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ANALYSIS OF INNOVATION IN BRICS COUNTRIES

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Abstract: The process of globalization creates intense competition in the global market, requiring the economies of all countries to gain a competitive advantage through the development of innovation. This paper analyzes the innovation capabilities of all ten BRICS member states, including both the founding countries (Brazil, Russia, India, China, and South Africa) and the new members (Egypt, Ethiopia, Indonesia, Iran, and the United Arab Emirates). The analysis is based on the values of the Global Innovation Index (GII), which contributes to the creation of an environment in which innovation factors are continuously assessed and enables a comprehensive evaluation of innovation policies. The aim of the paper is to group BRICS countries into a homogeneous cluster in order to better understand their innovation capacities based on data collected over a five-year period. The research results provide a more comprehensive insight into the position of each BRICS member, identifying both the countries that stand out as leaders in innovation and those that lag behind.

Keywords: Innovation, Global Innovation Index, BRICS, Cluster analysis.

1. INTRODUCTION

The current level of innovative development in many countries, particularly in developing and emerging economies, remains insufficient to achieve comprehensive structural and institutional modernization of their economic systems. This insufficiency is further exacerbated by the pressures of globalization, which continuously challenge national innovation systems and compel them to adapt to the evolving demands of the global market. Contemporary literature has already identified a positive correlation between economic, political, and social dimensions of globalization and the performance of technological innovation, suggesting that successful integration into the global system can enhance

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innovation capacity—provided that domestic systems are adequately prepared to respond (Petkovski, 2023).

In this context, it becomes clear that successful integration into the global system, while capable of enhancing innovation capacity, requires not only the adaptation of domestic innovation systems but also their substantial strengthening through coordinated integration and innovation processes. This is precisely where integration and innovation must act synergistically: innovation potential, although an integral part of integration potential, simultaneously influences its further deepening and development. In the case of countries such as BRICS members, the alignment of development policies and research programs, the expansion of financial resources, and the creation of a shared technological framework open up broader opportunities for innovation and enable deeper economic interconnectedness. A key factor in realizing this potential is the unification of national efforts toward integration with innovation-driven development trends, thereby forming a unified trajectory toward sustainable modernization and competitiveness within the global market (Sidorova, 2018).

The combination of the Global Innovation Index (GII) and cluster analysis provides deeper insights into the innovation performance of BRICS countries and enables the identification of key factors influencing their innovation capacity. The aim of this paper is to explore the application of GII and cluster analysis in studying innovation within BRICS nations. Cluster analysis is used to determine which BRICS countries lead in innovation and which are lagging, grouping them according to similarities in their innovation characteristics. This approach facilitates the identification of shared challenges and opens up opportunities for mutual cooperation aimed at fostering innovation-driven development (Nikolić et al., 2024).

The initial part of the paper presents a review of relevant literature on innovation, its importance for economic development, and methods for measuring innovation capacity. The paper then analyzes the positions of BRICS countries based on the GII, with a focus on their specific strengths and weaknesses. The next section outlines the research methodology, including a description of the Global Innovation Index and cluster analysis as tools for grouping countries according to innovation parameters. Based on the research results, key innovation factors in BRICS countries will be identified, along with their classification into homogeneous cluster groups.

In the final section, the paper discusses the implications of the findings and provides policy recommendations aimed at strengthening innovation capacity within the BRICS framework. It also offers suggestions for future research and specific actions that could contribute to the development of innovation and the promotion of sustainable economic growth in these countries. This study contributes to a better understanding of innovation processes within BRICS and provides a foundation for developing effective strategies to enhance competitiveness and technological advancement in this international partnership.

2. LITERATURE REVIEW

Innovations are increasingly recognized as a key driver of economic development and global competitive advantage. In this context, states bear the responsibility to formulate and implement appropriate policies aimed at enhancing their national innovation capacities. A considerable body of literature has examined the innovation performance of BRICS countries; however, nearly all existing studies have focused exclusively on the original five members of the bloc: Brazil, Russia, India, China, and South Africa. To date, academic research has not included the newly admitted members — Egypt, Ethiopia, Indonesia, Iran, and the United Arab Emirates — which can be attributed to their relatively recent accession to the alliance.

One representative study in this field is by Petkovski (2023), in which the author aimed to construct a structural model of the innovation environment within BRICS countries, using indicators based on the Global Innovation Index (GII). The research covered only the founding BRICS members and revealed significant disparities in innovation capacity levels. The most notable progress was observed in China and India, while Brazil exhibited a decline in innovation potential, indicating the need for a revision of its national innovation policies.

Another highly relevant study investigating the determinants of national innovation system efficiency in BRICS countries is Yuezhou (2011). This research utilizes Data Envelopment Analysis (DEA) in conjunction with panel data analysis to evaluate performance over time. The findings reveal considerable disparities in efficiency: China, India, and Russia attain relatively high scores, while Brazil and South Africa lag behind, pointing to the necessity of structural reforms and policy improvements in these countries.

Although cluster analysis has most frequently been applied to innovation research within the European Union and other European nations, such methodological approaches provide a valuable foundation for analyzing BRICS countries as well. The work of Nikolić et al. (2024) serves as an illustrative example; through cluster analysis of innovation indicators, the authors grouped EU countries based on similarities derived from the Global Innovation Index. This approach enabled a clearer understanding of innovation capacities and contributed to the development of more effective policy measures. Given the diversity of innovation profiles among BRICS members, cluster analysis could prove to be a useful tool for identifying groups of countries with shared challenges and capabilities, thus facilitating the formulation of targeted innovation strategies.

A particularly noteworthy contribution to the literature is the study by Sidorova (2018), which analyzes BRICS countries' innovation capacities through hierarchical cluster analysis using data on the number of researchers, R&D investments, patent registrations, and technological exports. The author identified two clusters: one comprising China as the innovation leader, and the other including the remaining countries with lower and more fragmented innovation performance. Although China clearly stands out, its advantages are not absolute. Russia ranks highest on several key indices, including the Knowledge-Based Economy Index and the Global Modernization Index. In general, each BRICS country possesses distinct strengths in developing and deploying national innovation potential. Despite its structural limitations, South Africa demonstrates comparatively strong results in institutional development and market sophistication among BRICS members. The research emphasizes the importance of coordinated research programs and investment in education as critical factors for improving innovation systems within the BRICS framework.

While studies on BRICS remain limited in scope, existing research underscores the need for more extensive comparative analyses and a broader inclusion of newly admitted members. Such efforts would enhance the understanding of innovation dynamics within the BRICS alliance and support the creation of more targeted and effective innovation policies.

3. GLOBAL INNOVATION INDEX IN BRICS COUNTRIES

The GII is one of the most relevant tools for measuring the innovation capabilities of countries worldwide and is therefore applicable to BRICS member states as well. This index combines a range of indicators related to the input dimensions of innovation—such as institutions, human capital, research, infrastructure, and market sophistication—as well as output indicators encompassing knowledge creation, technological products, and creative outputs. In the context of BRICS countries, the GII enables a comparative analysis of innovation potential among member states by identifying their strengths and weaknesses within national

innovation systems. Existing research reveals significant disparities among these countries: China and India demonstrate consistent growth and dominate across most innovation indicators, while Brazil and South Africa are frequently ranked lower due to limited investments in research and development and weaker institutional support. The inclusion of new members such as Egypt, Ethiopia, Indonesia, Iran, and the United Arab Emirates introduces additional challenges and underscores the need for expanded analyses to better understand their innovation positions within the BRICS framework. As a tool, the GII provides a solid foundation for designing innovation-stimulating policies, enabling decision-makers to identify trends, monitor progress, and align strategies with the demands of the global innovation landscape.

3.1. The BRICS group

The acronym BRIC was first introduced in 2001 by Goldman Sachs in its paper titled Building Better Global Economic BRICs, which presented growth projections for four leading emerging economies that are ethnically and geographically heterogeneous. The term was quickly adopted by the public, particularly in the media. The original group consisted of Brazil, Russia, India, and China. In 2010, a new acronym—BRICS—was introduced with the inclusion of South Africa into the initial BRIC group. This expansion extended the alliance to encompass over 40% of the global population and nearly 30% of the world's land mass (Rajput et al. 2012).

By early 2023, the five founding BRICS members had, in terms of Gross Domestic Product (GDP) measured by Purchasing Power Parity (PPP), surpassed the G7 countries, accounting for approximately 31.5% of global GDP. The G7 comprises the world's most industrialized nations and collectively represents around 58% of global net wealth. The Group of Seven was established in 1976, when Canada joined the original Group of Six (G6), which included France, Germany, Italy, Japan, the United Kingdom, and the United States (Statista, 2025). Figure 1 shows the geographical distribution of G7 and BRICS member countries (Statista, 2025; BRICS, 2025).

Figure 1. G7 and BRICS member countries (Statista, 2025)

On January 1, 2024, the BRICS group welcomed four new members: Egypt, Ethiopia, Iran, and the United Arab Emirates, followed by the accession of Indonesia on January 6, 2025.

The aim of this most recent expansion is to promote the creation of a multipolar world order that amplifies the previously marginalized voices of the Global South and seeks to reduce the dominance of the Global North, positioning BRICS member states at the center of the global agenda (BRICS, 2025).

3.2. The Global Innovation Index (GII)

The Global Innovation Index (GII) was established by the World Intellectual Property Organization (WIPO) with the aim of systematically monitoring and reporting on key global innovation trends, as well as ranking countries based on their innovation performance on an international scale. Since 2007, the index has been published annually through a collaboration between INSEAD, Cornell University, and WIPO. To facilitate a clearer understanding of the interrelationships between various dimensions of innovation, a graphical representation of the GII conceptual framework is used, as shown in Figure 2. Calculating the overall GII score is a complex process that encompasses numerous dimensions and components. Each GII component corresponds to a specific index developed by the World Bank, UNESCO, or other relevant institutions, and is expressed through quantitative, qualitative, or composite indicators (the latter being calculated as a weighted average of the respective components). In order to enable comparisons and ranking, all indicators are normalized on a scale from 0 to 100 using the min-max method. Rankings are published both for the overall GII and for each individual dimension and component (Nikolić et al., 2024, WIPO, 2025).

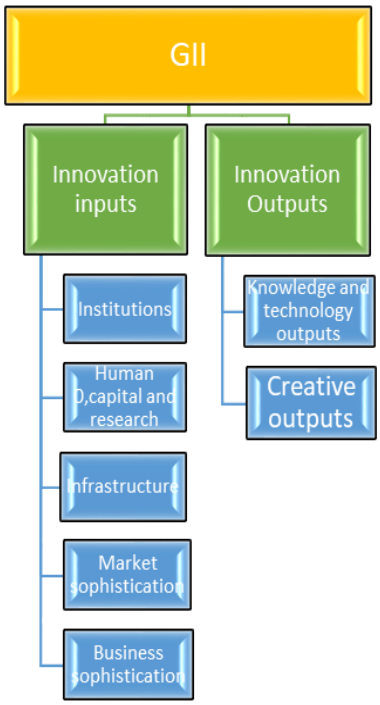

Figure 2. GII Dimensions (Nikolić et al., 2024)

The main objective of this research is to explore the innovation capabilities of BRICS countries. Accordingly, the study was conducted on a sample of BRICS member states, which now includes ten countries: Brazil, Russia, India, China, South Africa, Egypt, Ethiopia, the United Arab Emirates, Indonesia, and Iran. The BRICS framework represents a particularly intriguing area of research, as this alliance is now considered the fastest-growing market in the

world, encompassing nearly half of the global population. Therefore, its role in the field of innovation is highly significant. Some studies suggest that population growth trends are closely linked to intensive technological innovation, as in highly populated countries, demand is largely driven by population size (Coccia, 2014). Moreover, the population structure of BRICS countries shows a continuing increase across all member states (World Data Bank, 2023). This factor has thus emerged as a key reason for including BRICS data in the present research (Petkovski, 2023).

The Global Innovation Index (GII) for 2025 consists of seven key dimensions that offer a comprehensive overview of a country's innovation potential.

The *Institutional dimension* covers the political, regulatory, and business environment, all of which significantly influence innovation development.

Human capital and research evaluate educational resources, investments in education, and scientific activity.

Infrastructure includes access to ICT, general infrastructure (such as energy and logistics), and environmental sustainability. *Market sophistication* measures access to finance, trade flows, and the level of competition.

Business sophistication includes the number of skilled workers, collaboration between academia and industry, and firms' capacity to adopt new technologies.

Knowledge and technology outputs refer to the number of patents and scientific publications, the economic impact of knowledge, and its diffusion through technology and investment.

Creative outputs encompass intangible assets, cultural and digital content, including mobile apps and online presence.

This framework allows for accurate comparisons between countries and a better understanding of their innovation performance.

4. DATA AND METHODOLOGY

The introduction of cluster analysis as a methodological approach in the study of innovation within BRICS member countries represents a significant step toward understanding the complex dynamics of their innovation systems. This method enables the identification of behavioral patterns and shared characteristics among BRICS nations, thus providing a basis for the formulation of innovation policies that reflect the current state of development. The application of cluster analysis facilitates the recognition of similarities and differences in institutional frameworks, human capital, infrastructure, and technological capacities among these countries, further contributing to their strategic positioning within the global economy.

Cluster analysis also allows for the identification of countries with high innovation potential, the mapping of regional specificities, and the diagnosis of barriers that hinder innovation development. It is particularly useful in the context of pronounced economic, cultural, and political differences that exist among BRICS members, as it supports the exploration of opportunities for collaboration and knowledge exchange. Rather than promoting a uniform model, this analysis highlights the need for flexible, tailored approaches that take into account local conditions and development priorities.

In this context, cluster analysis emerges as a valuable tool for improving both national and transnational innovation strategies, strengthening the competitiveness of BRICS countries, and creating sustainable pathways toward technological and economic progress.

In this study, cluster analysis was applied to the values of seven dimensions of the Global Innovation Index (GII) for BRICS member countries, including the five new members: Egypt, Ethiopia, Indonesia, Iran, and the United Arab Emirates. Table 1 presents the average

values for all innovation parameters over the period from 2020 to 2024. For each country, indicators such as human capital, research and development, infrastructure, market, business environment, knowledge creation, and technological outputs were analyzed. The aim was to identify similarities and differences in the innovation profiles of the countries and, based on the results, to propose tailored innovation policies.

In the application of cluster analysis, the exact number of groups into which the observation units will be classified is often not known in advance. Therefore, a two-step approach is commonly employed to determine the most appropriate cluster structure. In the first stage, hierarchical cluster analysis using Ward's method is applied to estimate the optimal number of clusters. Subsequently, in the second stage, the analysis is repeated with the predetermined number of clusters in order to allocate each observation unit to its respective group. The entire procedure is carried out using the SPSS statistical software package.

Table 1. Average values for 10 countries in the time period from 2020 to 2024 (WIPO, 2025)

Number	Country	Total GII	Institution	Human capital and research	Infrastructure	Market sophistication	Bussines sophistication	Knowledge and technological results	Creativity
1	**Brazil**	69,40	91,40	62,40	74,20	75,60	54,20	64,80	73,20
2	**Egypt**	90,20	107,40	94,20	93,20	90,00	103,00	74,40	88,00
3	**Ethiopia**	125,00	115,00	129,80	121,40	124,20	125,20	84,60	121,80
4	**India**	42,60	57,40	51,20	78,00	24,20	55,20	26,80	55,20
5	**Indonesia**	72,40	79,80	89,60	70,40	45,40	94,20	71,40	75,80
6	**Iran**	61,00	127,80	54,60	81,20	47,40	113,80	51,80	44,40
7	**South Africa**	62,00	74,00	76,20	76,40	34,20	58,40	59,60	67,80
8	**China**	12,00	50,40	21,20	23,40	15,20	14,20	5,20	13,00
9	**Russian Federation**	49,80	92,69	30,20	66,60	55,40	45,40	51,00	54,00
10	**United Arab Emirates**	32,40	16,80	17,80	14,00	26,00	23,40	62,20	41,80

5. RESULTS AND DISCUSSION

Table 2 presents the agglomeration coefficients for each step of the hierarchical cluster analysis conducted on the sample of BRICS countries. The table outlines nine merging stages, illustrating the formation of clusters from ten down to one. The column containing the agglomeration coefficients enables the observation of similarity changes between country groups at each stage. Notably, stages 8 and 9 exhibit a sharp increase in coefficients, rising from 19123,673 to 40161,245, and subsequently to 75297,652. These values indicate that clusters merged at these stages are significantly less similar. Based on this observation, it can be concluded that the optimal number of clusters among the BRICS countries is *three*. Beyond this point, further merging results in a loss of homogeneity among country groups.

Table 2. Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	5	7	985,840	0	0	6
2	1	9	2280,220	0	0	3
3	1	4	5174,587	2	0	6
4	8	10	8138,967	0	0	8
5	2	3	11259,647	0	0	9
6	1	5	14391,268	3	1	7
7	1	6	19123,673	6	0	8
8	1	8	40161,245	7	4	9
9	1	2	75297,652	8	5	0

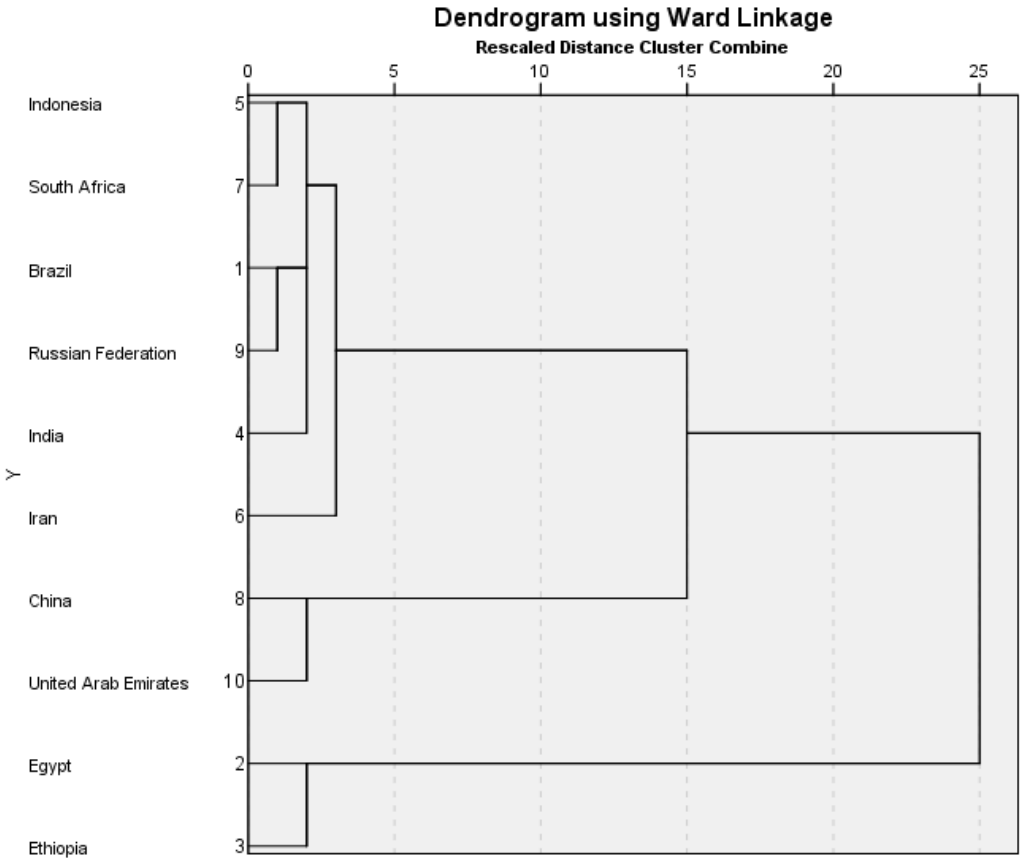

Figure 3. Dendrogram for determining the number of clusters

Figure 3 presents a dendrogram constructed using the hierarchical clustering method with Ward's linkage, analyzing the member states of the expanded BRICS alliance (commonly referred to as BRICS+). This designation includes ten countries: Brazil, Russia, India, China, South Africa, as well as newly affiliated members—Egypt, Ethiopia, Iran, the United Arab Emirates, and Indonesia.

The dendrogram reveals the formation of three clearly differentiated clusters:

The first cluster, comprising Brazil, Russia, India, Indonesia, Iran, and South Africa, is characterized by a moderate level of innovation development. These countries are grouped at a relatively low level of rescaled distance, indicating a high degree of similarity in their innovation-related characteristics. The countries within this cluster exhibit moderate innovation performance, along with potential for further progress through enhanced infrastructure and research capacity.

The second cluster includes China and the United Arab Emirates, which demonstrate a high degree of mutual similarity, yet merge with the previous group at a higher hierarchical level. These countries lead in terms of innovativeness within the BRICS+ group. This can be attributed to strong investments in technology, education, and research and development (R&D), as well as the presence of effective institutional frameworks that support innovation.

The third cluster, consisting of Egypt and Ethiopia, stands out as the most distinct pairing and the most distant from other member states, indicating significant differences in innovation capacity compared to the rest of the BRICS+ countries. This cluster represents the countries with the lowest innovation capabilities within the analyzed group. Their limited innovation output is largely due to insufficient investment in research infrastructure, education, and technological advancement.

6. CONCLUSION

Based on the analysis of the innovation capacities of the expanded BRICS alliance using cluster analysis, it can be concluded that this method represents an effective tool for understanding the complex relationships among countries in terms of innovation. Cluster analysis enabled the identification of behavioral patterns, institutional similarities and differences, as well as technological capacities across member states, thus laying the foundation for the formulation of tailored innovation policies. The formation of three distinct clusters indicates the existence of significant differences in levels of innovation development: the first cluster includes countries with moderate innovation capacities, the second consists of innovation leaders, while the third encompasses countries with limited potential. Notably, the analysis does not promote a one-size-fits-all development model, but rather emphasizes the importance of flexible approaches that account for local conditions and development priorities.

The identification of China and the UAE as innovation leaders confirms the effectiveness of their institutional frameworks and sustained investments in education and research, whereas Egypt and Ethiopia highlight the need for substantial improvements in infrastructure and technological advancement. This classification allows more strategic positioning of BRICS countries within the global economy and opens up opportunities for mutual cooperation and knowledge exchange. Furthermore, the use of cluster analysis provides a basis for designing national and transnational innovation strategies aimed at enhancing competitiveness and fostering sustainable technological progress. Overall, the findings suggest that despite economic and political differences, BRICS+ countries possess potential for mutual learning and collective strengthening of their innovation systems.

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