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ANALYSIS OF RESEARCH AND DEVELOPMENT PERFORMANCE INDICATORS OF THE EUROPEAN UNION AND SERBIA

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Abstract: The aim of this article is to review the position of certain countries of the European Union (EU) and Serbia with regard to the development of research and development activities in the function of strengthening in the future by applying relevant measures. The research of the treated problem in this paper is based on the application of the modern multi-criteria decision-making method known as the LMAW-DNMA method. Research on the performance indicators of research and development of the countries of the European Union and Serbia using the LMAW-DNMA method showed that the top five countries of the European Union in terms of research and development are in order: Germany, France, Italy, the Netherlands and Poland. Serbia is positioned in twenty-third place (Croatia twenty-seventh place, Slovenia twenty-fourth place). Therefore, the leading countries of the European Union are at the top in terms of research and development.

Keywords: LMAW-DNMA method; Investment in R&D; European Union countries; Serbia.

1. INTRODUCTION

The issue of research and development (R&D) and selection of research and development projects is very challenging, important, current and complex. The impact of research and development on innovation, development of new technology, competitiveness, growth, efficiency and performance of all entities (economy, region, company) is very significant (Ayan & Abacıoğlu, 2022; Николаева, 2022). For these reasons, the issue of research and development is comprehensively researched and studied. Based on that, this paper comparatively analyzes the research and development performance indicators of the European Union (EU) and Serbia. In doing so, a modern multi-criteria decision-making method known as the LMAW-DNMA method is applied. The goal and purpose of the research of the treated problem in this paper is to see it as fully as possible in the function of improving the research and development activities of the European Union and Serbia by applying relevant measures. The effects of this are to improve the performance of all entities.

2. LITERATURE REVIEW

There is an increasingly rich literature devoted to the analysis of research and development issues. It is considered from different aspects (Lukic & Vojteski Kljenak, 2017; Lukic & Perovic, 2019; Lukic, 2022, 2023a,b,c). We will point out some of them. In a separate study, the impact of research and development on entrepreneurship, innovation, digitization and digital transformation is discussed (Ancillo & Gavrila, 2023). Considerable attention has been paid to the relationship between R&D expenditure and economic growth in the BRICS-T countries (Bayraktar et al., 2022). A very important issue in the literature is the macroeconomic effects of public research and development (De Lipsis et al., 2023). Likewise, a comparative study on the efficiency of

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research and development activities of universities in China by region using the DEA-Malmquist approach (Du & Seo, 2022). A special aspect of research in the literature is the application of the fuzzy MCDM method in the evaluation of R&D projects (Dursun & Lılıç, 2023; Şen, 2023) and territorial effects (Fernández-García Tania et al., 2022). The impact of R&D activities on productivity is significant (Foreman-Peck & Zhou, 2022). Likewise, product and process innovations in Latin American countries (Henriquez et al., 2023). In the literature, special attention is paid to the analysis of the public fund for research and development intended for investment in the technology of renewable energy sources in Europe (Gasser et al., 2022). In a separate study, the issue of assessing the effectiveness of investments in research and development in the countries of the European Union was analyzed (Ginevičius, 2023). Investments in research and development are a significant determinant of business performance (He & Estébanez, 2023) and innovative activities (Janjić et al., 2021; Kučera & Milan Fiľa, 2022; Roszko-Wójtowicz et al., 2022). The question of the role of investments in research and development in sustainable development has been investigated in the literature (Rybalkin, 2022; Wu, 2023). Investments in research and development significantly affect innovation and thus the value of the company (Wanicki & Bartłomiej Nita, 2022).

3. RESEARCH METHODOLOGY

Performance indicators of research and development can be analyzed in a classic way and by applying multi-criteria decision-making methods. Application of multi-criteria decision-making methods gives more accurate results compared to classical analysis. Because several criteria are taken into account at the same time. Bearing that in mind, in this paper, the performance analysis of research and development indicators is performed using the LMAW-DNMA method.

The **LMAW** (Logarithm Methodology of Additive Weights) method is the latest method used to calculate criteria weights and rank alternatives (Demir, 2022; Liao & Wu, 2020). It takes place through the following steps : m alternatives $A = \{A_1, A_2, \dots, A_m\}$ are evaluated in comparison with n criteria $C = \{C_1, C_2, \dots, C_n\}$ with the participation of k experts $E = \{E_1, E_2, \dots, E_k\}$ and according to a predefined linguistic scale (Pamučar et al, 2021).

Step 1: Determination of weight coefficients of criteria

Experts $E = \{E_1, E_2, \dots, E_k\}$ set priorities with criteria $C = \{C_1, C_2, \dots, C_n\}$ in relation to previously defined values of the linguistic scale. At the same time, they assign a higher value to the criterion of greater importance and a lower value to the criterion of less importance on the linguistic scale. By the way, the priority vector is obtained. The label γ_{cn}^e represents the value of the linguistic scale that the expert $e(1 \leq e \leq k)$ assigns to the criterion $C_t(1 \leq t \leq n)$.

Step 1.1: Defining the absolute anti-ideal pointγ_{AIP}

The absolute ideal point should be less than the smallest value in the priority vector. It is calculated according to the equation:

$$\gamma_{AIP} = \frac{\gamma_{min}^e}{S}$$

where is γ_{min}^e the minimum value of the priority vector and *S* should be greater than the base logarithmic function. In the case of using the function Ln, the value of *S* can be chosen as 3.

Step 1.2: Determining the relationship between the priority vector and the absolute anti-ideal point

The relationship between the priority vector and the absolute anti-ideal point is calculated using the following equation:

$$n_{Cn}^e = \frac{\gamma_{Cn}^e}{\gamma_{AIP}} \quad (1)$$

So the relational vector $R^e = (n_{C1}^e, n_{C2}^e, \dots, n_{Cn}^e)$ is obtained. Where it n_{Cn}^e represents the value of the real vector derived from the previous equation, and R^e represents the relational vector *e* (1≤e≤k).

Step 1.3: Determination of the vector of weight coefficients

The vector of weight coefficients $w = (w_1, w_2, \dots, w_n)^T$ is calculated by the expert $e(1 \leq e \leq k)$using the following equation:

$$w_j^e = \frac{\log_A(n_{Cn}^e)}{\log_A\left(\prod_{j=1}^{n} n_{Cn}^e\right)}, A > 1 \quad (2)$$

where w_j^e it represents the weighting coefficients obtained according to expert evaluations e^{th} and the n_{Cn}^e elements of the realization vector *R*. The obtained values for the weighting coefficients must meet the condition that $\sum_{j=1}^{n} w_j^e = 1$.

By applying the Bonferroni aggregator shown in the following equation, the aggregated vector of weight coefficients is determined $w = (w_1, w_2, \dots, w_n)^T$

$$W_j = \left(\frac{1}{k.(k-1)} \cdot \sum_{x=1}^{k} \left(w_j^{(x)}\right)^p \cdot \sum_{\substack{y=1 \\ y \neq x}}^{k} \left(w_{ij}^{(y)}\right)^q\right)^{\frac{1}{p+q}} \quad (3)$$

The value of p and q are stabilization parameters and $p, q \geq 0$. The resulting weight coefficients should fulfill the condition that $\sum_{j=1}^{n} w_j = 1$.

The **DNMA** (Double Normalization-based Multiple Aggregation) method is a newer method for showing alternatives (Demir, 2022). Two different normalized (linear and vector) techniques are used, as well as three different coupling functions (full compensation - CCM, non-compensation - UCM and incomplete compensation - ICM). The steps of applying this method are as follows (Ecer, 2020; Liao & Wu, 2020):

Step 1: Normalized decision matrix

The elements of the decision matrix are normalized with linear $\left(\hat{x}_{ij}^{1N}\right)$ normalization using the following equation:

$$\hat{x}_{ij}^{1N} = 1 - \frac{\left|x^{ij} - r_j\right|}{max\left\{\max_i x^{ij}, r_j\right\} - min\left\{\min_i x^{ij}, r_j\right\}} \quad (4)$$

The vector $\left(\hat{x}_{ij}^{2N}\right)$ is normalized using the following equation:

$$\hat{x}_{ij}^{2N} = 1 - \frac{\left|x^{ij} - r_j\right|}{\sqrt{\sum_{i=1}^{m} (x^{ij})^2 + \left(r_j\right)^2}} \quad (5)$$

The value r_j is the target value for c_j the criterion and is considered $\max_i x^{ij}$ for both utility and $\min_i x^{ij}$ cost criteria.

Step 2: Determining the weight of the criteria

This step consists of three phases:

Step 2.1: In this phase, the standard deviation $(\sigma_j)$for the criterion $c_j$is determined with the following equation where *m is* the number of alternatives:

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}\left(\frac{x^{ij}}{\max_i x^{ij}} - \frac{1}{m}\sum_{i=1}^{m}\left(\frac{x^{ij}}{\max_i x^{ij}}\right)\right)^2}{m}} \quad (6)$$

Step 2.2: Values of the standard deviation calculated for the criteria se normalize with the following equation:

$$w_j^{\sigma} = \frac{\sigma_j}{\sum_{i=1}^{n} \sigma_j} \quad (7)$$

Step 2.3: Finally, the weights are adjusted with the following equation:

$$\hat{w}_j = \frac{\sqrt{w_j^{\sigma} . w_j}}{\sum_{i=1}^{n} \sqrt{w_j^{\sigma} . w_j}} \quad (8)$$

Step 3: Calculating the aggregation model

Three aggregation functions (CCM, UCM and ICM) are calculated separately for each alternative. CCM (Complete Compensatory Model) is calculated using the following equation:

$$u_1(a_i) = \sum_{j=1}^{n} \frac{\hat{w}_j . \hat{x}_{ij}^{1N}}{\max_i \hat{x}_{ij}^{1N}} \quad (9)$$

The UCM (Uncompensatory Model) is calculated using the following equation:

$$u_2(a_i) = \max_j \hat{w}_j \left(\frac{1 - \hat{x}_{ij}^{1N}}{\max_i \hat{x}_{ij}^{1N}}\right) \quad (10)$$

The ICM (Incomplete Compensatory Model) is calculated using the following equation:

$$u_3(a_i) = \prod_{j=1}^{n} \left(\frac{\hat{x}_{ij}^{2N}}{\max_i \hat{x}_{ij}^{2N}} \right)^{\hat{w}_j} \qquad (11)$$

Step 4: Integration of utility values

The calculated utility functions are integrated with the following equation using the Euclidean principle of distance:

$$DN_i = w_1 \sqrt{\varphi \left(\frac{u_1(a_i)}{\max_i u_1(a_i)} \right)^2 + (1-\varphi) \left(\frac{m - r_{1(a_i)+1}}{m} \right)^2} - w_2 \sqrt{\varphi \left(\frac{u_2(a_i)}{\max_i u_2(a_i)} \right)^2 + (1-\varphi) \left(\frac{r_2(a_i)}{m} \right)^2} + w_3 \sqrt{\varphi \left(\frac{u_3(a_i)}{\max_i u_3(a_i)} \right)^2 + (1-\varphi) \left(\frac{m - r_3(a_i) + 1}{m} \right)^2} \qquad (12)$$

In this case, the means $r_1(a_i)$ and $r_3(a_i)$ represent the ordinal number of the alternative a_i sorted by CCM and ICM functions in descending value (higher value first). On the other hand, $r_2(a_i)$ it shows the sequence number in the obtained order according to the increasing value (smaller value first) for the UCM function used. The label φ is the relative importance of the child value used and is in the range [0.1]. It is considered that it can be taken as $\varphi = 0.5$. The coefficients w_1, w_2, w_3 are obtained weights of the used functions CCM, UCM and ICM, respectively. The sum should be equal $w_1 + w_2 + w_3 = 1$.

When determining the weights, if the decision maker attaches importance to a wider range of performance alternatives, he can set a higher value for w_1. In case the decision maker is not willing to take risks, ie. to choose a poor alternative according to some criterion, he can assign a higher weight to w_2. However, the decision maker may assign a greater weight to w_3 if he simultaneously considers overall performance and risk. Finally, the *DN* values are sorted in descending order, with the higher value alternatives being the best.

4. RESULTS AND DISCUSSION

Recently, gross domestic expenditures for research and development have been increasing due to their importance in almost all countries of the world. In 2021, they amounted to 2.27% of the gross domestic product in the European Union, China (except Hong Kong) 2.40%, Japan 3.26% and United States 3.45% (*Source: Eurostat*). Gross domestic expenditure on research and development is higher in the United States than in the European Union, China (except Hong Kong) and Japan. In the European Union, gross domestic expenditure on research and development is lower than in China (except Hong Kong), Japan and the United States.

In all countries of the world, the participation of women in the total number of researchers is increasing. The participation of women in the total number of researchers in the leading countries of the European Union in 2019 was: Germany 28.1%, France 28.3% and Italy 34.2%. In the same year, it was 48.3% in Croatia and 33.3% in Slovenia. In Serbia, the participation of women in the total number of researchers in 2019 was 51.9% (*Source: Eurostat*). It is therefore higher than in the countries in the region (Croatia and Slovenia).

Table 1 shows the criteria, alternatives and initial data for 2021 (Annex).

Table 2 shows the correlation matrix of the initial data (annex).

There is therefore a strong correlation between Gross domestic expenditure on R&D, (€ Mio), Government budget allocations for R&D, (% of GDP) and Government budget allocations for R&D, (€ per inhabitant), and Number of researchers, (thousand full-time equivalents) at the level of statistical significance.

In this work by applying the LMAW method, the weight coefficients of the criteria are calculated (Table 3 - Annex, Figure 1).

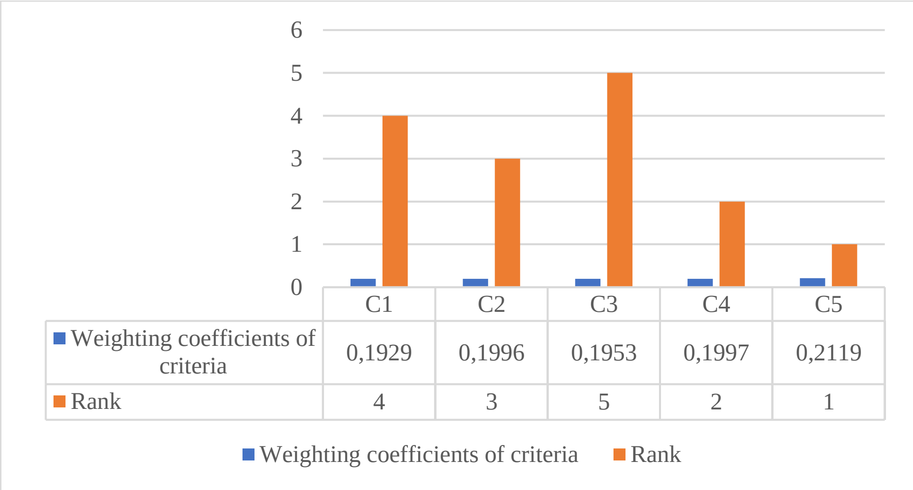

Figure 1: Weighting coefficients and ranking criteria

In this specific case, the most important criterion is C5 - Gross domestic expenditure on R&D, (%, relative to GDP). This means, in other words, that significant financial allocations for research and development can influence the achievement of target research results.

The selection and ranking of individual countries of the European Union and Serbia according to performance indicators of research and development will be carried out using the LMAW-DNMA method (Table 4 – 10 annex). (All calculations and results are by the authors).

The following can be pointed out in the discussion: First, the analysis of the problem treated in this work using the LMAW-DNMA method showed that the top five countries of the European Union in terms of research and development are, in order: Germany, France, Italy, the Netherlands and Poland. Therefore, the leading countries of the European Union are at the top in terms of research and development. In the European Union, Luxembourg ranks last in terms of research and development. Other, Serbia is positioned in twenty-third place. It therefore took a slightly better position than Croatia (twenty-seventh place) and Slovenia (twenty-fourth place). And finally, in terms of research and development, Serbia is significantly behind the leading countries of the European Union. This means, in other words, that Serbia needs to invest significantly more in research and development. The effects of this are the improvement of the overall performance of the Serbian economy. All in all, research and development are one of the critical factors of business success. In view of that, it is necessary to optimize financial allocations for research and development.

5. CONCLUSION

The analysis of the problem treated in this work using the LMAW-DNMA method showed that the top five countries of the European Union in terms of research and development are, in order: Germany, France, Italy, the Netherlands and Poland. Therefore, the leading countries of the European Union are at the top in terms of research and development. In the European Union, Luxembourg ranks last in terms of research and development. Serbia is positioned in twenty-third place. It therefore took a slightly better position than Croatia (twenty-seventh place) and Slovenia (twenty-fourth place). In terms of research and development, Serbia is significantly behind the leading countries of the European Union. This means, in other words, that Serbia needs to invest significantly more in research and development. The effects of this are the improvement of the overall performance of the Serbian economy.

In relation to the existing literature, the contribution of this paper is that, based on the latest available empirical data, using the latest method of multi-criteria decision-making (LMAW-DNMA), it indicates: what is the performance position of the countries of the European Union and Serbia in terms of research and development as a critical business factor success? This provides the basis for further theoretical, methodological, and empirical research on the problem of measurement and analysis of research and development performance in the countries of the European Union and Serbia and improvements in the future through the application of relevant measures. Likewise, it enables a comparative analysis of research and development performance indicators of the countries of the European Union and Serbia with other comparable countries (USA, China, Japan, Russia, etc.). Based on this, the performance of research and development can be improved as a critical factor for the business success of all countries.

REFERENCES

Ancillo, A. L., & Gavrila, S. G. (2023). The Impact of Research and Development on Entrepreneurship, Innovation, Digitization and Digital transformation. *Journal of Business Research*, 157, 113566. https://doi.org/10.1016/j.jbusres.2022.113566.

Ayan, B. & Abacıoğlu, S. (2022). Bibliometric analysis of the MCDM methods in the last decade: WASPAS,MABAC, EDAS, CODAS, COCOSO, and MARCOS. *International Journal of Business and Economic Studies*, 4(2), 65-85, Doi:https://doi.org/10.54821/uiecd.1183443

Bayraktar, Y., Dündar, N. ve Özyılmaz, A. (2022). The Relationship between R&D Expenditures and Economic Growth in BRICS-T Countries. *Eskişehir Osmangazi Üniversitesi İİBF Dergisi*, 17(3), 893 – 910. Doi: 10.17153/oguiibf.1151022

De Lipsis, V., Deleidi, M., Mazzucato, M., & Agnolucci, P. (2023) Macroeconomic Effects of Public R&D. UCL Institute for Innovation and Public Purpose, *Working Paper* Series (IIPP WP 2023-02). https://www.ucl.ac.uk/bartlett/public-purpose/wp2023-02

Demir, G. (2022). Analysis of the financial performance of the deposit banking sector in the Covid-19 period with LMAW-DNMA methods. *International Journal of Insurance and Finance*, 2(2), 17-36. https://doi.org/10.52898/ijif.2022.7

Du, Y., & Seo, W. (2022). A Comparative Study on the Efficiency of R&D Activities of Universities in China by Region Using DEA– Malmquist. *Sustainability*, 14, 10433. https://doi.org/10.3390/ su141610433

Dursun, M., & Lılıç, M. (2023). An Integrated Fuzzy MCDM Method for the Evaluation of R&D Projects. *Academic Platform Journal of Engineering and Smart Systems*, c. 11, sayı. 1, ss. 1-10. doi:10.21541/apjess.1104601

Ecer, F. (2020). Multi-criteriad Decision-making comprehensive approach from past to present. Seçkin Publications.

Fernández-García Tania, Liern Vicente, Pérez-Gladish Blanca, & Rubiera-Morollón Fernando, (2022). Measuring the territorial effort in research, development, and innovation from a multiple criteria approach: Application to the Spanish regions case. *Technology in Society*, 70, 101975. https://doi.org/10.1016/j.techsoc.2022.101975

Foreman-Peck, J., & Zhou, P. (2022). R&D subsidies and productivity in eastern European countries. *Economic Systems*, 46(2), 100978. https://doi.org/10.1016/j.ecosys.2022.100978

Gasser, M., Pezzutto, S., Sparber, W., & Wilczynski, E. (2022). Public Research and Development Funding for Renewable Energy Technologies in Europe: A Cross-Country Analysis. *Sustainability*, 14, 5557. https:// doi.org/10.3390/su14095557

Ginevičius, R., (2023). Assessment of the Effectiveness of Investment in R&D by European Union Countries. *Amfiteatru Economic*, 25(62), 251-264. DOI: 10.24818/EA/2023/62/251

Henriquez, R. O., Crespo, F. A., Geldes, C., Alves Ferreira, T., & Castillo-Vergara, M. (2023). Impact of R&D on the Innovation of Products and Processes in Latin Countries. *Axioms*, 12, 149. https://doi.org/10.3390/axioms12020149

He, M., & Estébanez, R. P. (2023). Exploring the Relationship between R&D Investment and Business Performance—An Empirical Analysis of Chinese ICT SMEs. *Sustainability*, 15, 5142. https://doi.org/ 10.3390/su15065142

Janjić, I., Jovanović, M., & Simonović, Z. (2021). The importance of research and development for innovative activity: the overview of the top countries in Europe and worldwide. *Economics of Sustainable Development*, 5(2), 19-28. https://doi.org/10.5937/ESD2102019J

Kučera, J., & Milan Fiľa, M. (2022). R&D expenditureperformance and economic development of the EU countries. *Entrepreneurship and Sustainability Issues*, 9(3), 227-241. DOI: 10.9770/jesi.2022.9.3(14)

Liao, H., & Wu, X. (2020). DNMA: A double normalization-based multiple aggregation methods for multi-expert multi-criteria decision making. *Omega*, 94, 102058. https://doi.org/10.1016/j.omega.2019.04.001

Lukic, R., & Vojteski Kljenak, D. (2017). Analysis of Intangible Assets in Retail Trade. Strategic *Management*, 22(2), 018-026.

Lukic, R., & Perovic, V. (2019). The Analysis of Intangible Costs of Trade Companies in Serbia. *International Journal of Industrial Engineering and Management*, 10(1), 197-203.

Lukić, R. (2022). Analysis of financial performance and efficiency of banks in Serbia using fuzzy LMAW and MARCOS methods. *Bankarstvo – Banking*, 4, 130-169. DOI: 10.5937/bankarstvo2204130L

Lukic, R. (2023a). Comparative analysis of transport and storage information systems of the European Union and Serbia using fuzzy LMAW and MARCOS methods. *Economy, Business & Development*, 4(1). 1-17DOI: 10.47063/ebd.00011

Lukic, R. (2023b). Application of the LMAW-DNMA method in the evaluation of the environmental problem in the agriculture of selected European Union countries. *Acta Agriculturae Serbica*, 28 (55), 49–61. doi: 10.5937/AASer2355049L

Lukic, R. (2023c). Measurement and Analysis of The Information Performance of Companies in The European Union and Serbia Based on The Fuzzy LMAW and MARCOS Methods. *Informatica Economică* vol. 27, no. 1, 17 – 31. DOI: 10.24818/issn14531305/27.1.2023.02

Николаева, Е. Е. (2022). *Современная экономическая теория: предмет и методология.* Вестник ТвГУ. Серия: *Экономика и управление*, (4), 7-15. DOI: 10.26456/2219-1453/2022.4.007–015

Pamučar, D., Žižović, M., Biswas, S., & Božanić, D. (2021). A new Logarithm Methodology of additive weights (LMAW) for multi-criteria decision-making: application in logistics. *Facta Universitatis Series: Mechanical Engineering*, 19(3), Special Issue: 361-380. https://doi.org/10.22190/FUME210214031P

Roszko-Wójtowicz, E., Dańska-Borsiak, B., Grzelak, M. M., & Pleśniarska, A. (2022). In search of key determinants of innovativeness in the regions of the Visegrad group countries. *Oeconomia Copernicana*, 13(4), 1015–1045. https://doi.org/10.24136/oc.2022.029

Rybalkin, O. (2022). Sustainable development goals progress in the European Union: correlation with EEPSE green economy index. *Access to science, business, innovation in digital economy, ACCESS Press*, 3(2): 121-135. https://doi.org/10.46656/access.2022.3.2(3)

Şen, H. (2023). R&D Project Selection with Gray-WASPAS Method. *The European*

Journal of Research and Development, 3(1), 37–45. https://doi.org/10.56038/ejrnd.v3i1.224

Wanicki, P., & Bartłomiej Nita, B. (2022). Evaluation of Methods Used to Study the Impact of Innovation on Enterprise Value. *Journal of EU Research in Business*, Vol. 2022 (2022), Article ID 413981, DOI: 10.5171/2022.413981

Wu, R. (2023). Innovation or Imitation? The Impacts of Financial Factors on Green and General Research and Development. Available at SSRN: https://ssrn.com/abstract=4329804 or http://dx.doi.org/10.2139/ssrn.4329804

ANNEX

Table 1: Initial data

	Initial data	Government budget allocations for R&D, (€ Mio)	Government budget allocations for R&D, (% of GDP)	Government budget allocations for R&D, (€ per inhabitant)	Number of researchers, (thousand full-time equivalents)	Gross domestic expenditure on R&D, (%, relative to GDP)
		C1	C2	C3	C4	C5
	E U	111,393.10	0.77	249.1	2002.2	2.27
A1	Belgium	3,664.46	0.73	317.1	76.3	3.19
A2	Bulgaria	166.60	0.23	24.1	16.2	0.81
A3	Czechia	1,493.56	0.63	139.6	48.1	2.00
A4	Denmark	3,095.51	0.92	530.0	45.0	2.81
A5	Germany	40,451.53	1.12	486.5	459.5	3.13
A6	Estonia	215.73	0.69	162.2	5.4	1.80
A7	Ireland	952.38	0.22	190.2	23.0	1.06
A8	Greece	1,550.21	0.85	145.2	44.3	1.44
A9	Spain	7,492.49	0.62	158.1	154.1	1.43
A10	France	17,659.91	0.71	261.0	340.0	2.21
A11	Croatia	413.56	0.71	102.5	9.5	1.27
A12	Italy	11,675.22	0.66	197.1	172.7	1.49
A13	Cyprus	110.57	0.46	123.4	1.6	0.89
A14	Latvia	84.35	0.25	44.6	4.5	0.71
A15	Lithuania	174.80	0.31	62.5	11.0	1.12
A16	Luxembourg	426.00	0.59	671.2	2.2	1.01
A17	Hungary	694.53	0.45	71.4	43.3	1.64
A18	Malta	35.34	0.24	68.5	1.0	0.65
A19	Netherlands	6,847.06	0.80	391.8	106.1	2.25
A20	Austria	3,269.58	0.81	366.0	55.1	3.22
A21	Poland	2,632.53	0.46	69.6	135.7	1.44
A22	Portugal	778.96	0.36	75.6	56.2	1.69
A23	Romania	393.39	0.16	20.5	19.1	0.48
A24	Slovenia	264.35	0.51	125.3	11.1	2.15
A25	Slovakia	407.24	0.41	74.6	17.5	0.95
A26	Finland	2,235.61	0.89	404.0	43.6	2.98
A27	Sweden	4,207.62	0.78	405.4	100.1	3.35
A28	Serbia	226.14	0.42	32.9	15.2	0.99
	Statistics					
	Mean	3986.4011	.5711	204.3179	72.0500	1.7200
	Median	865.6700	.6050	142.4000	43.4500	1.4650
	Std. Deviation	8195.41998	.24897	174.81623	105.20338	.87710
	The minimum	35.34	.16	20.50	1.00 am	.48
	Maximum	40451.53	1.12	671.20	459.50	3.35

Note: Author's statistics
Source: Eurostat

Table 2: Correlations

Correlations						
		1	2	3	4	5
1 Government budget allocations for R&D	Pearson Correlation	1	.562 **	.404 *	.953 **	.436 *
	Sig. (2-tailed)		.002	.033	.000	.020
	N	28	28	28	28	28
2 Government budget allocations for R&D	Pearson Correlation	.562 **	1	.717 **	.531 **	.806 **
	Sig. (2-tailed)	.002		.000	.004	.000
	N	28	28	28	28	28
3 Government budget allocations for R&D	Pearson Correlation	.404 *	.717 **	1	.341	.651 **
	Sig. (2-tailed)	.033	.000		.076	.000
	N	28	28	28	28	28
4 Number of researchers	Pearson Correlation	.953 **	.531 **	.341	1	.447 *
	Sig. (2-tailed)	.000	.004	.076		.017
	N	28	28	28	28	28
5 Gross domestic expenditure on R&D	Pearson Correlation	.436 *	.806 **	.651 **	.447 *	1
	Sig. (2-tailed)	.020	.000	.000	.017	
	N	28	28	28	28	28
**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).						

Note: Author's calculation

Table 3: Weight coefficients of the criteria

	Weighting coefficients of criteria	Rank
C1	0.1929	4
C2	0.1996	3
C3	0.1953	5
C4	0.1997	2
C5	0.2119	1

Note: Author's calculation

Table 4: Initial matrix

Initial Matrix	Kind	1	1	1	1	1
	Weight	0.1929	0.1996	0.1953	0.1997	0.2119
		C1	C2	C3	C4	C5
	A1	3,664.46	0.73	317.1	76.3	3.19
	A2	166.6	0.23	24.1	16.2	0.81
	A3	1,493.56	0.63	139.6	48.1	2
	A4	3,095.51	0.92	530	45	2.81
	A5	40,451.53	1.12	486.5	459.5	3.13
	A6	215.73	0.69	162.2	5.4	1.8
	A7	952.38	0.22	190.2	23	1.06
	A8	1,550.21	0.85	145.2	44.3	1.44
	A9	7,492.49	0.62	158.1	154.1	1.43
	A10	17,659.91	0.71	261	340	2.21
	A11	413.56	0.71	102.5	9.5	1.27

	A12	11,675.22	0.66	197.1	172.7	1.49
	A13	110.57	0.46	123.4	1.6	0.89
	A14	84.35	0.25	44.6	4.5	0.71
	A15	174.8	0.31	62.5	11	1.12
	A16	426	0.59	671.2	2.2	1.01
	A17	694.53	0.45	71.4	43.3	1.64
	A18	35.34	0.24	68.5	1	0.65
	A19	6,847.06	0.8	391.8	106.1	2.25
	A20	3,269.58	0.81	366	55.1	3.22
	A21	2,632.53	0.46	69.6	135.7	1.44
	A22	778.96	0.36	75.6	56.2	1.69
	A23	393.39	0.16	20.5	19.1	0.48
	A24	264.35	0.51	125.3	11.1	2.15
	A25	407.24	0.41	74.6	17.5	0.95
	A26	2,235.61	0.89	404	43.6	2.98
	A27	4,207.62	0.78	405.4	100.1	3.35
	A28	226.14	0.42	32.9	15.2	0.99
	MAX	40451.5300	1.1200	671.2000	459.5000	3.3500
	MIN	35.3400	0.1600	20.5000	1.0000	0.4800

Table 5: Linear normalization matrix

Linear Normalization Matrix		C1	C2	C3	C4	C5	MAX
	A1	0.0898	0.5938	0.4558	0.1642	0.9443	0.9443
	A2	0.0032	0.0729	0.0055	0.0332	0.1150	0.1150
	A3	0.0361	0.4896	0.1830	0.1027	0.5296	0.5296
	A4	0.0757	0.7917	0.7830	0.0960	0.8118	0.8118
	A5	1.0000	1.0000	0.7162	1.0000	0.9233	1.0000
	A6	0.0045	0.5521	0.2178	0.0096	0.4599	0.5521
	A7	0.0227	0.0625	0.2608	0.0480	0.2021	0.2608
	A8	0.0375	0.7188	0.1916	0.0944	0.3345	0.7188
	A9	0.1845	0.4792	0.2115	0.3339	0.3310	0.4792
	A10	0.4361	0.5729	0.3696	0.7394	0.6028	0.7394
	A11	0.0094	0.5729	0.1260	0.0185	0.2753	0.5729
	A12	0.2880	0.5208	0.2714	0.3745	0.3519	0.5208
	A13	0.0019	0.3125	0.1581	0.0013	0.1429	0.3125
	A14	0.0012	0.0938	0.0370	0.0076	0.0801	0.0938
	A15	0.0035	0.1563	0.0645	0.0218	0.2230	0.2230
	A16	0.0097	0.4479	1.0000	0.0026	0.1847	1.0000
	A17	0.0163	0.3021	0.0782	0.0923	0.4042	0.4042
	A18	0.0000	0.0833	0.0738	0.0000	0.0592	0.0833
	A19	0.1685	0.6667	0.5706	0.2292	0.6167	0.6667
	A20	0.0800	0.6771	0.5310	0.1180	0.9547	0.9547
	A21	0.0643	0.3125	0.0755	0.2938	0.3345	0.3345
	A22	0.0184	0.2083	0.0847	0.1204	0.4216	0.4216
	A23	0.0089	0.0000	0.0000	0.0395	0.0000	0.0395
	A24	0.0057	0.3646	0.1611	0.0220	0.5819	0.5819
	A25	0.0092	0.2604	0.0831	0.0360	0.1638	0.2604
	A26	0.0544	0.7604	0.5894	0.0929	0.8711	0.8711

	A27	0.1032	0.6458	0.5915	0.2161	1.0000	1.0000
	A28	0.0047	0.2708	0.0191	0.0310	0.1777	0.2708

Table 6: Vector Normalization Matrix

Vector Normalization Matrix		C1	C2	C3	C4	C5	MAX
	A1	0.4105	0.8877	0.7735	0.5266	0.9851	0.9851
	A2	0.3545	0.7437	0.5861	0.4524	0.7630	0.7630
	A3	0.3758	0.8589	0.6600	0.4918	0.8740	0.8740
	A4	0.4014	0.9424	0.9097	0.4880	0.9496	0.9496
	A5	1.0000	1.0000	0.8819	1.0000	0.9795	1.0000
	A6	0.3553	0.8762	0.6744	0.4391	0.8554	0.8762
	A7	0.3671	0.7408	0.6924	0.4608	0.7863	0.7863
	A8	0.3767	0.9223	0.6636	0.4871	0.8218	0.9223
	A9	0.4719	0.8560	0.6718	0.6227	0.8208	0.8560
	A10	0.6348	0.8819	0.7376	0.8524	0.8936	0.8936
	A11	0.3584	0.8819	0.6363	0.4441	0.8059	0.8819
	A12	0.5389	0.8675	0.6968	0.6457	0.8264	0.8675
	A13	0.3536	0.8099	0.6496	0.4344	0.7704	0.8099
	A14	0.3532	0.7495	0.5992	0.4379	0.7536	0.7536
	A15	0.3546	0.7668	0.6107	0.4460	0.7919	0.7919
	A16	0.3586	0.8474	1.0000	0.4351	0.7816	1.0000
	A17	0.3629	0.8071	0.6164	0.4859	0.8404	0.8404
	A18	0.3524	0.7466	0.6145	0.4336	0.7480	0.7480
	A19	0.4615	0.9079	0.8213	0.5634	0.8973	0.9079
	A20	0.4042	0.9107	0.8048	0.5004	0.9879	0.9879
	A21	0.3940	0.8099	0.6152	0.6000	0.8218	0.8218
	A22	0.3643	0.7811	0.6191	0.5018	0.8451	0.8451
	A23	0.3581	0.7236	0.5838	0.4560	0.7322	0.7322
	A24	0.3561	0.8243	0.6508	0.4461	0.8880	0.8880
	A25	0.3583	0.7955	0.6184	0.4540	0.7760	0.7955
	A26	0.3876	0.9338	0.8291	0.4862	0.9655	0.9655
	A27	0.4192	0.9021	0.8300	0.5560	1.0000	1.0000
	A28	0.3554	0.7984	0.5917	0.4512	0.7798	0.7984
	Adj Wj	0.1825	0.1945	0.2082	0.1974	0.2174	

Table 7: CCM (Compltete Compensatory Model)

CCM (Complete Compensatory Model)	u1(ai)	C1	C2	C3	C4	C5	SUM
	A1	0.0174	0.1223	0.1005	0.0343	0.2174	0.4919
	A2	0.0052	0.1233	0.0100	0.0569	0.2174	0.4128
	A3	0.0124	0.1798	0.0720	0.0383	0.2174	0.5199
	A4	0.0170	0.1896	0.2008	0.0233	0.2174	0.6482
	A5	0.1825	0.1945	0.1491	0.1974	0.2008	0.9242
	A6	0.0015	0.1945	0.0821	0.0034	0.1811	0.4626
	A7	0.0159	0.0466	0.2082	0.0363	0.1685	0.4755
	A8	0.0095	0.1945	0.0555	0.0259	0.1012	0.3866
	A9	0.0703	0.1945	0.0919	0.1376	0.1502	0.6444
	A10	0.1076	0.1507	0.1041	0.1974	0.1773	0.7371
	A11	0.0030	0.1945	0.0458	0.0064	0.1045	0.3541
	A12	0.1009	0.1945	0.1085	0.1419	0.1469	0.6927
	A13	0.0011	0.1945	0.1054	0.0008	0.0994	0.4011

	A14	0.0024	0.1945	0.0823	0.0161	0.1859	0.4810
	A15	0.0028	0.1363	0.0603	0.0193	0.2174	0.4361
	A16	0.0018	0.0871	0.2082	0.0005	0.0402	0.3377
	A17	0.0074	0.1453	0.0403	0.0451	0.2174	0.4555
	A18	0.0000	0.1945	0.1843	0.0000	0.1546	0.5333
	A19	0.0461	0.1945	0.1782	0.0679	0.2012	0.6878
	A20	0.0153	0.1379	0.1158	0.0244	0.2174	0.5108
	A21	0.0351	0.1817	0.0470	0.1734	0.2174	0.6545
	A22	0.0080	0.0961	0.0418	0.0564	0.2174	0.4197
	A23	0.0410	0.0000	0.0000	0.1974	0.0000	0.2384
	A24	0.0018	0.1218	0.0576	0.0075	0.2174	0.4062
	A25	0.0064	0.1945	0.0665	0.0273	0.1367	0.4314
	A26	0.0114	0.1698	0.1409	0.0211	0.2174	0.5605
	A27	0.0188	0.1256	0.1232	0.0427	0.2174	0.5277
	A28	0.0032	0.1945	0.0146	0.0226	0.1427	0.3775

Table 8: UCM (Uncompensatory model)

UCM (Uncompensatory Model)	u2(ai)	C1	C2	C3	C4	C5	MAX
	A1	0.1651	0.0722	0.1077	0.1631	0.0000	0.1651
	A2	0.1773	0.0711	0.1982	0.1405	0.0000	0.1982
	A3	0.1701	0.0147	0.1363	0.1591	0.0000	0.1701
	A4	0.1655	0.0048	0.0074	0.1741	0.0000	0.1741
	A5	0.0000	0.0000	0.0591	0.0000	0.0167	0.0591
	A6	0.1810	0.0000	0.1261	0.1940	0.0363	0.1940
	A7	0.1666	0.1479	0.0000	0.1611	0.0489	0.1666
	A8	0.1730	0.0000	0.1527	0.1715	0.1162	0.1730
	A9	0.1122	0.0000	0.1163	0.0598	0.0672	0.1163
	A10	0.0749	0.0438	0.1041	0.0000	0.0402	0.1041
	A11	0.1795	0.0000	0.1624	0.1910	0.1130	0.1910
	A12	0.0816	0.0000	0.0997	0.0555	0.0705	0.0997
	A13	0.1814	0.0000	0.1028	0.1966	0.1180	0.1966
	A14	0.1801	0.0000	0.1260	0.1813	0.0316	0.1813
	A15	0.1797	0.0582	0.1479	0.1781	0.0000	0.1797
	A16	0.1807	0.1074	0.0000	0.1969	0.1773	0.1969
	A17	0.1751	0.0491	0.1679	0.1523	0.0000	0.1751
	A18	0.1825	0.0000	0.0239	0.1974	0.0629	0.1974
	A19	0.1364	0.0000	0.0300	0.1295	0.0163	0.1364
	A20	0.1672	0.0565	0.0924	0.1730	0.0000	0.1730
	A21	0.1474	0.0128	0.1612	0.0240	0.0000	0.1612
	A22	0.1745	0.0984	0.1664	0.1410	0.0000	0.1745
	A23	0.1415	0.1945	0.2082	0.0000	0.2174	0.2174
	A24	0.1807	0.0726	0.1506	0.1899	0.0000	0.1899
	A25	0.1761	0.0000	0.1417	0.1701	0.0807	0.1761
	A26	0.1711	0.0247	0.0673	0.1763	0.0000	0.1763
	A27	0.1637	0.0689	0.0850	0.1547	0.0000	0.1637
	A28	0.1793	0.0000	0.1936	0.1748	0.0748	0.1936

Table 9: ICM (Incomplete compensatory model)

ICM (Incomplete Compensatory Model)	u3(ai)	C1	C2	C3	C4	C5	MAX
	A1	0.8524	0.9800	0.9509	0.8837	1.0000	0.7019
	A2	0.8695	0.9950	0.9466	0.9020	1.0000	0.7386
	A3	0.8572	0.9966	0.9432	0.8927	1.0000	0.7193
	A4	0.8546	0.9985	0.9911	0.8768	1.0000	0.7416
	A5	1.0000	1.0000	0.9742	1.0000	0.9955	0.9698
	A6	0.8481	1.0000	0.9470	0.8725	0.9948	0.6971
	A7	0.8702	0.9885	0.9739	0.8999	1.0000	0.7538
	A8	0.8492	1.0000	0.9338	0.8816	0.9752	0.6818
	A9	0.8970	1.0000	0.9508	0.9391	0.9909	0.7937
	A10	0.9395	0.9974	0.9608	0.9907	1.0000	0.8921
	A11	0.8485	1.0000	0.9343	0.8733	0.9806	0.6789
	A12	0.9168	1.0000	0.9554	0.9434	0.9895	0.8176
	A13	0.8596	1.0000	0.9551	0.8843	0.9892	0.7182
	A14	0.8708	0.9989	0.9534	0.8984	1.0000	0.7451
	A15	0.8636	0.9937	0.9473	0.8928	1.0000	0.7259
	A16	0.8293	0.9683	1.0000	0.8485	0.9478	0.6459
	A17	0.8579	0.9922	0.9375	0.8975	1.0000	0.7162
	A18	0.8716	0.9996	0.9599	0.8980	1.0000	0.7510
	A19	0.8839	1.0000	0.9794	0.9101	0.9975	0.7858
	A20	0.8495	0.9843	0.9582	0.8744	1.0000	0.7006
	A21	0.8745	0.9972	0.9415	0.9398	1.0000	0.7716
	A22	0.8576	0.9848	0.9373	0.9022	1.0000	0.7142
	A23	0.8776	0.9977	0.9540	0.9108	1.0000	0.7608
	A24	0.8464	0.9856	0.9374	0.8729	1.0000	0.6826
	A25	0.8645	1.0000	0.9489	0.8952	0.9946	0.7304
	A26	0.8466	0.9935	0.9688	0.8734	1.0000	0.7117
	A27	0.8533	0.9802	0.9619	0.8906	1.0000	0.7165
	A28	0.8627	1.0000	0.9395	0.8934	0.9949	0.7204

Table 10: Results of the LMAW-DNMA method

	Results of the LMAW-DNMA method										**w1**	**w2**	**w3**	
											0.6	**0.1**	**0.3**	
		CCM		**φ**	**UCM**		**φ**	**ICM**		**φ**	**Utility Values**			**Rank Order**
		u1(ai)	**Rank**	**0.5**	**u2(ai)**	**Rank**	**0.5**	**u3(ai)**	**Rank**	**0.5**				
Belgium	**A1**	0.4919	13	0.5522	0.1651	8	0.5738	0.7019	22	0.5415	0.5511	0.5511		**15**
Bulgaria	**A2**	0.4128	21	0.3749	0.1982	27	0.9382	0.7386	12	0.6887	0.5254	0.5254		**18**
Czechia	**A3**	0.5199	11	0.6040	0.1701	10	0.6080	0.7193	16	0.6188	0.6088	0.6088		**12**
Denmark	**A4**	0.6482	6	0.7638	0.1741	13	0.6544	0.7416	11	0.7064	0.7356	0.7356		**7**
Germany	**A5**	0.9242	1	1.0000	0.0591	1	0.1938	0.9698	1	1.0000	0.9194	0.9194		**1**
Estonia	**A6**	0.4626	16	0.4828	0.1940	23	0.8575	0.6971	24	0.5237	0.5325	0.5325		**16**
Ireland	**A7**	0.4755	15	0.5073	0.1666	9	0.5876	0.7538	8	0.7638	0.5923	0.5923		**13**
Greece	**A8**	0.3866	24	0.3216	0.1730	11	0.6274	0.6818	26	0.5029	0.4066	0.4066		**26**
Spain	**A9**	0.6444	7	0.7428	0.1163	4	0.3915	0.7937	4	0.8564	0.7418	0.7418		**6**

France	**A10**	0.7371	2	0.8848	0.1041	3	0.3470	0.8921	2	0.9423	0.8483	0.8483	**2**
Croatia	**A11**	0.3541	26	0.2813	0.1910	21	0.8167	0.6789	27	0.4976	0.3997	0.3997	**27**
Italy	**A12**	0.6927	3	0.8438	0.0997	2	0.3282	0.8176	3	0.8869	0.8052	0.8052	**3**
Cyprus	**A13**	0.4011	23	0.3423	0.1966	24	0.8809	0.7182	17	0.6050	0.4750	0.4750	**21**
Latvia	**A14**	0.4810	14	0.5281	0.1813	19	0.7602	0.7451	10	0.7248	0.6103	0.6103	**10**
Lithuania	**A15**	0.4361	18	0.4341	0.1797	18	0.7403	0.7259	14	0.6509	0.5298	0.5298	**17**
Luxembourg	**A16**	0.3377	27	0.2633	0.1969	25	0.8992	0.6459	28	0.4716	0.3894	0.3894	**28**
Hungary	**A17**	0.4555	17	0.4618	0.1751	15	0.6840	0.7162	19	0.5801	0.5195	0.5195	**20**
Malta	**A18**	0.5333	9	0.6493	0.1974	26	0.9182	0.7510	9	0.7450	0.7049	0.7049	**8**
Netherlands	**A19**	0.6878	4	0.8219	0.1364	5	0.4611	0.7858	5	0.8341	0.7895	0.7895	**4**
Austria	**A20**	0.5108	12	0.5806	0.1730	12	0.6390	0.7006	23	0.5328	0.5721	0.5721	**14**
Poland	**A21**	0.6545	5	0.7862	0.1612	6	0.5458	0.7716	6	0.8086	0.7689	0.7689	**5**
Portugal	**A22**	0.4197	20	0.3934	0.1745	14	0.6687	0.7142	20	0.5682	0.4734	0.4734	**22**
Romania	**A23**	0.2384	28	0.1841	0.2174	28	1.0000	0.7608	7	0.7851	0.4460	0.4460	**25**
Slovenia	**A24**	0.4062	22	0.3575	0.1899	20	0.7978	0.6826	25	0.5079	0.4466	0.4466	**24**
Slovakia	**A25**	0.4314	19	0.4156	0.1761	16	0.7007	0.7304	13	0.6685	0.5200	0.5200	**19**
Finland	**A26**	0.5605	8	0.6820	0.1763	17	0.7163	0.7117	21	0.5569	0.6479	0.6479	**9**
Sweden	**A27**	0.5277	10	0.6271	0.1637	7	0.5608	0.7165	18	0.5917	0.6098	0.6098	**11**
Serbia	**A28**	0.3775	25	0.3060	0.1936	22	0.8396	0.7204	15	0.6332	0.4575	0.4575	**23**
	MAX	0.9242			0.2174			0.9698					