and performance among EU countries. Their findings revealed varying performance levels across EU countries concerning eco-innovation efforts. Some researchers (Constantin et al., 2023) conducted a study applying cluster analysis to investigate both the direct impact of the Eco-Innovation Index on resource productivity and the indirect effect mediated through the Digital Inclusion index. Their findings suggest that countries with stronger economies exhibit superior performance in terms of digital inclusion within the context of eco-innovation and resource utilization. Some authors (Hajdukiewicz & Pera, 2023) investigated the eco-innovation performance of the EU countries utilizing the Eco-Innovation index. Using cluster analysis, they discovered that the majority of economies classified as catching-up eco-innovators demonstrated enhancements in their overall eco-innovation performance. Despite this progress, these countries struggled to significantly diminish the innovation gap between them. Therefore, after undertaking a relevant literature review, the authors decided to conduct a cluster analysis applying the average values of the five subdimensions of the overall Eco-Innovation Index (Figure 1) for the two five-year periods (2013-2017; 2018-2022) (Eco-IS, 2012-2022):

- Eco-innovation input (EI) refers to the activities and resources that organizations allocate towards the development and implementation of environmentally innovative solutions. According to the Eco-Innovation Scoreboard, eco-innovation typically includes various factors such as governments' environmental and energy R&D appropriations and outlays, aimed at exploring and developing eco-friendly technologies, processes, and materials.

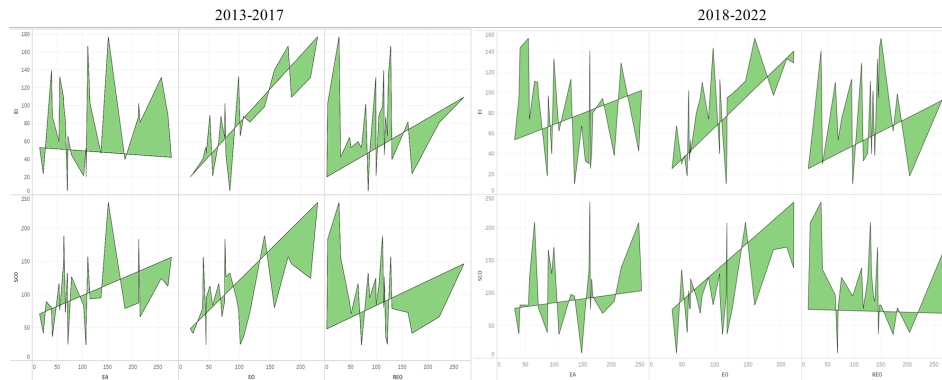
- Eco-innovation activities (EA) encompass a broad spectrum of endeavors and actions carried out by governments, organizations, and stakeholders, focused on developing novel solutions that tackle environmental issues and yield economic and social advantages.

- Eco-innovation output (EO) describes the tangible results that arise from eco-innovation activities and includes eco-innovation-related patents and eco-innovation-related academic publications.

- Resource efficiency outcomes (REO) denote the results or effects of initiatives, and policies, targeted at optimizing resource utilization within a particular system or context. Indicators that measure the effectiveness and impact of resource efficiency initiatives and policies encompass material productivity, water productivity, energy productivity, and GHG emissions productivity.

- Socio-economic outcomes (SCO) encompass the broader effects of policies and interventions on the welfare and development of societies, covering both economic prosperity and social progress. These outcomes may include exports of products from eco-industries, employment in environmental protection and resource management activities, and value-added in environmental protection and resource management activities.

Figure 1: Average values of five Eco-Innovation Index subdimensions within both periods



3. RESULTS AND DISCUSSION

The multivariate methodology known as Agglomerative Hierarchical Cluster Analysis served as the methodological background for the current research, ensuring the member countries of the European Union are grouped according to comparable features in the field of eco-innovation. The final few rounds of the agglomeration layout undergo the most substantial alterations as the analyzed items begin to associate with one another (Radenović et al., 2022). The number of clusters is defined by the final decrease in the squared Euclidean distance, as per the agglomeration scheme that employs Ward's technique (Fanelli, 2018). Ward's technique stands out from the others because it employs analysis of variance to calculate the distance between clusters (Fanelli, 2019). Concerning the output findings of the agglomeration scheme, the authors concluded that there are a total of four clusters after performing a cluster analysis applying the eco-innovation indicator values in commercial statistical software.

Table 1: Descriptive statistics within clusters in both analyzed periods

Clusters	Countries	Mean				
		2013–2017				
		EI	EA	EO	REO	SCO
1	France, Germany, Netherlands, Belgium, Luxembourg, Ireland, Malta (7)	91.25	50.85	112.90	153.90	67.94
2	Latvia, Lithuania, Poland, Portugal, Slovenia, Croatia, Hungary, Bulgaria, Greece, Cyprus (10)	46.64	81.38	61.10	70.63	87.71
3	Spain, Italy, Romania, Czechia, Slovakia, Estonia (6)	73.47	228.18	58.32	101.57	113.90
4	Austria, Denmark, Finland, Sweden (4)	143.24	145.51	191.34	91.79	177.16
Clusters	Countries	2018–2022				
		EI	EA	EO	REO	SCO
		1	Portugal, Ireland, Italy, Greece, Cyprus, Malta, Belgium, Netherlands, France, Germany, Poland, Latvia, Slovenia (13)	81.82	85.52	101.22
2	Spain, Czechia, Slovakia, Austria, Hungary, Croatia, Romania, Bulgaria, Lithuania (9)	51.83	177.47	54.61	97.07	87.34
3	Denmark, Luxembourg (2)	113.66	85.32	181.29	181.51	181.36
4	Estonia, Finland, Sweden (3)	103.94	209.22	185.65	56.32	194.70

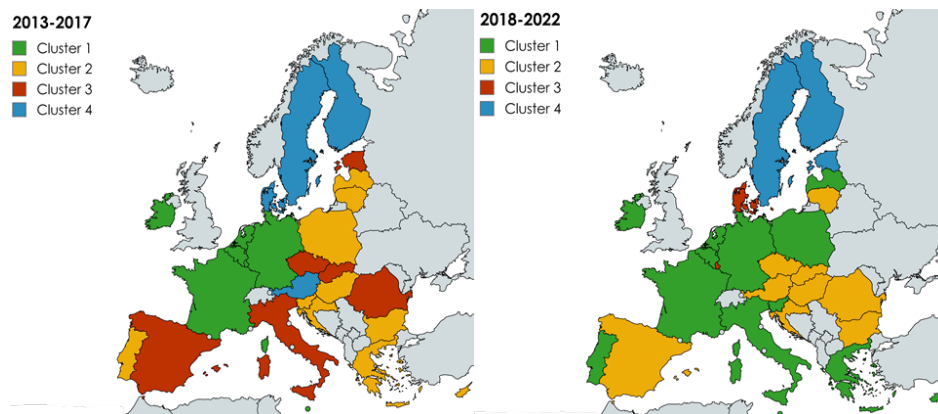
*Indicators: Eco-innovation input (EI); Eco-innovation activities (EA); Eco-innovation output (EO); Resource efficiency outcomes (REO); Socio-economic outcomes (SCO)

For the specified periods (2013-2017) and (2018-2022), the cluster mean values represent the average performance scores of countries within each cluster across different eco-innovation indicators. Across all clusters and indicators (EI, EA, EO, REO, SCO), there are notable variations in mean performance scores between different clusters and periods (Table 1). First and foremost, when compared to other clusters, Cluster 4 tends to have higher mean scores for most indicators in both periods, indicating better overall performance of eco-innovation compared to other clusters. Dominant clusters are those that, when compared to other clusters, continuously show greater performance mean values across eco-innovation indicators. In the presented data, dominant clusters can be identified based on higher mean scores for

the majority of eco-innovation indicators (EI, EA, EO, REO, and SCO). For instance, in the first observed period (2013-2017), Cluster 4 appears to be dominant due to its higher mean scores across indicators (EI, EO, and SCO), while Cluster 3 emerges as dominant due to its greater mean scores among indicators (EA and REO). For the period 2018-2022, Cluster 4 maintains its position with the highest mean scores for various indicators (EA, EO, and SCO). Additionally, Cluster 3 again arises as a noteworthy cluster across several indicators (EA, EO, and SCO).

Migration of countries entails the transition of countries from one cluster to another between different periods and those changes are depicted on European map charts (Figure 2). It provides valuable insights into the dynamics of eco-innovation performances within the EU over time. In the provided data, Luxembourg is observed to have migrated from Cluster 1 to Cluster 3 between the two periods, which indicates changes in the overall eco-innovation performances (EI, EA, EO, REO, and SCO), meanwhile, Latvia, Poland, Portugal, Slovenia, Greece, Cyprus, transitioned from Cluster 2 to Cluster 1. Furthermore, Spain, Romania, Czechia, and Slovakia have migrated from Cluster 3 to Cluster 2, whereas Estonia transitioned from Cluster 3 to Cluster 4. Additionally, Italy moved from Cluster 3 to Cluster 1, Austria migrated from Cluster 4 to Cluster 2, and Denmark shifted from Cluster 4 to Cluster 3. The movement of countries across eco-innovation performance clusters can be explained by various factors impacting their progress in this domain. Changes in cluster composition might arise due to fluctuations in eco-innovation performance, policy priorities, or other contextual factors. Some countries underwent significant migration between clusters, either advancing or declining in eco-innovation performance. For instance, Luxembourg demonstrates strength in resource efficiency outcomes, while Estonia's notable strengths lie in eco-innovation activities. Italy's relative weaknesses are evident in socioeconomic outcomes, whereas Austria primarily exhibits relative weaknesses in eco-innovation activities.

Figure 2: European map chart of countries migrations through clusters in two five-year periods.



The authors applied certain validation tests to verify the trustworthiness of the previously explained cluster procedure. One of the fundamental presumptions and a preliminary test for executing the analysis of variance (ANOVA) for comparing the means of many populations is the homogeneity of variances (Levene's statistics). Authors are permitted to conduct a one-way ANOVA if the p-value is greater than 0.05, which indicates that the assumption of homogeneity of variance has been properly achieved (Esmailzadeh, 2019). Levene's test revealed unequal variances for a few eco-innovation variables in both examined phases (Table 2, column Sig., the p-value is above 0.05).

Table 2: Test of the homogeneity of variances

Variables	2013–2017		2018–2022		Decision
	Levene Stats	Sig.*	Levene Stats	Sig.	
EI	.646	.594	1.862	.164	Confirmed
EA	3.140	.045	.901	.456	Confirmed
EO	1.497	.242	4.550	.012	Confirmed
REO	1.321	.292	.283	.837	Confirmed
SCO	.438	.728	.548	.655	Confirmed

*Statistical significance at the level of 0.05.

Statistically significant distinctions in the Eco-Innovation Index subdimensions are being indicated for the variables in addition to the previous Levene statistics results, as shown in the significance column of ANOVA output, where the value is less than 0.05 for all indicators in both periods (Table 3).

Table 3: ANOVA procedure for both analyzed periods

Variables	ANOVA 2013-2017	Mean Square	Sig.*	ANOVA 2018-2022	Mean Square	Sig.	Decision
EI	Between Groups	9401.94	.000	Between Groups	3825.59	.046	Approved
EA	Between Groups	40226.33	.000	Between Groups	22743.75	.000	Approved
EO	Between Groups	19614.77	.000	Between Groups	19153.08	.000	Approved
REO	Between Groups	9704.28	.030	Between Groups	10836.62	.042	Approved
SCO	Between Groups	11201.79	.002	Between Groups	17444.57	.000	Approved

*Statistical significance at the level of 0.05.

4. CONCLUSION

The results indicate significant differences in the cluster structures between the two observed periods. These shifts in cluster composition and mean scores over time indicate dynamic changes in the eco-innovation landscape among EU countries. There has been a migration of countries from one cluster to another, which indicates inequality in achieving performance measured based on the proposed indicators. A certain number of countries remained in the same cluster, while the majority of countries moved to other clusters in the period 2018-2022, compared to the period 2013-2017. It is apparent that some countries have progressed in their eco-innovation, prompting revisions in cluster categorizations or average scores. In general, the European Commission eco-innovation index shows that from 2013 to 2022, the performance of EU countries in the field of eco-innovation has increased. It is expected that this trend of increasing the environmental innovation index will continue in the future, due to the improvement of the values of the relevant indicators and the very ambitious goals set by the EU through various initiatives related to the environment and climate, such as the European Green Deal. Unfortunately, the evident gain in resource-efficiency outcomes is overshadowed by the regression of certain parameters of some EU members. Romania, Bulgaria and Lithuania had the greatest decreases in eco-innovation activities, input, and value-added in socioeconomic compared to 2013.

Based on the results of the study, certain policy implications can be highlighted. Policymakers have to customise interventions to tackle the specific requirements and obstacles of each cluster. Policymakers have to track progress within each cluster over time and adapt strategies to ensure the achievement of goals. To foster eco-innovation, share expertise and expedite advancements towards sustainability goals, policymakers have to facilitate partnerships between government, industry, academia and civil society organizations within and across clusters. To advance sustainability agendas globally, policymakers can explore forming partnerships with non-EU countries to leverage resources, expertise and best practices. Policymakers may employ the results of this research to identify the best practices, prioritize areas for intervention, and create tailored strategies to enhance eco-innovation performance across the EU.

To generate and execute eco-innovations that lead to the realization of the circular economy paradigm, strategic activities are required. Therefore, there is a need for additional research in this field. However, the limitations of this study may be identified if there are notable differences in the eco-innovation potential being utilized by European Union countries that belong to the same cluster.

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