8th International Scientific Conference ITEMA 2024 – Selected Papers
DOI: https://doi.org/10.31410/ITEMA.S.P.2024.59

Eco-Innovation R&D-Oriented Initiatives: EU27 Two-Step Clustering

Ivana Janjić[1]
Miljana Talić[2]
Žarko Rađenović[3]
Milica Đokić[4]

Received: January 14, 2025
Accepted: April 8, 2025
Published: June 2, 2025

Keywords:
R&D;
Eco-Innovation Index;
Eco-innovation;
Eco-innovation performance

Abstract: *In today's business environment, research and development (R&D) and eco-innovation are crucial in determining success on micro and macro levels. This study aims to analyze the significance of R&D for achieving some eco-innovation performance (eco-innovation inputs, eco-innovation activities, eco-innovation outputs) of the EU countries evaluated by the Eco-Innovation Index. Data from the Eco-Innovation Scoreboard is utilized to investigate the average value of eco-innovation performance among EU member states throughout two periods of time 2013-2017 and 2018-2022. Authors have used two-step cluster analysis for grouping similar EU27 countries and gathering outcomes that precisely depict the EU members' migration among R&D-oriented clusters. The highest indicators' values in the first period (2013-2017), whereas the lowest share, has the cluster consisting of Denmark, Finland and Sweden. In the second period, the most R&D dominant cluster comprises the same countries as in the first one, including Germany. Other countries such as Bulgaria, have lost their position in the second analyzed period and should put more stress on the R&D policy improvement.*

1. INTRODUCTION

To overcome environmental concerns and to enhance technological capabilities that lead to new and innovative solutions is necessary to implement R&D activities. In the knowledge-based economy, R&D efforts are key to improving the eco-innovation capability. Rationally coordinating and allocating R&D activities has become crucial for boosting eco-innovation performance. R&D is a critical input in environmental innovation and enables better implementation of green knowledge, leading to increased efficiency and effectiveness of production and acceptance of technology. Sustainable development issues can be solved by introducing and developing eco-innovation, as well as achieving targeted environmental goals. On the other hand, eco-innovation incorporates and transforms ecologically sustainable practices into activities that focus on developing society and the economy. R&D initiatives could increase absorptive capacity, widen and exploit accumulated firm knowledge, and enhance the efficiency of natural resources. The number of green patents can measure the creation of new knowledge. The preconditions for developing eco-innovation activities are R&D intensity, number of R&D projects, and investment in R&D personnel. Promotion of R&D through adequate governmental incentives is one of the factors that can have a high impact on creating eco-innovations. In the last few decades, eco-innovation has been fostered throughout the European Union (EU) policy plan. EU promotes and assesses the eco-innovation performance between EU member states through the Eco-Innovation Scoreboard. Eco-Innovation Scoreboard presents a set of indicators and sub-indicators that evaluate and monitor the overall eco-innovation performance of EU member states over time.

1 University of Niš, Innovation Centre, University square 2, 18000, Niš, Republic of Serbia
2 University of Niš, Innovation Centre, University square 2, 18000, Niš, Republic of Serbia
3 University of Niš, Innovation Centre, University square 2, 18000, Niš, Republic of Serbia
4 University of Niš, Innovation Centre, University square 2, 18000, Niš, Republic of Serbia

The object of this article is to explore the role of R&D in driving eco-innovation performance (eco-innovation inputs, eco-innovation activities and eco-innovation outputs) across EU countries, that have been evaluated by the Eco-Innovation index. Therefore, the study is organized into several major parts. Following the introduction, Section 2 presents a literature review. After that, there is a description of the used methodology and the presentation of the results. The last part drew a conclusion and suggestions for future research.

2. LITERATURE REVIEW

In a modern and globalized environment, eco-innovation is one of the strategies segment that can enhance competitiveness and sustainable development on the local, national and regional levels. The prime goals of eco-innovation are minimising harm to the natural environment, optimising renewable resource usage, and developing a green economy (Terzić, 2023, p. 16). Implementing R&D and technology strategies is the precondition for creating eco-innovations. Developing a sustainable innovation system largely depends on absorptive capacity, which is driven by extensive R&D efforts (Miao et al., 2024). Differences in eco-innovation activities across countries often result from varying levels of R&D input. R&D is essential for driving sustainable innovations and achieving climate change goals (Sarpong et al., 2023).

R&D enables gathering the knowledge required to develop the capacity to absorb new ideas, which in turn supports the creation of innovative technological solutions and eco-innovations. R&D activities build a knowledge foundation that enhances the ability to take advantage of future technological opportunities (Miroshnychenko & De Massis, 2020). Additionally, implementing R&D activities provides the tools needed to absorb and apply knowledge, enhance existing scientific systems, and create new sustainable products and processes (Sarpong et al., 2023). In a longitudinal study, Horbach (2008) emphasizes that improving technological capabilities (knowledge capital) through R&D drives environmental innovations, while Cainelli et al. (2011) argue that general R&D is not strongly connected to the adoption of eco-innovations.

The academic community has a significant role in generating knowledge and advancing eco-innovative technologies (Shkarupeta & Babkin, 2024). The ability to transform new ideas into economically viable eco-innovations depends on the availability of skilled R&D researchers and talent. R&D personnel plays a critical role in the process of facilitating and coordinating the innovation capability (Pan et al., 2021). Training and developing talented professionals in the R&D sector is essential for achieving high-value technological knowledge. Strengthening and building powerful scientific cadres is crucial in the process of generating scientific knowledge and creating eco-innovation (Sarpong et al., 2023).

Over the past few years, governments have emphasized the importance of environmental protection and increased the allocation of resources to R&D of renewable energies. The level of pollution that affects the environment has prompted governments to incorporate sustainability into their strategies. At the national level, the government plays a central role in policy-making and management of eco-innovation (Jang et al., 2015). During the early stage of eco-innovation, it is essential to introduce governmental policies and apply policy instruments. Thus, different instruments and programs such as environmental regulations and financial incentives that support R&D can be suggested to stimulate businesses to develop eco-innovation as the strategic objective (Jang et al., 2015).

Monitoring indicators related to R&D in the field of eco-innovation can provide useful information on the current situation and serve as a basis for identifying areas for improvement where needed. Investment in R&D, primarily through public and private spending, is essential for achieving competitiveness (Mas-Verdú et al., 2020), and corporate and private investment support is important as well (Garcia-Alvarez-Coque et al., 2021). These are factors that are also relevant for the development of eco-innovation, so encouraging these elements can have a dual impact on competitiveness, directly and indirectly through the effects achieved by eco-innovation (Chaparro-Banegas et al., 2023).

At the European Union level, a definition of eco-innovation according to which it is “any innovation that makes progress towards a more green and sustainable economy by reducing environmental pressures, increasing resilience or using natural resources more efficiently” has been widely accepted (EC, 2022a). The importance of using certain indicators that measure the development of eco-innovations has also been recognized. To monitor eco-innovation performance in European countries, the Eco-Innovation Performance Index (Eco-IS) has been developed. Eco-IS is a composite index that relies on 12 indicators grouped into five categories: eco-innovation inputs (EI), eco-innovation activities (EA), eco-innovation outcomes (EO), resource efficiency outcomes (REO) and socio-economic outcomes (SCO) (EEA, 2023). The number of indicators within this index has changed over time. The index is used to measure the progress of countries covered by this methodology, for comparison between them, as well as to measure the overall eco-innovation performance of EU countries.

The index is based on a methodology that, among others, includes indicators related to R&D within three indicator categories - eco-innovation inputs, eco-innovation activities, eco-innovation outcomes. Indicators in the eco-innovation inputs group: governments’ environmental and energy R&D appropriations and outlays and total R&D personnel and researchers, show the extent to which the government prioritizes investments to support R&D in the field of environment and energy, but also provide information on human resources for R&D in this area. The first indicator is measured as a share of GDP, while information on human resources for R&D is presented as a share of total employment (EC, 2024).

Eco-innovation activities consider indicators to monitor the scope and scale of eco-innovation activities of a business, focusing on the efforts and activities undertaken rather than on the results. This indicator is measured by the number of ISO 14001 certificates, indicating the importance of compliance with environmental management requirements for the business (Al-Ajlani et al., 2022).

Eco-innovation outputs describe the direct results of eco-innovation activities. Indicators in this group monitor the extent to which the knowledge outputs generated by businesses and researchers relate to eco-innovation. This is achieved by collecting data on patents indicating new inventions in the field of eco-innovation, as well as on academic publications in the field of eco-innovation (Al-Ajlani et al., 2022).

Patents can be a measure of a country’s technological capabilities and can be used to determine the technological position of nations in a certain technology area. On the other hand, internal R&D activities play a crucial role in ensuring a firm’s participation in eco-innovative processes, which are related to investments in patents (Lee & Min, 2015; Triguero et al., 2016). The number of patents is often considered a reliable indicator for assessing the results of R&D efforts and the output of innovation processes (Marín-Vinuesa et al., 2018). Some authors have criticized the use of green patents as reliable measures of eco-innovation, emphasizing that they do not fully represent the outcomes of innovation activities and do not necessarily indicate investment in eco-innovation (Rennings et al., 2006).

The importance of the above indicators is also recognized in the European Innovation Scoreboard (EIS), where similar indicators related to R&D can be found: R&D expenditure in the public sector (percentage of GDP), Direct government funding and government tax support for business R&D (percentage of GDP), R&D expenditure in the business sector (percentage of GDP), intellectual assets (EC, 2022b). According to this methodology, R&D spending is considered as one of the main drivers of economic growth and an essential element for the transition to a knowledge-based economy. This also implies the importance of R&D expenditure indicators, which provide important assumptions about the future competitiveness and progress of the EU countries in which these indicators are monitored (EC, 2022b).

3. METHODOLOGY

This study utilizes a methodology based on a two-step cluster analysis, which was performed in commercial statistical software packages, focused on grouping similar EU27 countries and investigating their migration across R&D-oriented clusters over two periods of time: 2013-2017 and 2018-2022. „The Two-Step cluster analysis is a hybrid approach which first uses a distance measure to separate groups and then a probabilistic approach (similar to latent class analysis) to choose the optimal subgroup model (Benassi et al., 2020)". Specific eco-innovation sub-indicators (from eco-innovation inputs, eco-innovation activities, eco-innovation outputs as indicators' groups) defined by the Eco-Innovation Index, were used to examine the significance of R&D for achieving eco-innovation performance (EEA, 2023):

- *Governments environmental and energy R&D appropriations and outlays (RD),*
- *Eco-innovation activities (EA),*
- *Eco-innovation related patents (PAT).*

Afterward, the output of the auto-clustering table in two-step cluster analysis sublimates the potential number of clusters after cluster criteria computing authors (Radjenovic & Boskov, 2022). Using a bottom-up approach, smaller values of Schwarz's Bayesian Criterion (BIC) indicate a better solution, which implies an automatically assigned number of clusters by authors (Table 1).

Table 1. Auto-clustering process for choosing the appropriate number of clusters

Auto-Clustering				
Number of Clusters	**Schwarz's Bayesian Criterion (BIC)**	**BIC Change[a]**	**Ratio of BIC Changes[b]**	**Ratio of Distance Measures[c]**
1	338,07			
2	384,78	46,70	1,00	1,81
3	457,85	73,07	1,56	1,80
4	545,33	87,48	1,87	1,05
5	633,68	88,35	1,89	1,33
6	726,30	92,61	1,98	1,47
7	823,03	96,73	2,07	1,01
8	919,92	96,89	2,07	1,14
9	1017,87	97,95	2,09	1,20
10	1117,10	99,22	2,12	1,04

a. The changes are from the previous number of clusters in the table.
b. The ratios of changes are relative to the change for the two cluster solutions.
c. The ratios of distance measures are based on the current number of clusters against the previous number of clusters.

Source: Authors' calculations

The aforementioned clustering technique has a very high level of interpretability and scalability. Furthermore, its flexibility handles large datasets and mixed data types, while minimizing the within-cluster variance and maximizing between-cluster variance. Shaping data with two-step cluster analysis determines the optimal number of clusters through a model selection criterion, with the Bayesian Information Criterion (BIC), reducing the need for the user to predefine this number.

4. RESULTS AND DISCUSSION

The output results of the applied cluster for the first analyzed period depict the existence of five clusters, of which the largest cluster size is occupied by the second cluster (29.6%). On the other hand, the aforementioned cluster consisting of Malta, Latvia, Greece, Cyprus, Croatia, Bulgaria, Poland, and Portugal is not the most dominant in terms of the values of the analyzed indicators of the eco-innovations (Figure 1). The fourth cluster composed of Denmark, Finland and Sweden shows the best movement of the analyzed indicators in the first period, although its size is 11.1% (the smallest country size contribution).

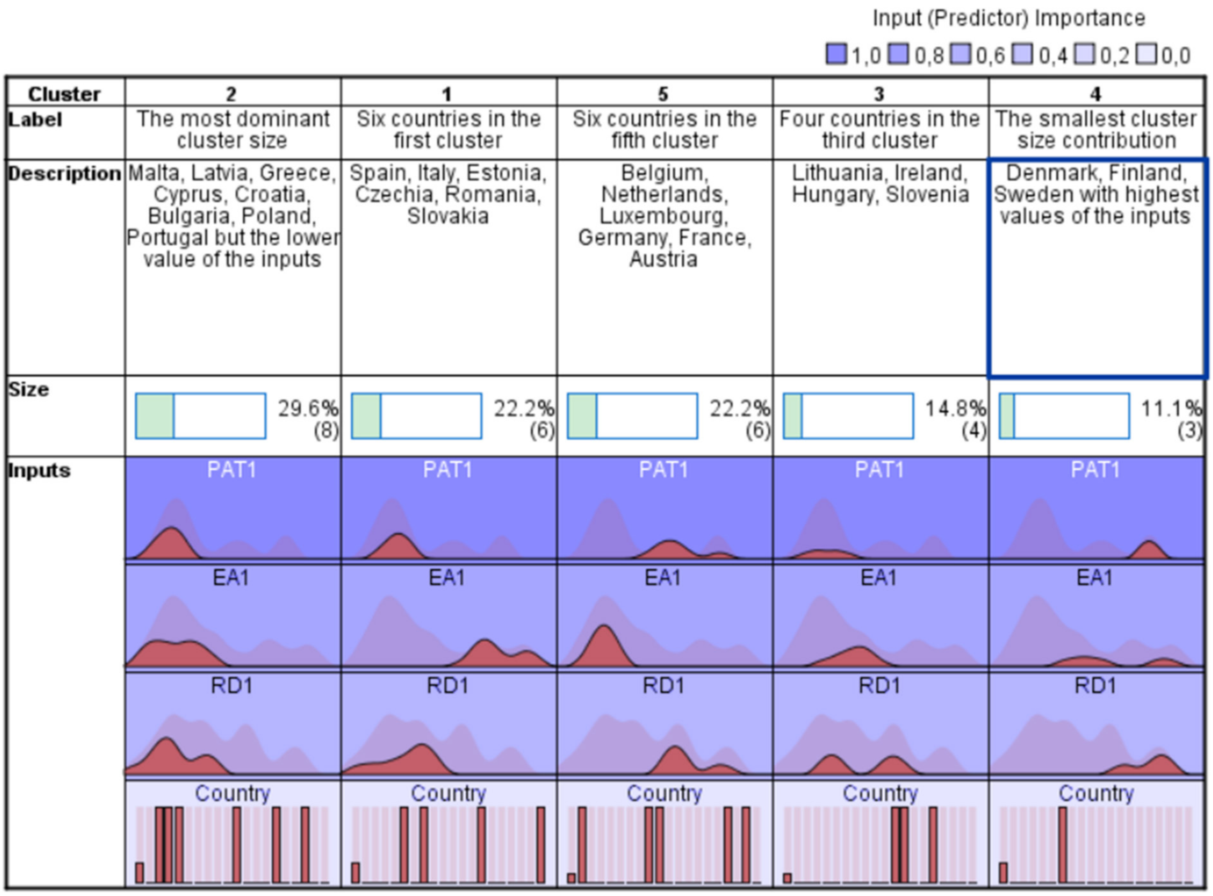

Figure 1. The cluster architecture for the first analyzed period

Source: Authors' calculations

The mean value of the analyzed sub-indicators in the formed clusters shows the conditions prevailing in the analyzed period when it comes to R&D eco-innovations. Accordingly, it can be observed that the fourth cluster has very high values for all three sub-indicators and represents the leader in the formed constellation of clusters (Table 2).

Additionally, in the second analyzed period, there are changes in the perception of the R&D sector of the eco-innovations, and accordingly, the appearance of migratory movements. Germany migrated to another cluster consisting of Denmark, Finland and Sweden, which represents the cluster with the smallest share but with the highest subindicator values. Bulgaria lost its original position and migrated to a cluster that has a weaker performance than the cluster in which it was in the first analyzed period. The first and fourth clusters in which Spain, Italy, Hungary, Ireland and Slovenia are located, also represent clusters with a promising state in terms of R&D performance in the field of eco-innovations (Figure 2).

Table 2. Mean values of the formed constellation of cluster for the first period

Centroids							
		RD1*		EA1		PAT1	
		Mean	STDEV**	Mean	STDEV	Mean***	STDEV
Cluster	1	68,33	34,92	228,33	36,68	46,00	10,46
	2	47,00	30,34	59,37	35,72	33,50	11,46
	3	101,50	47,02	107,50	27,44	48,00	17,75
	4	195,00	27,78	173,00	75,44	155,66	1,52
	5	148,50	25,04	54,16	11,92	113,83	24,90
	Combined	98,81	59,97	115,51	79,50	69,85	46,04

* RD1, EA1, PAT1- subindicators values for the first analyzed period
** STDEV- Standard deviation
*** Mean- mean value of the analyzed indicators across the given clusters

Source: Authors' calculations

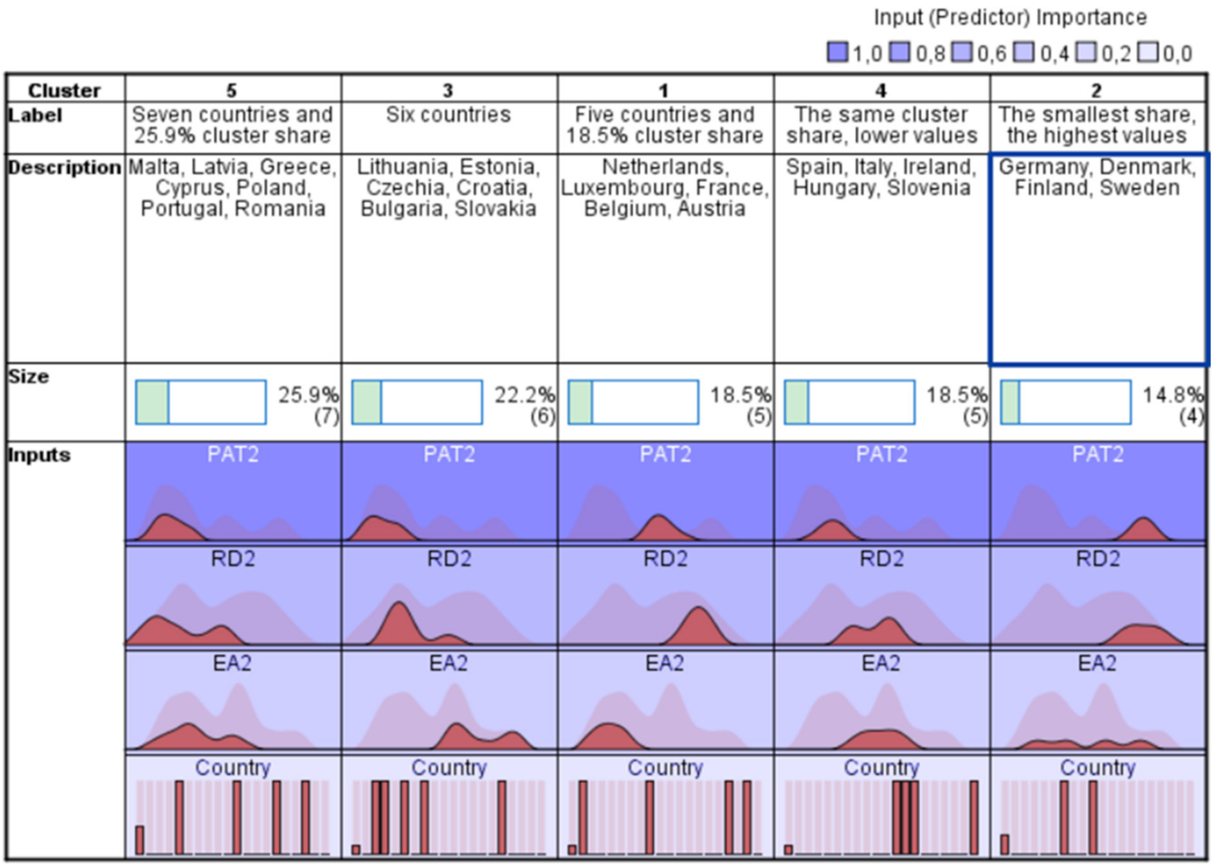

Figure 2. The cluster architecture for the second analyzed period
Source: Authors' calculations

The cluster constellation that was formed in the second analyzed period shows that the second cluster has dominance in the *Governments environmental and energy R&D appropriations and outlays sub-indicator* as well as the *Eco-innovation related patents* sub-indicator, while the third cluster has good performance in the *Eco-innovation activities* sub-indicator.

Table 3. Mean values of the formed constellation of cluster for the second period

Centroids							
		RD2		EA2		PAT2	
		Mean	STDEV	Mean	STDEV	Mean	STDEV
Cluster	1	168,40	13,81	61,80	21,74	96,40	11,86
	2	184,50	23,51	133,75	71,00	147,75	8,69
	3	70,50	27,66	198,50	43,82	29,33	14,65
	4	116,60	26,53	147,80	30,21	47,80	9,93
	5	55,57	41,74	91,57	44,85	34,28	12,59
	Combined	110,18	58,53	126,48	63,66	64,00	44,38

*RD2, EA2, PAT2- subindicators values for the second analyzed period

** STDEV- Standard deviation

*** Mean- mean value of the analyzed indicators across the given clusters

Source: Authors' calculations

5. CONCLUSION

In order to create a favorable environment for the development of an eco-innovative sustainable concept, the members of the European Union must establish efficient, unified and harmonized regulatory and political frameworks. Such frameworks can improve the daily functioning of industrial parks and promote the R&D concept of eco-innovations. In this way, the industrial sector will be able to fully utilize its potential in supporting economic development and generating positive effects beyond the borders of the European Union. Establishing R&D departments in green locations or upgrading existing ones in the region can be a catalyst for sustainable growth, creating an enabling environment where businesses benefit from adopting the EU's green agenda. The potential economic, environmental and social benefits are enormous. Eco-industrial parks can boost job creation and improve competitiveness by creating a more dynamic business environment, improving efficiency and productivity, providing high-quality infrastructure and attracting investment.

Denmark, Finland, and Sweden are recognized for their leadership in sustainable development and eco-innovation, particularly in R&D policies. The most dominant cluster in both analyzed periods with Germany, has developed strong R&D policies with integrated sustainability into their economic and innovation strategies, fostering eco-innovation through various government policies, investments, and collaborations between industry, academia, and government agencies. These policies not only encourage research into green technologies but also create innovation ecosystems where businesses, governments, and academic institutions collaborate to drive sustainable development. The integration of circular economy principles, focused on renewable energy, and commitment to achieving climate goals are central to the eco-innovation R&D strategies in these countries. Through public funding, incentives, and international collaboration, Denmark, Finland, and Sweden are setting the stage for a green and sustainable future. Government-industry collaboration based on public-private partnerships is central to the eco-innovation strategies in all three countries.

Bulgaria's innovation performance has varied over time. Although there has been a decrease in the number of SMEs introducing business process innovations, the number of SMEs implementing product innovations has risen by 13.6 percentage points since 2017. Regarding linkages, the country has seen a growth of 13.7 percentage points compared to 2017, driven by an increase in innovative SMEs collaborating with others and public-private co-publications. However, Bulgaria's performance in intellectual assets has experienced a significant decline, with design applications dropping by 61.5 percentage points, and a nearly negligible decrease in PCT patent applications.

In contrast to the overall trend, trademark applications have increased by 17.9 percentage points. Trademark and design applications are among Bulgaria's strengths, ranking 8th and 5th among EU Member States, with 118.9% and 147.6% of the EU average, respectively, in 2024.

The potential for future research in this field is enormous considering the importance of the subject and the extent it covers. Eco-innovations are the prerequisite for achieving sustainable development while R&D capacity and activities determine their progress. The results have shown that across the EU there have been significant disparities between member countries in their eco-innovation performance, R&D capability and innovation ecosystems. Future work in this area could be more focused on examining the country-specific problems and obstacles in attaining higher innovation performance. Furthermore, appropriate strategies and measures that would eliminate or minimize those causes of low innovation capability and weak R&D sector should be proposed. Not only would such actions help reduce the discrepancy between EU countries, but also in reaching common goals of sustainable development on the European level.

Acknowledgment

This research was financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract No. 451-03- 66/2024-03/200371).

References

Al-Ajlani, H., Cvijanović, V., Es-Sadki, N., & Müller, V. (2022). EU Eco-Innovation Index 2022: *Policy brief.* https://doi.org/10.13140/RG.2.2.11440.43522

Benassi, M., Garofalo, S., Ambrosini, F., Patrizia, R., Raggini, R., De Paoli, G., Ravani, C., Giovagnoli, S., Orsoni, M., & Piraccini, G. (2020). Using Two-Step Cluster Analysis and Latent Class Cluster Analysis to Classify the Cognitive Heterogeneity of Cross-Diagnostic Psychiatric Inpatients. *Frontiers in Psychology*, *11,* 1085. https://doi.org/10.3389/fpsyg.2020.01085

Cainelli, G., Mazzanti, M., & Zoboli, R. (2011). Environmental innovations, complementarity and local/global cooperation: Evidence from North-East Italian industry. *International Journal of Technology, Policy and Management, 11*, 328–368. https://doi.org/10.1504/IJTPM.2011.042090

Chaparro-Banegas, N., Mas-Tur, A., Park, H. W., & Roig-Tierno, N. (2023). Factors driving national eco-innovation: New routes to sustainable development. *Sustainable Development, 31*(4), 2711-2725. https://doi.org/10.1002/sd.2541

EC. (2022a). *Eco-index 2022 — indicators and methodology*, European Commission.

EC. (2022b). *European Innovation Scoreboard 2022 – Methodology Report*. European Union.

EC. (2024). *EU Eco-Innovation Index 2024*, European Commission, Luxembourg: Publications Office of the European Union.

EEA. (2023). *Eco-innovation index*. Retrieved from https://www.eea.europa.eu/en/analysis/indicators/eco-innovation-index-8th-eap

Garcia-Álvarez-Coque, J. M., Mas-Verdú, F., & Roig-Tierno, N. (2021). Life below excellence: Exploring the links between top-ranked universities and regional competitiveness. *Studies in Higher Education*, *46*(2), 369–384. https://doi.org/10.1080/03075079.2019.1637843

Horbach, J. (2008). Determinants of environmental innovation—New evidence from German panel data sources. *Research Policy, 37*(1), 163-173. https://doi.org/10.1016/j.respol.2007.08.006

Jang, E., Park, M., Roh, T., & Han, K. (2015). Policy Instruments for Eco-Innovation in Asian Countries. *Sustainability, 7*(9), 12586-12614. https://doi.org/10.3390/su70912586

Lee, K.-H., & Min, B. (2015). Green R&D for eco-innovation and its impact on carbon emissions and firm performance. *Journal of Cleaner Production*, *108*(1), 534-542. https://doi.org/10.1016/j.jclepro.2015.05.114

Marín-Vinuesa, L. M., Scarpellini, S., Portillo-Tarragona, P., & Moneva, J. M. (2018). The Impact of Eco-Innovation on Performance Through the Measurement of Financial Resources and Green Patents. *Organization & Environment, 33*(2), 1-26. https://doi.org/10.1177/1086026618819103

Mas-Verdú, F., Roig-Tierno, N., Nieto-Aleman, P. A., & Garcia-Alvarez Coque, J.-M. (2020). Competitiveness in European regions and top-ranked universities: Do local universities matter? *Journal of Competitiveness, 12*(4), 91–108. https://doi.org/10.7441/joc.2020.04.06

Miao, M., Saide, S., Ratna, S., & Muflih, M. (2024). Business Continuity Innovation in Disruption Time: Sociotechnical Systems, Business Analytics, Virtual Business, and Mediating Role of Knowledge Absorptive Capacity. *IEEE Transactions on Engineering Management, 71*, 13201-13212. https://doi.org/10.1109/tem.2021.3086306

Miroshnychenko, I., & De Massis, A. (2020). Three decades of research on corporate governance and R&D investments: a systematic review and research agenda. *R&D management, 50*(5), 648-666. https://doi.org/10.1111/radm.12432

Pan, X., Guo, S., Li, M., & Song, J. (2021). The effect of technology infrastructure investment on technological innovation ——A study based on spatial durbin model. *Technovation, 107*, 102315. https://doi.org/10.1016/j.technovation.2021.102315

Radjenovic, Z., & Boskov, T. (2022). Economic Effects of Congress Tourism: Two- Step Cluster Approach. *In: Fifth International Scientific Conference: Challenges of Tourism And Business Logistics in the 21st Century*, https://www.doi.org/10.46763/YFNTS2251185r

Rennings, K., Ziegler, A., Ankele, K., & Hoffmann, E. (2006). The influence of different characteristics of the EU environmental management and auditing scheme on technical environmental innovations and economic performance. *Ecological Economics*, *57*, 45-59. https://doi.org/10.1016/j.ecolecon.2005.03.013

Sarpong, D., Boakye, D., Ofosu, G., & Botchie, D. (2023). The three pointers of research and development (R&D) for growth-boosting sustainable innovation. *Technovation, 122*, 102681. https://doi.org/10.1016/j.technovation.2022.102581

Shkarupeta, E., & Babkin, A. (2024). Eco-innovative development of industrial ecosystems based on the quintuple helix. *International Journal of Innovation Studies, 8*(3), 273-286. https://doi.org/10.1016/j.ijis.2024.04.002

Terzić, L. (2023). Why is the transition to a green economy important for achieving sustainability? A review of some theoretical approaches and empirical research presented in the literature, *Economic Thought Journal, 68*(3), 307-332. https://doi.org/10.56497/etj2368303

Triguero, A., Moreno-Mondéjar, L., & Davia, M. A. (2016). Leaders and Laggards in Environmental Innovation: An Empirical Analysis of SMEs in Europe. *Business Strategy and the Environment, 25*(1), 28-39. https://doi.org/10.1002/bse.1854