

## **Comparative Analysis Of R&D Expenditure Performance in the European Union: An Application Using the OCRA Method**

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### **Abstract**

In the current era of intense global competition, countries that develop technology rather than just adopt it can emerge as leaders. R&D spending is a crucial tool for both nations and institutions to develop technology and foster innovation, while leveraging their economic strengths. This study seeks to analyze the R&D spending performance of 23 EU countries. To do this, six variables related to R&D expenditure were used as decision criteria. Data from 2014, 2019, and 2023 were examined using the OCRA (Operational Competitiveness Rating) method, a Multi-Criteria Decision-Making (MCDM) approach. The analysis showed that the countries with the highest R&D spending in all three years were Germany, France, and the Netherlands, in that order.

**Key words:** R&D Expenditure, Economic Growth, EU Countries, OCRA

**JEL Code:** O32, E6, C44

### **1. Introduction**

In today's global economy, technological advancement and innovation have become key determinants of competitiveness, economic growth, and sustainable development. Countries that actively invest in research and development (R&D) are more likely to generate innovation, improve productivity, and strengthen their position in the global economy. R&D activities not only contribute to the creation of new knowledge but also facilitate the transformation of this knowledge into commercially viable products and processes, thereby enhancing economic performance.

R&D is commonly defined as a set of creative and systematic activities undertaken to increase the stock of knowledge and to devise new applications from existing knowledge (OECD, 2015). In this context, higher levels of R&D investment are generally associated with stronger innovation capacity, increased

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high-technology exports, and improved economic outcomes. Particularly in knowledge-based economies, R&D expenditures play a crucial role in fostering long-term growth and technological progress.

The European Union (EU) has placed significant emphasis on R&D investments as part of its long-term development strategy. In recent years, the EU has aimed to strengthen its global competitiveness by increasing R&D intensity and promoting innovation-driven growth. Despite these efforts, considerable disparities persist among EU member states in terms of R&D investment levels, innovation capacity, and technological performance. These differences highlight the need for a comprehensive evaluation of R&D performance across countries (Eurostat, 2025).

A substantial body of literature has examined the relationship between R&D expenditures and economic growth, innovation, and high-technology exports. Most existing studies employ econometric approaches such as panel data analysis, regression models, and causality tests to analyze these relationships. While these studies provide valuable insights into the effects of R&D investments, they generally focus on single relationships and do not offer a comprehensive framework for evaluating overall R&D performance. In contrast, studies that assess R&D performance within a multi-criteria decision-making (MCDM) framework remain relatively limited. Evaluating R&D performance requires simultaneous consideration of multiple input and output indicators, including sectoral R&D expenditures, innovation outputs, and macroeconomic performance measures. Therefore, there is a need for analytical approaches that can integrate these multiple dimensions into a unified performance assessment framework.

This study aims to evaluate the R&D expenditure performance of 23 European Union countries for the years 2014, 2019, and 2023 by employing the OCRA (Operational Competitiveness Rating) method, a multi-criteria decision-making technique. The study incorporates six indicators representing both input and output dimensions of R&D activities and applies the standard deviation method to determine objective criterion weights. This study contributes to existing literature in several important ways. First, it provides a comprehensive performance evaluation by simultaneously considering multiple R&D-related indicators rather than focusing on a single relationship. Second, it applies the OCRA method—an approach rarely used in the context of R&D performance analysis—thereby offering a novel methodological perspective. Third, the use of the standard deviation method reduces subjectivity in the weighting process. Finally, by analyzing multiple time periods, the study enables a comparative and dynamic assessment of R&D performance across EU countries. The remainder of the paper is structured as follows. Section 2 reviews the relevant literature on R&D expenditures and their economic implications. Section 3 presents the dataset, variables, and methodology employed in the analysis. Section 4 reports the empirical findings and discusses the results. The final section concludes with the study and provides policy implications.

## 2. Literature Review

Innovation through research and development has gained prominence since the 1980s. However, the conceptual foundations of R&D activities can be traced back to Schumpeter (1970), who emphasized the central role of innovation, research, and development in driving economic transformation. In line with this perspective, endogenous growth theory considers technological progress as an outcome of intentional economic activities rather than an exogenous factor. Romer (1986) and Lucas (1988) argue that human capital accumulation and specialized research activities are key mechanisms through which technological advancement occurs. Similarly, Romer (1990) identifies R&D as a fundamental source of sustained economic growth, suggesting that research efforts generate long-term productivity gains.

Building on this theoretical foundation, a large body of empirical literature has examined the relationship between R&D expenditures and economic growth. Several studies report on the positive and significant impact of R&D investments on growth. For instance, Bayar and Taşel (2012) find that both R&D expenditures and R&D personnel positively affect economic growth. Similarly, Kaur and Singh (2016) identify a positive relationship between R&D expenditures and growth in developing countries, emphasizing the role of technological activities in economic convergence. Mladenovic et al. (2016) provide supporting evidence for EU countries, while Ersin et al. (2022) highlight that R&D expenditures positively influence economic growth regardless of their share in GDP. More recent evidence also supports these findings, as Tung and Hoang (2024) demonstrate the growth-enhancing effects of R&D spending in developing economies.

However, the empirical findings are not entirely uniform. Tuna et al. (2015), for example, do not find evidence of a long-run relationship between R&D expenditures and economic growth in Turkey. Similarly, Inekwe (2015) shows that the impact of R&D expenditures varies across income groups, being significant in middle- and high-income countries but insignificant in low-income economies. These mixed findings suggest that the effectiveness of R&D investments may depend on country-specific characteristics and structural conditions. In addition to economic growth, another important dimension of R&D performance is its impact on high-technology exports. The literature consistently emphasizes that R&D investments enhance countries' export competitiveness, particularly in high-technology sectors. Mansfield (1980) highlights that corporate R&D activities improve product quality and provide a competitive advantage in international markets. Lall (1992) further argues that technological capabilities are a key determinant of high-technology production and exports in developing countries. Coe and Helpman (1995) emphasize the importance of both domestic and foreign R&D investments, particularly for smaller economies.

Empirical studies largely support these arguments. Seyoum (2004), Braunerhjelm and Thulin (2006), and Yaman et al. (2020) find a positive

relationship between R&D expenditures and high-technology exports. Göçer (2013) reports that increases in R&D spending significantly boost both high-technology exports and economic growth. Similarly, Sandu and Ciocanel (2014) find that business-sector R&D expenditures have a stronger impact on high-technology exports than public-sector spending. Meo and Usmani (2014) show that countries with higher R&D investments tend to achieve better performance in both patents and high-technology exports. Ozkan and Yilmaz (2017) argue that increasing R&D expenditure is essential for enhancing innovation and export performance. However, some studies also indicate that the impact of R&D on exports may vary over time; for instance, Coskun and Eygu (2020) find that R&D expenditures initially have a negative effect on exports in Turkey, but this effect becomes positive in the long run.

Another critical outcome of R&D activities is patent generation, which reflects innovation capacity and technological advancement. The patent system plays a crucial role in encouraging R&D investments by ensuring returns to innovation (Griliches, 1990; Hall, Jaffe, & Trajtenberg, 2005). Empirical evidence generally supports a strong relationship between R&D expenditures and patent activity. Igor (2005) identifies a positive link between R&D spending and patent applications, while Ulku (2006) shows that R&D investments increase patent stock, particularly in countries with large markets. Sinha (2008) finds a bidirectional relationship between patents and economic growth in Japan, although the relationship is unidirectional in Korea. Türedi (2016) also reports a positive causal relationship between R&D expenditures, patents, and economic growth in OECD countries. More recent studies, such as Paula and Silva (2021), confirm that R&D expenditures significantly influence patent applications and contribute to national development. However, evidence from regional analyses, such as Onder (2019), suggests that R&D policies may not always be effective, particularly in terms of commercialization outcomes.

Recent studies further reinforce the importance of R&D expenditures in multiple dimensions of economic performance. Xuan (2025) emphasizes the short-term role of R&D in driving innovation, while Wang (2025) highlights its effectiveness in supporting firm development and innovation processes. Similarly, Koç et al. (2026) demonstrate that R&D expenditures positively affect trade openness and economic growth. Chmielewski et. al. (2025) finds that R&D investments have a positive and significant impact on both economic growth and unemployment in EU-27 countries. Zarska and Masarova (2026), using patent applications as outputs and R&D expenditures and personnel as inputs, shows that Germany and Italy have a comparative advantage in high-innovation sectors among selected EU countries. In addition, Hu et al. (2025) provide evidence that R&D expenditures significantly influence export volumes and highlight the role of innovation and human capital in enhancing international competitiveness.

Overall, the existing literature clearly demonstrates that R&D expenditures play a crucial role in promoting economic growth, high-technology exports, and innovation outputs such as patents. However, most of these studies focus on single relationships using econometric approaches, and relatively few studies provide a comprehensive evaluation of R&D performance by simultaneously considering multiple input and output indicators. This gap highlights the need for analytical frameworks that can assess R&D performance in a multidimensional and comparative manner.

### 3. Dataset and Methodology

This study analyzed the R&D expenditure performance of twenty-three EU member states. Data from 2014, 2019, and 2023 were collected from the World Bank and Eurostat databases. The OCRA method was applied to assess the performance of decision options, using the following decision criteria: business enterprise sector (BES), government sector (GOV), higher education sector (HES), high-technology exports (HTE), gross domestic product (GDP), and patent applications to the European Patent Office (PA). These variables are detailed in the following paragraphs.

***Business enterprise sector (% of GDP) (max) (C1):*** Business enterprise expenditure on r&d

***Government sector (% of GDP) (max) (C2):*** is total intramural expenditure on r&d performed in the national territory during a specific reference period.

***Higher education sector (% of GDP) (max) (C3):*** higher education expenditure on r&d

***High-technology exports (current US \$) (max) (C4):*** High-technology exports are products with high R&D intensity, such as aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery.

***Gross domestic product (GDP) (at market prices) (max) (C5):*** Gross domestic product (GDP) at market prices is the result of the production activity of resident producer units. It is defined as the value of all goods and services produced less than the value of any goods or services used in their creation.

***Patent applications: (number)(max) (C6):*** This indicator measures requests for the protection of an invention filed with the European Patent Office (EPO) regardless of whether they are granted or not. Applications are allocated according to the country of residence of the first applicant listed on the application form (first-named applicant principle) as well as according to the country of residence of the inventor.

#### The Standard Deviation Method

The performance score calculated by analyzing an MCDM problem is heavily influenced by the weights assigned to the criteria. Usually, decision-makers assign these weights. However, because of the uncertainty inherent in this process,

the results can be affected by decision-makers' biases. To prevent this, objective weighting methods like the standard deviation (SD) can be used. The SD method greatly enhances MCDM by assigning weights to each criterion fairly, reducing personal bias in decision-making. The SD method is performed according to the following steps (Maheshwari *et al.*, 2021: 350; Diakoulaki *et al.*, 1995: 766; Zardari *et al.*, 2015: 34-35; Murat, 2020: 92).

*Step 1:* The decision matrix X is composed for m decision alternative and n criteria.

$$X = [x_{ij}]_{m \times n} = \begin{matrix} & C_1 & C_2 & \dots & C_n \\ \begin{matrix} A_1 \\ A_2 \\ \dots \\ A_m \end{matrix} & \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \end{matrix} \quad i = 1, 2, 3, \dots, m; \quad j = 1, 2, 3, \dots, n \quad (1)$$

*Step 2:* The decision matrix (X) is normalized using Equation 2.

$$x_{ij}^* = \frac{x_{ij} - \min(x)_{ij}}{\max(x)_{ij} - \min(x)_{ij}} \quad (2)$$

where  $x_{ij}^*$ : the normalized value of the *i*th alternative with respect to the *j*th criterion

*Step 3:* The standard deviation value for each criterion is calculated by Equation (3).

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^m (x_{ij}^* - \overline{x_{ij}^*})^2}{m}} \quad (3)$$

where  $\overline{x_{ij}^*}$  is the average of the values of each *j*th criterion. The criteria weights are obtained through Equation (4).

$$w_i = \frac{\sigma_j}{\sum_{j=1}^n \sigma_j} \quad (4)$$

### The OCRA method

The OCRA (Operational Competitiveness Rating) is a nonparametric method proposed by Parkan (1994) and used in performance analysis. Considering some of the evaluation difficulties encountered in data envelopment analysis (DEA), OCRA was developed as an alternative to DEA. This method provides the opportunity to conduct cross-sectoral analysis and evaluate the relative performance of alternatives. The OCRA procedure is described as below (Parkan and Wu, 2000: 498-499; Chatterjee and Chakraborty, 2012: 387-388; Ecer, 2020: 191-192; Özbek, 2019: 284-286).

*Step 1:* The initial decision matrix X is constituted for m decision alternative and n criteria

$$X = [x_{ij}]_{m \times n} = \begin{matrix} & C_1 & C_2 & \dots & C_n \\ \begin{matrix} A_1 \\ A_2 \\ \dots \\ A_m \end{matrix} & \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} & i = 1, 2, 3, \dots, m; & j = 1, 2, 3, \dots, n \end{matrix} \quad (1)$$

*Step 2:* Preference ratings of the criteria are calculated via Equation (2) and (3).

$$I_i = \sum_{j=1}^g w_j \frac{\max(x_{ij}) - x_{ij}}{\min(x_{ij})} \quad \text{for cost-oriented criteria} \quad (2)$$

where g: number of cost-oriented criteria.

$$O_i = \sum_{j=g+1}^n w_j \frac{x_{ij} - \min(x_{ij})}{\min(x_{ij})} \quad \text{for benefit-oriented criteria} \quad (3)$$

where  $w_j$ : the criterion weight.

*Step 3:* The linear preference rating of the criteria is determined.

$$\bar{I}_i = I_i - \min(I_i) \quad \text{for cost-oriented criteria} \quad (4)$$

$$\bar{O}_i = O_i - \min(O_i) \quad \text{for benefit-oriented criteria} \quad (5)$$

*Step 4:* In this step, the overall preference score (Pi) is calculated.

$$P_i = (\bar{I}_i + \bar{O}_i) - \min(\bar{I}_i + \bar{O}_i) \quad (6)$$

#### 4. Empirical Findings.

This study aimed to analyze the performance of R&D expenditures based on six decision criteria: business enterprise sector expenditures (BES), government sector expenditures (GOV), higher education sector expenditures (HES), high-technology exports (HTE), gross domestic product (GDP), and patent applications to the European Patent Office (PA). In the analysis, BES, GOV, and HES were regarded as inputs, while HTE, GDP, and PA were considered outputs. All criteria were beneficial. Data collected over three years were analyzed using the SD-based OCRA method. The initial decision matrix for 2023, generated from these criteria, is presented in Table 1.

**Table 1.** The Initial Decision-Making Matrix

Country/Criteria	C1	C2	C3	C4	C5	C6
Austria	2.27	0.25	0.76	27308	-1	2332
Belgium	2.46	0.31	0.54	50647	1.2	2587
Bulgaria	0.51	0.23	0.05	3178	1.9	41
Czechia	1.19	0.29	0.34	52422	0	239
Denmark	1.83	0.09	1.06	16067	0.6	2597
Estonia	1.06	0.16	0.6	2085	-3	71
Finland	2.09	0.24	0.75	5292	-0.9	2336
France	1.44	0.25	0.46	115256	1.4	10864
Germany	2.12	0.38	0.54	255687	-0.3	24942
Greece	0.74	0.31	0.44	2973	2.3	161
Hungary	1	0.15	0.22	24367	-0.8	109
Ireland	1.36	0.04	0.18	91363	-2.5	1071
Italy	0.76	0.19	0.33	52167	0.7	5082
Latvia	0.3	0.16	0.37	2129	2.9	27
Lithuania	0.43	0.16	0.45	3.74	0.3	128
Holland	1.56	0.11	0.56	110952	-0.6	7057
Poland	1	0.03	0.52	29592	0.2	669
Portugal	1.06	0.08	0.51	4196	2.6	331
Romania	0.32	0.14	0.06	9724	2.4	42

Slovakia	0.58	0.18	0.27	10122	2.2	56
Slovenia	1.47	0.35	0.29	4206	2.1	153
Spain	0.84	0.27	0.38	25806	2.7	2129
Sweden	2.67	0.15	0.77	25152	-0.2	5125

**Source:** Authors' calculations

To perform a comprehensive analysis of the data in Table 1, descriptive statistics were calculated for the decision criteria and presented in Table 2.

**Table 2.** Descriptive Statistics for Decision Criteria

Criteria	Minimum	Maximum	Mean	Std. deviation	Range
<b>BES</b>	0.3	2.67	1.26	0.70	2.37
<b>GOV</b>	0.03	0.38	0.20	0.09	0.35
<b>HES</b>	0.05	1.06	0.45	0.24	1.01
<b>HTE</b>	2.085	255.687	40.19	58.10	253.602
<b>GDP</b>	-3	2.9	0.62	1.65	5.9
<b>PA</b>	27	24942	2963	5521.92	24915

**Source:** Authors' calculations

The analysis of these criteria across countries showed that the average BES was 1.26, with Sweden, Belgium, and Austria exhibiting the best performance. The countries with the highest GOV were Germany, Slovenia, and Belgium. It was observed that Denmark, Sweden, and Austria had the highest HES expenditures, with values significantly above the average. The average HTE in EU countries was \$40.19, and Germany had the highest HTE income at \$255.69, followed by France and the Netherlands. Latvia, Spain, and Portugal had the highest GDP. Germany led with 24,942 patent applications filed with the European Patent Office, while France had the second-highest number with 10,864.

After creating the decision-making matrix, the next step was to calculate the criteria weights for the OCRA analysis. For this, the Standard Deviation (SD) method, an objective approach to assign weights to criteria, was used. The criteria weights calculated with the SD method are shown in Table 3.

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**Table 3. SD Criteria Weights**

<b>Criteria/Year</b>	<b>2023</b>	<b>2019</b>	<b>2014</b>
C1 (BES: business enterprise sector)	0.19	0.20	0.22
C2 (GOV: government sector)	0.18	0.15	0.17
C3 (HES: higher education sector)	0.15	0.16	0.17
C4 (HTE: high-technology exports)	0.15	0.15	0.15
C5 (GDP: Gross domestic product)	0.18	0.19	0.14
C6 (PA: patent applications)	0.14	0.14	0.14

**Source:** Authors' calculations

Relative criterion performances were calculated using the decision-making matrix and the corresponding criterion weights. Analyses were then conducted with linear preference rankings and overall preference rankings. The analysis results for 2023 are presented in Table 4.

**Table 4. OCRA Findings and Rankings**

<b>Country</b>	<b>Qi</b>	<b>Pi</b>	<b>Rank</b>		
Austria	4.057	14.346	18.402	17.749	8
Belgium	3.859	17.242	21.101	20.447	6
Bulgaria	0.626	0.211	0.836	0.183	22
Czechia	2.310	4.904	7.214	6.560	12
Denmark	3.746	14.860	18.606	17.953	7
Estonia	2.254	0.590	2.844	2.191	18
Finland	3.851	12.787	16.638	15.985	9
France	2.602	66.047	68.649	67.996	2
Germany	4.056	151.365	155.422	154.768	1
Greece	2.448	0.812	3.260	2.607	16
Hungary	0.988	2.252	3.240	2.587	17
Ireland	0.442	12.282	12.724	12.071	11
Italy	1.410	30.704	32.114	31.460	5
Latvia	1.059	0.000	1.059	0.406	21
Lithuania	1.389	0.813	2.201	1.548	19
Holland	2.155	45.532	47.686	47.033	3
Poland	1.197	5.556	6.753	6.099	13

Portugal	1.502	1.789	3.291	2.638	15
Romania	0.000	0.653	0.653	0.000	23
Slovakia	1.050	0.769	1.819	1.166	20
Slovenia	2.693	0.870	3.563	2.909	14
Spain	2.090	12.929	15.019	14.366	10
Sweden	3.750	29.057	32.807	32.154	4

**Source:** Authors' calculations

The findings presented in Table 4 indicate that the top three countries with the strongest R&D expenditure performance in 2023 are Germany, France, and the Netherlands, followed by Sweden and Italy. The countries with the weakest performance include Romania, Bulgaria, and Latvia. The OCRA procedures were also applied to the 2019 and 2014 data, with the results displayed in Table 5.

**Table 5.** OCRA Rankings for 2023, 2019, and 2014

Country	2023		2019		2014	
	Pi	Rank	Pi	Rank	Pi	Rank
Austria	17.749	8	21.407	7	43.234	7
Belgium	20.447	6	23.979	6	41.641	9
Bulgaria	0.183	22	1.820	20	1.183	21
Czechia	6.560	12	9.136	12	9.128	13
Denmark	17.953	7	20.665	8	41.978	8
Estonia	2.191	18	3.373	17	2.389	18
Finland	15.985	9	15.458	9	45.554	6
France	67.996	2	82.207	2	212.388	2
Germany	154.768	1	200.358	1	499.284	1
Greece	2.607	16	3.370	18	2.801	17
Hungary	2.587	17	5.209	14	4.524	15
Ireland	12.071	11	11.408	11	14.054	11
Italy	31.460	5	33.190	5	72.577	5
Latvia	0.406	21	0.000	23	0.581	22
Lithuania	1.548	19	2.984	19	1.362	20
Holland	47.033	3	56.808	3	139.266	3
Poland	6.099	13	6.994	13	11.177	12

Portugal	2.638	15	3.713	16	4.112	16
Romania	0.000	23	1.580	22	0.000	23
Slovakia	1.166	20	1.726	21	2.035	19
Slovenia	2.909	14	4.505	15	5.024	14
Spain	14.366	10	15.337	10	30.060	10
Sweden	32.154	4	35.236	4	77.803	4

**Source:** Authors' calculations

Based on the Pi values and country rankings from the analysis of 2019 data presented in Table 5, Germany had the strongest R&D expenditure performance, like 2023 and 2014. Additionally, France and the Netherlands ranked second and third. The three countries with the weakest R&D expenditure performance in 2019 were Latvia, Romania, and Slovakia. In 2014, Bulgaria was among the weakest countries, along with Romania and Latvia.

## **5. Conclusion**

This study evaluates the R&D spending performance of 23 European Union countries for the years 2014, 2019, and 2023 using the OCRA method. The analysis incorporates six indicators, namely business sector R&D expenditures, public sector R&D expenditures, higher education sector R&D expenditures, high-technology exports, gross domestic product, and patent applications to the European Patent Office, thereby providing a comprehensive and multi-dimensional assessment of R&D performance. The findings reveal that R&D expenditure play a crucial role in shaping economic growth, innovation capacity, and international competitiveness. Across all three periods, Germany, France, and the Netherlands consistently rank among the top-performing countries, followed by Sweden and Italy, whereas Romania, Bulgaria, and Latvia remain at the lower end of the ranking. The persistence of these rankings over time indicates that structural differences in R&D capacity across EU countries are relatively stable and difficult to change in the short run.

These findings are consistent with the existing literature emphasizing the positive role of R&D expenditures in economic performance. In particular, the strong performance of countries with higher R&D investments supports the results of Ersin et al. (2022) and Tung and Hoang (2024), who demonstrate that R&D spending significantly contributes to economic growth. Furthermore, the observed relationship between R&D performance and high-technology exports aligns with earlier and more recent studies, such as Mansfield (1980), Coe and Helpman (1995), and Yaman et al. (2020), which highlight the importance of R&D investments in enhancing export competitiveness.

In addition, the results indicate that countries with higher R&D performance achieve better outcomes in terms of patent applications and high-technology exports. This finding supports the literature suggesting that R&D investments foster innovation outputs and technological development (Griliches, 1990; Paula and Silva, 2021). Moreover, it is observed that countries where business sector R&D expenditure exceed 1% of GDP tend to perform better, highlighting the critical role of private sector participation in R&D activities. This result is also in line with studies emphasizing the importance of firm-level innovation and private investment in driving technological progress. At the same time, the study highlights significant disparities among EU countries. Countries with lower rankings are characterized by relatively low R&D expenditures and weaker innovation outputs. This finding is consistent with the literature indicating that insufficient R&D investment limits both innovation capacity and long-term economic growth, particularly in less developed economies. From a broader perspective, the findings also point to increasing global competition in R&D activities. The rapid growth of R&D expenditures in countries such as China, along with sustained investments in the United States, South Korea, and Japan, has significantly intensified global competition. In this context, strengthening R&D performance has become essential for maintaining the European Union's competitiveness in the global economy.

From a policy perspective, the results suggest that EU countries—particularly those with lower performance levels—should focus on strengthening their innovation ecosystems, increasing private sector involvement in R&D, and improving the effectiveness of patent systems. In addition, enhancing coordination among business, government, and higher education sectors appears to be a key factor in improving overall R&D performance.

In conclusion, this study not only confirms the critical role of R&D expenditures in promoting economic growth, innovation, and competitiveness, but also demonstrates the importance of evaluating R&D performance within a multi-criteria framework. By linking empirical findings with the existing literature, the study provides a more comprehensive and policy-relevant understanding of R&D performance across EU countries.

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