THE EUROPEAN JOURNAL OF APPLIED ECONOMICS

EJAE 2025, 22(1): 86 - 97
ISSN 2406-2588
UDK: 330.341.1(4)
303.722.4:005.336.4
DOI: 10.5937/EJAE22-55532
Original paper/Originalni naučni rad

CLUSTER ANALYSIS OF RESEARCH AND DEVELOPMENT CAPACITY IN EUROPE

Dejan Brcanov[1],
[0000-0003-4059-5232]
Viktorija Petrov[1]*,
[0000-0001-6216-9715]
Karlo Bala[2]
[0000-0002-9267-236X]

[1]Faculty of Economics in Subotica, University of Novi Sad, Novi Sad, Serbia

[2]Institute for Artificial Intelligence Research and Development of Serbia, Novi Sad, Serbia

Abstract:
The role of innovation in economic development cannot be overstated, particularly in the context of emerging market economies and newly industrialized countries, where it serves as a catalyst for national growth and international competitiveness. Human capital plays an indispensable role in developing knowledge economies, and its importance has become increasingly emphasized within the European Union as the region seeks to maintain its competitiveness in green and digital transitions. Cluster analysis offers a methodologically robust approach to grouping countries on similarities in their R&D profiles. By identifying clusters with comparable R&D characteristics, it is possible to gain deeper insights into the strengths and weaknesses of national innovation systems. Understanding the distribution of R&D capacity across Europe can facilitate international collaborations and promote knowledge among countries with similar strengths and challenges. This research paper aims to explore the clustering of European countries based on their R&D capacity, providing a comprehensive analysis of key metrics and their implications for national innovation strategies. The study relies on the most important distinction identified among four clusters of the total 35 European countries that were the subject of the research.

Keywords:
research and development, higher education, innovation capacity, economic growth, cluster.

JEL Classification:
O32, O38

INTRODUCTION

Research and development (R&D) plays a pivotal role in driving economic growth, fostering innovation, and enhancing national competitiveness in the global landscape. A nation's commitment to research and development (R&D), reflected in its investment levels and human capital allocation, serves as a crucial indicator of its potential for technological advancement and long-term economic prosperity. Understanding the diverse R&D landscape across European countries is essential for policymakers seeking to design effective strategies for promoting innovation and optimizing resource allocation.

Article info:
Received: December 18, 2024
Correction: February 27, 2025
Accepted: March 04, 2025

*E-mail: viktorija.petrov@ef.uns.ac.rs

In 2021, EU research ministers adopted conclusions on the governance of the European Research Area (ERA) on the pact for research and innovation, which is meant to be a political guide to implementing ERA. It includes a non-binding commitment by member states to reform national R&D systems and boost public and private investments to 3% of GDP. Under the pact, member states are committed to setting common EU principles and values for research and innovation and to agree on shared priorities. The EU Commission blames low R&D investment for economic stagnation in 2024. For more than two decades, member states have been urged to increase domestic R&D investment to at least 3% of GDP, but efforts have been sluggish at best in most member states. Only Belgium, Sweden, Austria, Germany, and Denmark had reached the 3% target by 2020, according to the Eurostat base (2024). The EU average of 2.2% is well below the US, Japan, and South Korea.

This research paper aims to explore the clustering of European countries based on their R&D capacity, providing a comprehensive analysis of key metrics and their implications for national innovation strategies. The study focuses on two primary indicators: gross domestic expenditure on R&D (GERD) and R&D personnel, which are further investigated by sector of performance. GERD, expressed as a percentage of GDP, represents the overall financial commitment a nation makes towards R&D activities, encompassing investments from both the public and private sectors. Finally, the share of R&D personnel and researchers in the total active population and employment captures the human capital dimension of R&D capacity, highlighting the availability of skilled individuals engaged in research activities. This distribution reflects national priorities and the structure of the innovation ecosystem.

Human capital plays an indispensable role in the development of knowledge economies (Petrov Ćelić, Đ., Uzelac, Z. & Drašković, Z., 2020), and its importance has become increasingly prominent within the European Union as the region seeks to maintain its competitiveness in the context of green and digital transitions (Eurofound, 2024). The availability of talented individuals, particularly those with advanced research training such as PhD graduates, is critical for fostering innovation and sustaining economic growth (Petrov Drašković, Z., Ćelić, Đ. & Uzelac, Z., 2022; OECD, 2007). Alfred Marshall famously emphasized human capital as the most important investment in an economy, while Lucas (1988) identified it as a primary driver of growth. Furthermore, regional disparities in human capital, as Cipolla (1969) argued, can be as consequential as differences between nations. These disparities influence not only the distribution of innovation potential but also the capacity of regions to contribute to broader national objectives.

The role of innovation in economic development cannot be overstated, particularly in emerging market economies and newly industrialized countries, where it serves as a catalyst for national growth and international competitiveness (Petrov V., 2022; Guan and Chen, 2012). Within Europe, the distribution of R&D capacity reveals significant variation in national priorities, resource allocation, and structural dynamics.

Cluster analysis serves as a powerful tool for grouping countries based on their similarities across these key R&D indicators. By identifying distinct clusters of European countries with comparable R&D profiles, a deeper understanding of the factors that contribute to national innovation systems could be gained. This analysis can reveal best practices, identify areas for improvement, and inform policy recommendations tailored to the specific characteristics of each cluster. Furthermore, understanding the distribution of R&D capacity across Europe can facilitate international collaborations and promote knowledge sharing among countries with similar strengths and challenges.

This research contributes to the existing literature on R&D and innovation by providing an updated and comprehensive analysis of the European R&D landscape. While previous studies have examined individual aspects of R&D capacity, this research integrates multiple indicators to provide a more holistic perspective. The findings of this study will be relevant to policymakers, researchers, and businesses interested in understanding the dynamics of innovation in Europe and developing strategies for promoting R&D investment and human capital development. The subsequent sections of this paper will describe firstly literature review, the methodology employed, present the results of the cluster analysis, discuss the implications of the findings, and offer concluding remarks.

LITERATURE REVIEW

The Frascati Manual (OECD, 2015) categorizes R&D activities into three types: basic research, applied research, and experimental development. Basic research aims to gain new knowledge about fundamental principles and facts, without a specific application in mind. Applied research seeks new knowledge, but focuses on practical goals or objectives. Experimental development involves systematic work that uses knowledge from research and experience to create new products or processes or improve existing ones. Zhou and Dahal (2024) and data from the OECD's Research and Development Statistics indicate that China has surpassed the United States in experimental research and development (R&D). However, the United States continues to maintain a leading position in both applied and fundamental research domains. The paper by Del Bo (2016) reviews the features of current Research Infrastructures (RIs) in the EU. It suggests two ways to measure the return on public investment in RIs: a cost-effectiveness ratio and a count of bibliometric citations. The findings indicate how to assess the potential benefits of existing and future RI projects across various scientific fields.

Dibolt (2018) suggests that human capital can impact economic development and growth directly or indirectly, especially by helping create technology. Acemoglu and Autor (2012) identify several ways human capital influences technological progress. First, talented individuals can drive technological advancements provided they have access to education. These individuals are likely the most significant contributors to technology. Second, the overall workforce can also affect technology. This happens because of the benefits that come from human capital and because human capital encourages more investment in technology.

Abdelaty and Weiss (2023) assert that R&D capacity is a key driver of open innovation. Their study examines the moderating role of appropriation strategies in shaping the impact of internal R&D capacity on firms' external innovation collaborations. The authors emphasize innovation collaboration as a robust form of openness, highlighting the critical interplay between R&D capacity and appropriation strategies in shaping firms' approaches to external collaboration. Lin and Ye (2024) studied data from 2009 to 2022 involving 6,487 Chinese A-share listed companies. They used regression models to explore how R&D affects innovation, considering various factors. The results showed a strong positive link between R&D investment and the likelihood of innovation. The study of Yin (2023) investigated the relationship between innovation spirit, R&D investment, and innovation performance of micro and small enterprises using data from the 2015 China Micro and Small Enterprise Survey. They found that innovation spirit has a significant positive impact on innovation performance and that R&D investment is an important mechanism through which innovation spirit affects innovation performance.

Yin (2023) highlighted that innovation spirit, as a critical element of entrepreneurship, exerts a significant influence on various aspects, including R&D investment, innovation performance, innovation promotion, and production. The finance of innovation in developing countries has been of great interest, as these regions face unique challenges in funding their innovative activities. Guan and Chen (2012) noted that industrial innovation is widely recognized as a key driver of national economic growth and international competitiveness for emerging market economies and newly industrialized countries. The relationship between research and development expenditures and innovation outcomes has been extensively studied, with some research indicating that firms with higher R&D spending tend to have greater innovation output (Zhang and He, 2013). Balsalobre-Lorente, Zeraibi, Shehzad, and Cantos-Cantos (2021) argue that, due to the knowledge- and information-intensive nature of innovation, enterprises can effectively gather and access advanced technological knowledge and information worldwide through their global R&D networks. This access serves as a critical informational foundation for strengthening their innovative capabilities. Financial limitations restrict the ability to innovate, as insufficient funding reduces opportunities for experimentation, business creation, and the development of novel ideas. These challenges are particularly evident among the younger population. Matić et al. (2023) demonstrated that financial constraints have a significant negative impact on the entrepreneurial intentions of students in Western Balkan countries, highlighting the critical role of access to financial resources in fostering innovation and entrepreneurial activity.

It has been found that R&D globalization activities significantly enhance firms' innovation capabilities, with the overseas experience of executives positively influencing the relationship between both dimensions of R&D globalization and innovation outcomes (Ma and Ji, 2024). Additionally, executives' political affiliations contribute positively to this relationship but only concerning the depth of R&D globalization. Firms typically engage in innovation when they identify knowledge with commercial potential. However, this knowledge is not confined solely to the firm's internal environment; instead, it is dispersed across a wide array of both internal and external sources (Chesbrough and Bogers, 2014). Zhang, Luo, Du, and Xu (2024) conclude that R&D subsidies serve as a catalyst for fostering strategic green innovation. The relationship between R&D subsidies and substantive green innovation follows an inverted U-shaped pattern. Additionally, environmental regulations, public attention, and green finance are identified as moderating factors that influence this relationship. Arroyabe, Arranz, De Arroyabe, and De Arroyabe (2024) explored the complex dynamics surrounding the adoption of artificial intelligence (AI) in small and medium-sized enterprises (SMEs), with a particular emphasis on the interaction between digital capabilities, innovation capabilities, and support from the business environment. The study provides new insights into the processes of AI integration in SMEs, shedding light on the roles of both internal resources and external support in facilitating successful adoption.

METHODS AND RESULTS

Cluster analysis is frequently applied in the study of economic phenomena, offering valuable tools for identifying groupings or segments within an economy. These groupings can provide critical insights for businesses and policymakers, guiding strategic decision-making (Listiyoko and Purno 2020; Stamenković, Milanović, and Janković-Milić 2021). At its foundation, cluster analysis involves partitioning a dataset into distinct groups, or clusters; the similarity among objects within the same cluster is maximized, while the similarity to objects in other clusters is minimized. This methodology facilitates the discovery of underlying structures and patterns within complex datasets, providing researchers and data analysts with the means to derive meaningful insights and make informed decisions.

Two widely used clustering techniques are hierarchical clustering and k-means clustering. Hierarchical clustering, a form of unsupervised learning, constructs a hierarchy of clusters often represented as a dendrogram. This method begins by treating each data point as an individual cluster, progressively merging the most similar clusters in successive steps until a single, comprehensive cluster is formed. Conversely, k-means clustering is a partitioning algorithm designed to divide a dataset into a pre-specified number of clusters, denoted as k. The algorithm operates iteratively, initially assigning each data point to the cluster whose centroid is closest. It then recalculates the centroids as the mean of the data points within each cluster. This process repeats until the centroids stabilize or a predefined number of iterations is reached. Both methods are integral to identifying and interpreting the inherent structures within data, making them indispensable in economic and broader analytical contexts.

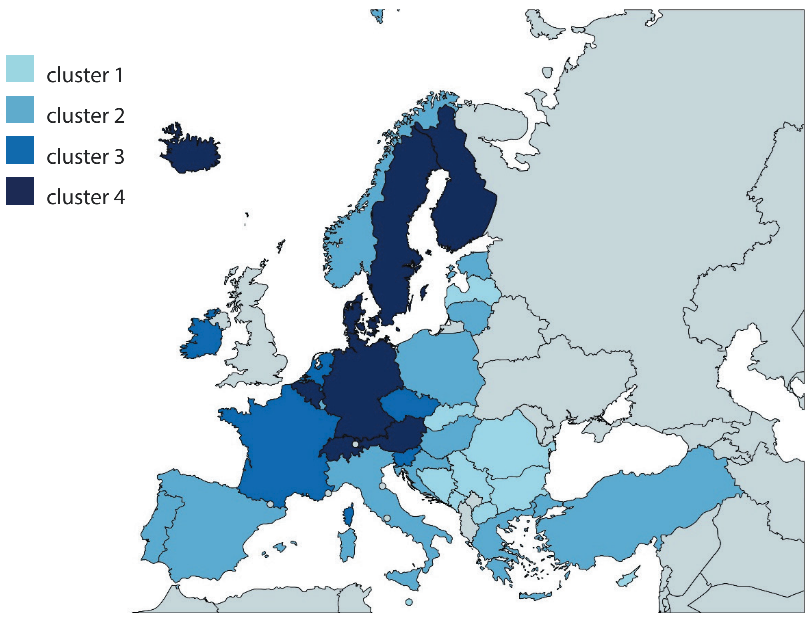
Indicators used for conducting the analysis are presented in Table 1 with the specific name of the indicators and abbreviations used in the process of assessing data. All necessary data have been provided by the Eurostat statistical base.

Table 1. Indicators used for Cluster Analysis

Indicator	Abbreviation
Gross domestic expenditure on R&D by Business enterprise sector	rd_e_gerdreg_b
Gross domestic expenditure on R&D by Government sector	rd_e_gerdreg_g
Gross domestic expenditure on R&D by Higher education sector	rd_e_gerdreg_h
Share of R&D personnel in the labor force by Business enterprise sector	estat_rd_p_perslf_b
Share of R&D personnel in the labor force by Government sector	estat_rd_p_perslf_g
Share of R&D personnel in the labor force by Higher education sector	estat_rd_p_perslf_h

Cluster analysis by k-means, with k = 4, provided following results presented in Figure 1.

Figure 1. Geographical distribution of clusters based on Cluster Analysis



With such a definition of clusters, mean values of indicators, across clusters, and corresponding p-values of ANOVA test are given in Table 2.

Table 2. Average values of indicators with p-value of ANOVA test

Variable / Cluster	1	2	3	4	p-value
rd_e_gerdreg_b	**0.30**	**0.82**	**1.52**	**2.14**	**<0.001**
rd_e_gerdreg_g	0.11	0.18	0.20	0.18	0.318
rd_e_gerdreg_h	**0.20**	**0.41**	**0.37**	**0.74**	**<0.001**
estat_rd_p_perslf_b	**0.21**	**0.67**	**1.08**	**1.41**	**<0.001**
estat_rd_p_perslf_g	0.11	0.17	0.18	0.13	0.361
estat_rd_p_perslf_h	**0.22**	**0.46**	**0.44**	**0.59**	**<0.001**

According to the ANOVA analysis results, not all indicators contribute to the separation of observations into groups. The average values of Gross domestic expenditure on R&D by the Government sector and the Share of R&D personnel in the labor force by the Government sector between the clusters are not statistically significant. However, the analysis of characteristics and different levels of achievement in R&D can be induced from these results.

Cluster 1 countries (Bosnia and Herzegovina, Bulgaria, Cyprus, Latvia, Malta, Montenegro, North Macedonia, Romania, Serbia, and Slovakia) have the lowest average values for all indicators, which indicates significant limitations in the development of R&D infrastructure and human resources. Allocations to R&D by the business enterprise sector (0.30) and the Higher education sector (0.20) indicate a low level of investment; the share of R&D personnel in the labor force by the Business enterprise sector (0.21) and the Higher education sector (0.22) suggests an insufficient availability of experts. These countries are in the early stages of development, facing the fundamental challenge of establishing the basic infrastructure for R&D. The lack of integration between the research and industrial sectors further limits their potential to generate innovation. However, this cluster has the potential for progress through targeted investments and international cooperation.

Countries grouped in cluster 2 (Croatia, Estonia, Greece, Hungary, Italy, Lithuania, Luxembourg, Norway, Poland, Portugal, Spain, and Turkey) are characterized by steady, however limited development of R&D sectors. Expenditures for R&D by the Business enterprise sector (0.82) and by the Higher education sector (0.41) are proving an important role of these sectors in total research work. The share of R&D personnel in the labor force by the Business enterprise sector (0.67) and the Higher education sector (0.46) are indicators of increasing innovative potential, although the innovation capacities are developing. This cluster has gathered countries that have increasing innovation potential, although these capacities are still under development. This cluster includes countries that are gradually strengthening their innovation capacity, often relying on initiatives to associate industry and academic institutions. This indicates the need for further improving the integration of research and its application in practice.

Cluster 3 includes countries (Czechia, France, Ireland, Netherlands, and Slovenia) that have made significant progress in balancing R&D investment and human resource utilization. Expenditures for R&D by the Business enterprise sector have a dominant role (1.52); Higher education is also an important factor (0.37). Allocations to R&D by the Business enterprise sector (1.08) and higher education (0.44) indicate a functional integration between research institutions and industry. This cluster shows a high level of cooperation and coordination, which enables the effective commercialization of research results. These countries often have specialized sectors, such as green energy or information technology, in which they demonstrate significant competitiveness.

Countries in cluster 4 (Austria, Belgium, Denmark, Finland, Germany, Iceland, Sweden, and Switzerland) represent leaders in the field of R&D, with the highest average values of the indicator. Expenditures for R&D by the Business enterprise sector dominate investments (2.14), while the role of higher education is significantly prominent (0.74). Human resources are highly integrated in the Business sector (1.41) and higher education (0.59), enabling the continuous improvement of innovation capacities. These countries have developed mechanisms for connecting academic, research, and industrial subjects, which contributes to the creation of globally competitive technologies and solutions. Their success is the result of long-term investments in research, education, and infrastructure, as well as the ability to attract international talent.

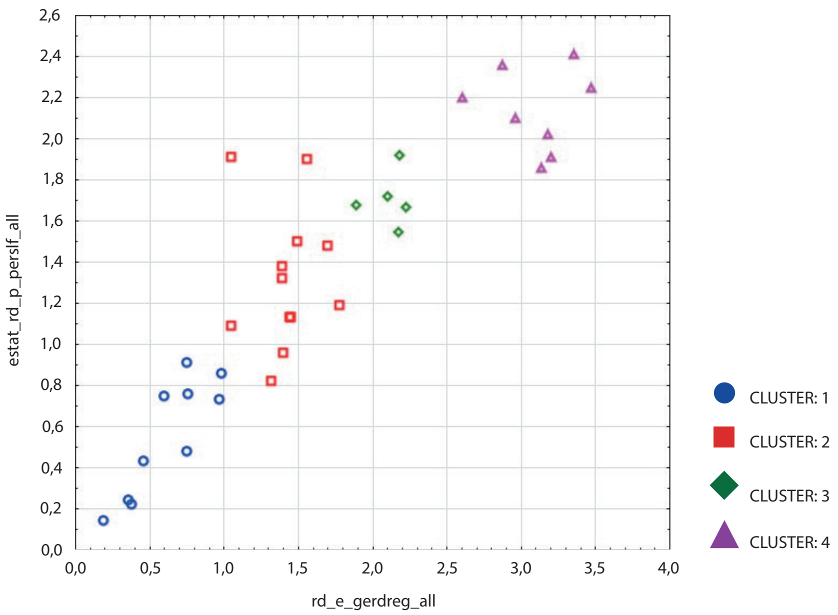
Table 3. Comparison of averages of total expenditures for research and development and total share of research personnel in the total workforce by clusters

Variable / Cluster	1	2	3	4
rd_e_gerdreg	0.620	1.418	2.112	3.095
estat_rd_p_perslf	0.552	1.318	1.708	2.139

In order to further understand the different levels of development of R&D capacities among clusters, the average values of the total expenditures for research and development and the total share of R&D personnel in the total labor force are presented.

The average values presented in Table 3 offer a clear comparison among the clusters, which is further illustrated in Figure 3. There can be noted that only Cluster 4 countries on average meet the target of a minimum of 3% of total R&D allocations.

Figure 2. Scatterplot of total expenditures for research and development and total share of research personnel in the total workforce by clusters



DISCUSSION

The average values of the purchasing power standard (PPS) and the human capital index (HCI) provide significant insight into the economic and social capacities of the cluster. These indicators illuminate the relation between economic prosperity and human resources, signifying the role these factors play in shaping capacity for research, development and innovation.

Table 4. Economic and Social Capacities of the Clusters

Cluster	Current prices, purchasing power standard (PPS, EU27 from 2020) per capita	Human capital index (HCI)
1	29553.13	0.65
2	39484.52	0.73
3	47782.96	0.78
4	41289.18	0.76

Source: Authors' own calculations based on data obtained from the Eurostat base (https://doi.org/10.2908/NAMA_10_PC) and Our World base (https://ourworldindata.org/research-and-development)

Cluster 1 stands out with the lowest average values for both indicators, with a PPS of 29553 and an HCI of 0.65. These results indicate serious challenges in terms of economic prosperity and investment in human resources. Countries in this cluster often face limitations in infrastructure and education, which limit their ability to generate and sustain innovation. Lack of economic power further slows efforts to develop human capital, which indicates the need for targeted international support and development policies.

The average PPS value of 39485 indicates a moderate level of economic prosperity among countries in Cluster 2. This value, although significantly higher than the one obtained for Cluster 1, still lags behind the results of more advanced clusters. Similarly, the human capital index (HCI = 0.73) reflects a relatively high, but underdeveloped level of human potential to support sustainable development and innovation. This cluster brings together countries that balance between developing basic economic capacities and investing in human capital, providing a basis for future progress.

Average values in Cluster 3 show significantly stronger capacities in comparison to the previous two clusters. With a PPS of 47783 and an HCI of 0.78, the countries in this cluster reflect stable economic development and high levels of human capital. These countries have a basis for further development of innovation systems, where economic prosperity enables strong support for research and development. A high HCI indicates advanced educational systems and well-developed human resources, which are key to competitiveness in a global innovation environment.

Cluster 4, with the highest average values for both indicators (PPS = 41.289; HCI = 0.76), represents countries with the most developed economic and human resources. A high level of economic prosperity allows these countries to invest in high-quality education systems, research infrastructure, and advanced technologies. HCI results confirm their ability to attract and retain talented professionals, which contributes to sustainable development and global competitiveness.

Data obtained from UNESCO Institute for Statistics (2024) on a number of researchers and students enrolled in STEM education provide insight into the level of education and development of human capital that has a direct influence on the R&D sector. The average values of the indicators that shed light on the capacity of countries to generate a highly qualified workforce in science, technology, engineering, and mathematics (STEM), crucial for research, development, and innovation, are presented in Table 5.

Table 5. Level of Education and Development of Human Capital

Cluster	Researchers per mil (FTE)	Enrolment in STEM programs			Graduation in STEM programs		
		Bachelor's	Master's	Doctoral	Bachelor's	Master's	Doctoral
1	1875.65	54.96	12.77	2.98	8.39	4.43	0.47
2	4291.78	53.06	20.29	5.48	9.62	5.68	0.78
3	5469.08	56.58	22.52	5.82	11.90	9.04	0.98
4	7402.72	64.43	27.38	7.33	11.60	7.06	1.03

Source: Authors' own calculations based on data obtained from UNESCO (https://data.uis.unesco.org/), Eurostat (https://doi:10.2908/EDUC_UOE_ENRA31 and https://doi.org/10.2908/EDUC_UOE_GRAD04)

Cluster 1 records the lowest values for most indicators. These results reflect insufficiently developed capacities for education and research, especially at higher levels. This cluster indicates the need for greater investments in the educational system and programs that encourage research activity, as well as strengthening the connection between educational institutions and the labor market.

The values associated with Cluster 2 suggest countries that have a stable, but not fully developed system for education and research in STEM fields. Limitations are evident in the transition of students from basic to advanced levels of study, which may indicate the need for additional investment in high-quality research programs and infrastructure.

Cluster 3 reflects countries that have developed educational systems, especially in STEM fields, and a significant capacity to generate highly qualified professionals. These countries demonstrate the ability to connect education with research and industry, enabling high productivity and innovation.

Cluster 4 has the highest average values for all indicators. These countries show extremely developed education and research systems, with a strong focus on STEM fields. Their ability to educate, retain and engage top talent enables them to take a leading position in the global knowledge-based economy.

CONCLUSIONS

Based on the previous discussion, it is possible to describe the cluster characteristics. Countries in Cluster 1 record the lowest values of investment in R&D and a limited number of qualified experts. Limited capacities for education and research, together with low innovation performance, indicate the need for significant reforms and additional financial and infrastructural investments. Cluster 2 countries are characterized by a moderate level of economic investment in research and development (R&D) and limited human resources in STEM fields. Although there is a stable basis for innovation, the capacities of education, research, and commercialization of innovations are not sufficiently developed for a significant contribution to economic growth. Cluster 3 countries achieve high R&D investment values and have developed human resources, especially in STEM fields. Strong educational and research capacities enable the integration of innovations into industrial and market processes, resulting in high economic effects and competitiveness in the global market. Cluster 4 represents the global leaders in innovation, with the highest levels of investment in R&D and extremely developed human resources. Their innovation systems, along with advanced research infrastructures and a high rate of commercialization, enable them to set standards for scientific and technological achievements.

The clusters show a clear progression from countries with low investment and limited resources in Clusters 1 and 2 to global leaders in Cluster 4. Increasing investment in R&D, education, and human resources is essential for countries to move from lower to higher clusters and achieve sustainable competitiveness.

REFERENCES

Abdelaty, H., & Weiss, D. (2023). R&D capacity and the innovation collaboration paradox: the moderating role of the appropriation strategy. *Innovation, 25*(2), 111-128.

Acemoglu, D., & Autor, D. (2012). What Does Human Capital Do? A Review of Goldin and Katz's The Race between Education and Technology. *Journal of Economic Literature, 50* (2): 426–63.

Arroyabe, M. F., Arranz, C. F., De Arroyabe, I. F., & De Arroyabe, J. C. F. (2024). Analyzing AI adoption in European SMEs: A study of digital capabilities, innovation, and external environment. *Technology in Society, 79*, 102733.

Balsalobre-Lorente, D., Zeraibi, A., Shehzad, K., & Cantos-Cantos, J. M. (2021). Taxes, R&D expenditures, and open innovation: Analyzing OECD countries. *Journal of Open Innovation: Technology, Market, and Complexity, 7*(1), 36. https://doi.org/10.3390/joitmc7010036

Chesbrough, H., & Bogers, M. (2014). Explicating open innovation: Clarifying an emerging paradigm for understanding innovation. *New Frontiers in Open Innovation. Oxford: Oxford University Press, Forthcoming*, 3-28.

Cipolla, C. M. (1969). Literacy and Development in the West. Penguin Books.

Del Bo, C. F. (2016). The rate of return to investment in R&D: The case of research infrastructures. *Technological Forecasting and Social Change, 112*, 26-37. https://doi.org/10.1016/j.techfore.2016.02.018

Diebolt, C., & Hippe, R. (2019). The long-run impact of human capital on innovation and economic development in the regions of Europe, *Applied Economics, 51:5,* 542-563.

Eurofound. (2024). Role of human capital inequalities in social cohesion and convergence. Publications Office of the European Union, Luxembourg. https://www.eurofound.europa.eu/sites/default/files/2024-09/ef23033en.pdf

Eurostat. (n.d.). Graduates in education (EDUC_UOE_GRAD04).

Eurostat. (n.d.). Gross domestic product at market prices (NAMA_10_PC).

Eurostat. (n.d.). Participation rates in education (EDUC_UOE_ENRA31).

Eurostat. (n.d.). Personnel in R&D by sectors of performance and occupation.

Eurostat. (n.d.). Regional gross domestic expenditure on R&D (GERD) by sectors of performance and NUTS 2 regions (RD_E_GERDREG).

Guan, J., & Chen, K. (2012). Modeling the relative efficiency of national innovation systems. *Research policy, 41*(1), 102-115.

Lin, Y., & Ye, J. (2024). The impact of corporate R&D on the transformation of intellectual property into intangible assets. *Finance Research Letters, 70*, 106337.

Listiyoko, L., & Purno, M. (2020, March). Sample Identification Approach by K-Means Clustering In Thinner Retail Market Segmentation. In *Journal of Physics: Conference Series* (Vol. 1477, No. 2, p. 022004). IOP Publishing. doi:10.1088/1742-6596/1477/2/022004

Lucas Jr, R. E. (1988). On the mechanics of economic development. *Journal of monetary economics, 22*(1), 3-42.

Ma, C., & Ji, X. (2024). R&D globalization and enterprise innovation capability. *Finance Research Letters, 65*, 105613.

Matić, M., Leković, B., & Bobera, D. (2023). The influence of barriers on entrepreneurial intentions: Student entrepreneurship in Western Balkan countries. *Anali Ekonomskog fakulteta u Subotici, 59*(50), 51-66.

OECD. (2007). OECD Annual Report 2007. OECD Publishing, Paris.

OECD. (2015). Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities. OECD Publishing, Paris.

Our World in Data. (n.d.). Research and development. https://ourworldindata.org/research-and-development

Petrov, V., Ćelić, Đ., Uzelac, Z. & Drašković, Z. (2020). Three pillars of knowledge management in SMEs: evidence from Serbia. *International Entrepreneurship and Management Journal, 2*, 417-438.

Petrov, V., Drašković, Z., Ćelić, Đ., & Uzelac, Z. (2022). Commercializing University Knowledge in Serbia–An Empirical Evidence. *PaKSoM 2022*, 273.

Petrov, V. (2022). Mogućnosti prevazilaženja jaza između naučno-istraživačkog rada i komercijalizacije. *Nauka i inovacije kao pokretači privrednog razvoja, 1*. In: Mosurović Ružičić, M, Lazarević – Moravčević, M. Nauka i inovacije kao pokretači privrednog razvoja, Institut ekonomskih nauka, Beograd pp: 1-21.

Stamenković, M., Milanović, M., & Janković-Milić, V. (2021). Multivariate Statistical Analysis of Regional Economic Disparities at District Level in Serbia. *TEME*, 681-698.

UNESCO. (n.d.). UIS Statistics. https://data.uis.unesco.org/

World Intellectual Property Organization (WIPO). (2024, November). IP statistics.

Yin, X., Qi, L., Ji, J., & Zhou, J. (2023). How does innovation spirit affect R&D investment and innovation performance? The moderating role of business environment. *Journal of Innovation* & *Knowledge, 8*(3), 100398. https://doi.org/10.1016/j.jik.2023.100398

Zhang, X., & He, Y. (2013). R&D-based earnings management, accounting performance and market return: Evidence from national-recognized enterprise technology centers in China. *Chinese Management Studies, 7*(4), 572-585.

Zhang, Z., Luo, X., Du, J., & Xu, B. (2024). Substantive or strategic: Government R&D subsidies and green innovation. *Finance Research Letters, 67*, 105796.

Zhou, Y., & Dahal, S. (2024). Has R&D contributed to productivity growth in China? The role of basic, applied and experimental R&D. *China Economic Review, 88,* 102281.

KLASTER ANALIZA KAPACITETA ZA ISTRAŽIVANJE I RAZVOJ U EVROPI

Rezime:

Uloga inovacija u ekonomskom razvoju se ne može zanemariti u kontekstu tržišne ekonomije, posebno zemalja u razvoju i novo-industrijalizovanih zemalja, gde inovacije služe kao katalizator nacionalnog rasta i međunarodne konkurentnosti. Ljudski kapital igra nezamenjivu ulogu u razvoju ekonomije znanja i njegov značaj postaje sve izraženiji u Evropskoj uniji, pošto EU nastoji da održi svoju konkurentnost u kontekstu zelene i digitalne tranzicije. Klaster analiza nudi metodološki robustan pristup grupisanju zemalja na osnovu sličnosti u njihovim profilima strategije i politike istraživanja i razvoja. Identifikovanjem klastera sa uporedivim karakteristikama istraživanja i razvoja moguće je steći bolji uvid u prednosti i slabosti nacionalnih inovacionih sistema i politika. Razumevanje distribucije kapaciteta za istraživanje i razvoj širom Evrope može olakšati međunarodnu saradnju i promovisati razmenu znanja među zemljama sa sličnim snagama i izazovima. Ovaj istraživački rad ima za cilj da istraži grupisanje evropskih zemalja na osnovu njihovog kapaciteta za istraživanje i razvoj, pružajući sveobuhvatnu analizu ključnih pokazatelja i njihovih implikacija za nacionalne strategije inovacija. Urađena je analiza najvažnijih aspekata istraživanja i razvoja, pri čemu su identifikovana četiri klastera, u koje je grupisano ukupno 35 uključenih evropskih zemalja.

Ključne reči:

istraživanje i razvoj,
visoko obrazovanje,
inovacioni kapacitet,
ekonomski razvoj,
klasteri.

JEL Klasifikacija:

O32, O38