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Comparison of Innovation Performances of BRICS Countries through CRITIC and GRA Methods[1]

BRICS Ülkelerinin İnovasyon Performanslarının CRITIC ve GRA Yöntemleriyle Karşılaştırılması

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Ö Z

BRICS ülkelerinin son dönemde teknolojiye yaptıkları yatırımlar dikkat çekmektedir ve bu ülkeler dünya çapında araştırma yapan ulusların bir parçası hâline gelmişlerdir. Teknoloji politikaları için etkili bir kıyaslama aracı olarak kabul edilen Avrupa İnovasyon Skor Tablosu (AİST), BRICS dâhil birçok ülkenin inovasyon performanslarının karşılaştırmalı analizini sağlamaktadır. Mevcut araştırmada BRICS ülkelerinin inovasyon performansları, teknoloji politikası tartışmalarında en çok benimsenen kıyaslama araçlarından biri olan AİST verileri aracılığıyla kıyaslanmıştır. Böylece AİST verilerinde kullanılan kriterlerin önem düzeylerinin tespit edilmesi ve söz konusu ülkelerin inovasyon süreçlerinin analiz edilmesi hedeflenmiştir. Bu çalışmada, BRICS ülkelerinin inovasyon performanslarını karşılaştırmak için CRiteria Importance Through Intercriteria Correlation (CRITIC) ve Grey Relational Analysis (GRA) yöntemlerini kullanan entegre bir çerçeve sunulmaktadır. Uygulamanın ilk aşamasında kriterlerin önem dereceleri CRITIC yöntemiyle elde edilirken, ikinci aşamada ülkeler GRA aracılığıyla inovasyon performanslarına göre sıralanmaktadır. Veriler, Avrupa Toplulukları Komisyonu tarafından oluşturulan AİST veri tabanından istatistikler derlenerek elde edilmiştir. Modelin uygulamasında elde edilen sonuçlara göre kriter ağırlıkları şu şekilde sıralamaktadır: yüksek öğrenim (0,249), uluslararası ortak yayınlar (0,176), orta ve yüksek teknoloji ihracatı (0,122), sık atıf yapılan yayınlar (0,113), PCT patentler (0,094), kamu-özel ortak yayınlar (0,085), tasarımlar (0,083) ve ticari markalar (0,078). Ayrıca BRICS ülkeleri inovasyon performanslarına göre Çin (0,76), Rusya (0,6), Güney Afrika (0,516), Brezilya (0,426) ve Hindistan (0,378) olarak sıralanmaktadır.

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A B S T R A C T

BRICS countries' recent investments in technology have attracted attention, and they have become a part of the nations that conduct research around the world. The European Innovation Scoreboard (EIS), accepted as an effective benchmarking tool for technology policies, provides a comparative analysis of the innovation performances of many countries, including BRICS. In the current research, the innovation performances of BRICS countries were compared through EIS data, one of the most adopted benchmarking tools in technology policy discussions. Thus, it was aimed to determine the importance levels of the criteria used in the EIS data and to analyze the innovation processes of the countries in question. In this study, an integrated framework using CRiteria Importance Through Intercriteria Correlation (CRITIC) and Grey Relational Analysis (GRA) methods is presented to compare the innovation performances of BRICS countries. In the first stage of the application, the importance levels of the criteria are obtained using the CRITIC method, while in the second stage, countries are ranked according to their innovation performance through GRA. Data are obtained by compiling statistics from the EIS database created by the Commission of the European Communities. The results obtained in the practical application of the model rank the criteria according to their weights as follows: higher education (0.249), international joint publications (0.176), medium and high technology exports (0.122), frequently cited publications (0.113), PCT patents (0.094), public-private joint publications (0.085), designs (0.083) and trademarks (0.078). In addition, the BRICS countries are ranked according to their innovation performance as China (0.76), Russia (0.6), South Africa (0.516), Brazil (0.426), and India (0.378).

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Introduction

In today's world, the economies of BRICS countries attract large sums of capital for various reasons, and these countries make serious investments in research and development activities (Bornmann et al., 2015). The EIS, the most accepted benchmarking tool in technology policy studies, provides a comparative analysis of the innovation performance of global competitors of the European Union, including BRICS countries (Europa, 2022). The EIS, the result of a detailed study conducted by experts, enables the evaluation of innovation systems and allows comparisons among countries' performances.

CRITIC is a technique developed to obtain objective weights of criteria in decision-making problems (Diakoulaki et. al., 1995). The method differs from other criterion weighting methods because it is based on an objective weighting in which the standard deviations of the criteria and the correlation between the criteria are used together (Ayçin & Çakin, 2019). Therefore, the method has advantages such as reducing subjectivity and ignoring non-dominant characteristics (Ulutaş & Topal, 2020). GRA, an extension of grey system theory, is another effective decision-making technique that analyzes uncertain relationships between multiple factors and variables (Kuo et al., 2008). It is a measurement method that allows for the analysis of relationships between small numbers of data and sequences (Kao & Hocheng, 2003). GRA has advantages such as requiring a small number of samples, providing effective results with uncertain data, not needing any probability distribution, and being able to be done with a small number of operations (Altıntaş, 2021). Due to these advantages, an integrated approach was adopted in the current study, in which criterion weights are determined by the CRITIC method and alternatives are ranked by the GRA technique.

BRICS countries, which play an important role in the world economy, develop research and development investments and increase their participation in technology. In the current study, innovation performances of BRICS countries were compared by using EIS data, which is one of the most followed benchmarking tools in technology policy discussions. Thus, it is aimed to determine the importance levels of the criteria used in the EIS data and to analyze the innovation processes of the countries in question.

EIS is a benchmarking tool that allows reliable comparisons of performance indicators of different countries with the data it provides. However, determining the importance levels of the evaluation criteria that indicate the innovation performance of countries will make the data presented more meaningful. In addition, studies in the literature generally focus on evaluating the innovation performances of the European Union and G7 countries. In the current study, contrary to the general literature, the innovation performances of BRICS countries were compared. Especially in recent years, the importance of BRICS countries on the world economy has increased. This importance will be more meaningful with the innovation and entrepreneurship activities of the countries. For this reason, it is of particular importance to evaluate BRICS countries from the innovation perspective. The main purpose of the research is to eliminate a gap in the literature by both determining the importance of the criteria presented in the EIS and analyzing the BRICS countries from the innovation perspective.

When the relevant literature was examined, it was seen that there were not many studies in which countries were evaluated from an innovation perspective and innovation criteria were analyzed. Through the hybrid approach proposed in the current study, BRICS countries, which have attracted attention with their technological investments in recent years, will be compared. In addition, innovation criteria will be ranked according to their importance. The results obtained in the study provided meaningful findings for decision makers who will undertake innovative initiatives. It will also pave the way for researchers who want to make innovative comparisons of different regions, institutions or organizations. However, researchers who study BRICS countries can also benefit from the results obtained from the current study.

In this study, the innovation performances of BRICS countries are compared through an integrated approach in which CRITIC and GRA techniques are used together. In the practical application, the performances of the five BRICS countries are evaluated by considering eight criteria. In the first phase of the research, the degrees of importance of the criteria are obtained via the CRITIC method. In the second stage, countries are ranked according to their innovation performance through GRA. The data used are taken from the database of the EIS compiled by the Commission of the European Communities (Europa, 2022). The outcome of this analysis rank the BRICS countries as China (0.76), Russia (0.6), South Africa (0.516), Brazil (0.426) and India (0.378) from the perspective of innovation performance.

In the second part of the study, there is the Literature Review section in which the economies of BRICS countries and the concept of EIS are introduced and studies related to the evaluation of innovation performances are presented. In the next section, the methodology adopted in the study is introduced. In the fourth chapter, the steps followed in the implementation process are explained. Finally, Discussion and Conclusions section, where the findings of the study are interpreted and recommendations for future studies are included.

Literature Review

In this day and age, when geopolitical and economic transformations are continuously prevalent, the developing BRICS economies have assumed an important role in the world economy. These countries attract significantly larger capital due to their potential consumer markets (Vijayakumar et al., 2010), but the main factors driving their economic expansion differ among the bloc’s members. For instance, Russia and Brazil’s competitive advantage stems from their natural resource reserves, whereas for China, the main causes for the aforementioned phenomenon are cheap labor and low prices, and for India, it is the low-cost labor force (Radulescu et al., 2014). The community’s countries, recognized for their increasing participation in science and technology, are expanding their research and development investments to be part of the global research community (Bornmann et al., 2015).

The EIS, put forth by the European Commission to respond to the need to compare innovation practices in European countries, has proven itself to be one of the most watched benchmarking tools in technology policy discussions (Schibany & Streicher, 2008). The EIS provides a comparative analysis of the innovation performance of European countries and global competitors (Europa, 2022). EIS provides analyses of innovation processes and is a valuable tool for developing long-term strategies for sustainable economic development (Pop & Pop, 2018). The scoreboard allows for specific comparisons of performance scores and enables countries to identify areas that need to be addressed and improved (Europa, 2022). Innovation measurement is carried out through systematic studies conducted by experts using relevant indicators (Pop & Pop, 2018). The 2021 scoreboard demonstrates that innovation performance continues to improve across the EU; low-performing countries develop faster than high-performing ones, and therefore the innovation gap decreases (Europa, 2022). In the present assessment, the innovation performances of BRICS countries are compared through a proposed hybrid decision-making approach. This section reviews previous studies in the literature in which innovation performances are evaluated and analyzed.

Wang (2011) proposes a method that includes linguistic computation that can help organizational managers’ measure service innovation performance. The aim of Detcharat, Pongpun, and Tarathorn (2013) is to evaluate and rank the criteria of technological innovation capabilities in their application to a company producing automotive parts. Akman, Özcan, and Hatipoğlu (2015) developed an approach that examines the innovation strategies of companies and classifies their innovation parameters. Gupta and Barua (2016) sought to identify the facilitators that contribute to the innovation development of SMEs. Almeida, Santos and Monteiro (2017) analyzed and compared innovation performance models.

In the study conducted by Ayçin and Çakin (2019), the innovation performance of countries in the European region was measured by using Entropy and MABAC methods in an integrated manner. Kabadurmuş and Kabadurmuş (2019) weighed the innovation performances of different regions through a firm-level dataset on innovation that they obtained from the World Bank. Oralhan and Büyüktürk (2019), aimed to compare the innovation performance of European Union countries and Turkey with multi-criteria decision-making methods. Altıntaş (2020), aimed to determine the importance levels of the Global Innovation Index components for G7 countries through an integrated approach. Enjolras, Camargo, and Schmitt (2020) proposed a hybrid methodology to examine the synergetic effects of innovation and export activities. Musaad et al. (2020) constructed an integrated methodology to analyze and prioritize SME suppliers from the perspective of innovation capabilities.

Altintas (2021), compared the innovation performances of the Black Sea Economic Cooperation Organization group countries with an integrated approach, based on the component values determined in the Global Innovation Index. Satıcı (2021) evaluated the innovation performance of 27 countries that are members of the European Union and 8 countries that are not in the European Union using the CRITIC and WASPAS methods. Aktas, Ecer and Kabak (2022) developed an approach to evaluate European countries in terms of health services through their proposed hybrid decision-making model. Duran (2022), aims to increase the benefits to be obtained from innovation indices by evaluating the innovation performance of 10 developing countries with a multi-criteria approach. In the literature review, no study was found in which the innovation performances of countries were compared using multi-criteria approaches.

Methodology

Developed to calculate the objective weights of the criteria, CRITIC is an approach used in multi-criteria decision making (Diakoulaki et al., 1995) that takes into account both the contrast intensity of and the contradictions between the criteria (Rani et al., 2021). The contrast intensity of the criteria is accepted as the standard deviation, whereas the contradictions between the criteria are obtained by the correlation coefficient (Peng & Huang, 2020).

Unlike other objective weighting methods, which only give consideration to contrast intensity, the CRITIC method also takes into account conflicting relationships between criteria (Li, & Mo, 2015). The technique is based on the premise that, if the scores of a criterion differ more from one alternative than another, this criterion should provide more meaningful information (Zhu et al., 2020). The CRITIC method has been successfully applied in calculating the objective weights of the criteria in various decision-making problems, and it has been used in conjunction with other objective or subjective decision-making techniques in many studies (Krishnan et al., 2021).

GRA is an effective measurement method among current applications of grey system theory, which analyzes uncertain relationships between multiple factors and variables (Kuo, Yang & Huang, 2008). In other words, it is a quantitative analysis used to investigate the similarities and differences between factors in dynamic process development (Julong, 1989). The method is a useful approach to deal with insufficient, incomplete, and uncertain information and helps fill the gaps in statistical regression (Ho & Lin, 2003). By optimizing grey relational degrees, complex relationships between multiple performance characteristics can be resolved (Wang et al., 1996). It is a measurement method that allows for the analysis of relationships between small numbers of data and sequences (Kao & Hocheng, 2003).

This assessment adopts an approach in which criterion weights and alternative ranking are determined by CRITIC and GRA, respectively. The suggested steps are presented below.

Step 1. The decision matrix (DM) is created as shown in Equation (1).

$$X = \begin{matrix} A_1 \\ A_2 \\ \cdots \\ A_4 \end{matrix} \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{12} & \ddots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (1)$$

Step 2. At this stage, DM is normalized and Equation (2) is used for benefit-based criteria and Equation (3) is used for cost-based criteria.

$$r_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}} \quad (2)$$

$$r_{ij} = \frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}} \quad (3)$$

Step 3. The correlation matrix of the criteria consisting of linear relationship coefficients (ρ_{jk}) is derived from Equation (4).

$$\rho_{jk} = \frac{\sum_{i=1}^{m}(r_{ij}-\overline{r_j})(r_{ik}-\overline{r_k})}{\sqrt{\sum_{i=1}^{m}(r_{ij}-\overline{r_j})^2 \sum_{i=1}^{m}(r_{ik}-\overline{r_k})^2}} \quad (4)$$

Step 4. C_j values that combine the contrast intensity and contradiction features in the evaluation criteria and which express the total information are calculated using Equations (5) and (6).

$$\sigma_j = \sqrt{\frac{\sum_{i=1}^{m}(r_{ij}-\overline{r_j})^2}{m-1}} \quad (5)$$

$$C_j = \sigma_j \sum_{k=1}^{n}(1 - \rho_{jk}) \quad (6)$$

Step 5. The weighted values (w_j) of the criteria are calculated by dividing the C_j value of each criterion by the sum of the C_j values of all criteria (Equation (7)).

$$w_j = \frac{C_j}{\sum_{k=1}^{n} C_j} \quad (7)$$

Step 6. The DM created in Equation (1) is analyzed to compare the alternatives. By determining the ideal values that can be obtained for each alternative, a reference series is created via Equation (8).

$$x_0 = (x_0^{(j)}) \; j = 1,2, \dots , n \quad (8)$$

The difference between the reference series values and the normalized DM values is taken (Equation 9) to obtain the absolute value matrix (Δ_{0i}) as specified in Equation (10).

$$\Delta_{0i} = x_0^{(j)} - x_i^{(j)} \quad (9)$$

$$\Delta_{0i} = \begin{bmatrix} \Delta_{01}^{(1)} & \Delta_{01}^{(2)} & \cdots & \Delta_{01}^{(n)} \\ \Delta_{02}^{(1)} & \Delta_{02}^{(2)} & \cdots & \Delta_{02}^{(n)} \\ \vdots & \vdots & \cdots & \vdots \\ \Delta_{0m}^{(1)} & \Delta_{0m}^{(2)} & \cdots & \Delta_{0m}^{(n)} \end{bmatrix} \tag{10}$$

Step 7. The absolute value matrix is converted to the grey relation coefficient matrix via Equation (11–12–13). The coefficient ζ found in Equation (11) is a differential coefficient that has a value between [0,1].

$$\gamma_{0i}^{(j)} = \frac{\Delta_{min} + \zeta\Delta_{maks}}{\Delta_{0i}^{(j)} + \zeta\Delta_{maks}} \tag{11}$$

$$\Delta_{max} = \underset{i}{maks}\, \underset{j}{maks}\, \Delta_{0i}^{(j)} \tag{12}$$

$$\Delta_{min} = \underset{i}{min}\, \underset{j}{min}\, \Delta_{0i}^{(j)} \tag{13}$$

Step 8. Using Equation (14), the grey associative degrees (Γ_{0i}) of the alternatives are calculated when a high grey relational degree value of an alternative indicates a high similarity with the reference series. The expression $w_i^{(j)}$ in Equation (14) shows the weights of the criteria.

$$\Gamma_{0i} = \sum_{j=1}^{n} [w_i^{(j)} . \gamma_{0i}^{(j)}] \tag{14}$$

Application

In practice, the innovation performances of BRICS countries are compared with an integrated approach in which CRITIC and GRA methods are embedded. Criterion weights are determined by the latter method. Criteria evaluated in the practical application are listed as follows; higher education (C_1), international joint publications (C_2), most cited publications (C_3), public-private joint publications (C_4), PCT patents (C_5), trademarks (C_6), designs (C_7) and medium and high-tech exports (C_8). The innovation performances of the five BRICS countries (Brazil (A_1), Russia (A_2), India (A_3), China (A_4) and South Africa (A_5)) are then compared using the GRA, taking into account the aforementioned eight criteria. The data and criteria used in the study are compiled using statistics obtained from the EIS-EU and global competitors' database (Europa, 2022). The steps followed in the application are presented below.

Step 1. The innovation performances of the five BRICS countries are evaluated vis-a-vis the eight pre-defined criteria. The DM created is given in Table 1.

Table 1: DM

-	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.267	0.219	0.299	0.056	0.004	0.112	0.035	0.258
A_2	0.896	0.258	0.078	0.126	0.021	0.403	0.184	0.049
A_3	0.153	0.042	0.336	0.005	0.023	0.022	0.01	0.403
A_4	0.155	0.197	0.707	0.179	0.496	1	0.952	0.747
A_5	0.024	0.322	0.417	0.08	0.049	0.256	0.18	0.421

Step 2. All criteria used in the application are benefit based. Therefore, the normalization process is performed using Equation (2) for all criteria. The normalized DM created is shown in Table 2.

Table 2: Normalized DM

-	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.279	0.632	0.351	0.293	0.000	0.092	0.027	0.299
A_2	1	0.771	0	0.695	0.035	0.390	0.185	0
A_3	0.148	0	0.410	0	0.039	0	0	0.507
A_4	0.150	0.554	1	1	1	1	1	1
A_5	0	1	0.539	0.431	0.091	0.239	0.180	0.533

Step 3. The correlation coefficients for all criteria pairs are calculated using Equation (4), and the correlation matrix between criteria is obtained (Table 3).

Table 3: Correlation matrix between criteria

-	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
C_1	1	0.167	-0.728	0.272	-0.260	0.036	-0.148	-0.741
C_2	0.167	1	-0.085	0.485	-0.027	0.228	0.115	-0.198
C_3	-0.728	-0.085	1	0.401	0.850	0.646	0.781	0.989
C_4	0.272	0.485	0.401	1	0.760	0.940	0.857	0.331
C_5	-0.260	-0.027	0.850	0.760	1	0.933	0.985	0.831
C_6	0.036	0.228	0.646	0.940	0.933	1	0.979	0.604
C_7	-0.148	0.115	0.781	0.857	0.985	0.979	1	0.750
C_8	-0.741	-0.198	0.989	0.331	0.831	0.604	0.750	1

Step 4. C_j values are calculated for each criterion using Equations (5) and (6). First, σ_j values of all criteria are obtained using Equation (5). Then, the linear relationship coefficients derived for all pairs of criteria are subtracted from 1, and "1-ρ_{jk}" values are calculated. Finally, C_j values of all criteria are determined by Equation (6). Calculated σ_j, total 1-ρ_{jk} and finally C_j values are given in Table 4.

Table 4: C_j criteria values

-	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
$\sum_{k=1}^{n}(1-\rho_{jk})$	8.403	6.316	4.146	2.953	2.927	2.633	2.680	4.434
σ_j	0.395	0.372	0.362	0.382	0.430	0.395	0.412	0.366
C_j	3.321	2.347	1.500	1.129	1.259	1.041	1.105	1.624

Step 5. The criterion-weighted values of all criteria are obtained by applying Equation (7). The weights of the criteria are listed as w_1 = 0.249, w_2 = 0.176, w_3 = 0.113, w_4 = 0.085, w_5 = 0.094, w_6 = 0.078, w_7 = 0.083, and w_8 = 0.122.

Step 6. The reference series is created in the format x_0 = (1, 1, 1, 1, 1). The absolute value matrix formulated using Equation (9) is given in Table 5.

Table 5: Absolute value matrix

-	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.721	0.368	0.649	0.707	1	0.908	0.973	0.701
A_2	0	0.229	1	0.305	0.965	0.61	0.815	1
A_3	0.852	1	0.59	1	0.961	1	1	0.493
A_4	0.85	0.446	0	0	0	0	0	0
A_5	1	0	0.461	0.569	0.909	0.761	0.82	0.467

Step 7. Using Equation (11–12–13), a grey correlation coefficient matrix is obtained (Table 6). The discriminant coefficient value in Equation (11) is taken as 0.5.

Table 6: Grey relational coefficient matrix

-	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	0.410	0.576	0.435	0.414	0.333	0.355	0.339	0.416
A_2	1	0.686	0.333	0.621	0.341	0.45	0.38	0.333
A_3	0.37	0.333	0.459	0.333	0.342	0.333	0.333	0.504
A_4	0.37	0.529	1	1	1	1	1	1
A_5	0.333	1	0.52	0.468	0.355	0.397	0.379	0.517

Step 8. Using Equation (14), the grey relational degree values of all alternatives are obtained in which the values calculated in Step 5 via the CRITIC method are used for the criterion weights. The ranking results of the alternatives are presented in Table 7.

Table 7: Grey relational degree values of alternatives

-	Γ_{0i}	Ranking	Γ_{0i}
A_1	0,426	4	0,426
A_2	0,6	2	0,6
A_3	0,378	5	0,378
A_4	0,76	1	0,76
A_5	0,516	3	0,516

The success of BRICS countries in terms of innovation performance can be evaluated based on the Γ_{0i} value (Table 7). It is determined that the BRICS countries with the highest success in terms of innovation performance are China (A_4) and Russia (A_2). South Africa (A_5), Brazil (A_1) and India (A_3) then follow the first two performers.

Discussion and Conclusions

BRICS countries, having gained recognition for their investments in technology in recent years, have become a part of the world community that conducts research. Considered an important benchmarking tool in the field of technology policies, the EIS provides a detailed analysis of the innovation efficiency of many regions. This assessment aims to compare the innovation efficiency of the BRICS region with a hybrid approach using the CRITIC and GRA techniques.

The weight of the eight criteria determined in the first stage is calculated using the CRITIC technique. The results are based on the significance of the criteria for higher education (0.249), international joint publications (0.176), medium- and high-technology exports (0.122), frequently cited publications (0.113), PCT patents (0.094), public–private joint publications (0.085), designs (0.083), and trademarks (0.078). Then the innovation performances of the countries are compared using the GRA technique in which the outcome ranks the BRICS countries vis-a-vis their innovation performance as follows: China (0.76), Russia (0.6), South Africa (0.516), Brazil (0.426), and India (0.378). India and Brazil, whose innovation performance was found to be low as a result of the analysis, need to increase their innovation performance by focusing especially on components with high importance. In the perspective of this study, the criteria with the highest degree of importance were determined to be higher education and international joint publications. With long-term and systematic studies, these countries can create harmony with a more effective and healthy understanding of innovation. This will have a significant impact on the economic development of countries.

Showing the highest innovation performance among the BRICS countries, China stands out, especially in trademarks and designs. Taking second place, Russia’s success in higher education is striking. While South Africa is successful in international joint publications, it lags behind its counterparts in higher education. Brazil and India fail to show an effective performance in PCT patents, and public–private joint publications and design, respectively.

In future studies, other decision-making techniques can be applied and the results compared. Furthermore, subjective weighting methods can be applied by an expert committee, particularly in the criterion weighting process, and the innovation performances of different country groups can be compared. In addition, analysing the information and technology investments of BRICS countries using different datasets may also provide meaningful inferences. The number of evaluation criteria used in the performance evaluation process can be increased and more detailed findings can be obtained. In future studies, the innovation performances of countries can be analysed not only on the basis of the eight factors presented in the EIS, but also from the perspective of different variables and sub-variables.

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