Chapter 1
A Trajectory of Innovation Outputs among the BRICS Countries: Critical Perspectives of Brazil, Russia, India, China, and South Africa

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Abstract

Brazil, Russia, India, China, and South Africa (BRICS) are the important players of the emerging markets in the global economy and their innovation profiles matter for the economic growth of individual countries and the block. The purpose of this paper is to critically analyse and compare the international rankings in innovation outputs in terms of knowledge and technology outputs among the BRICS-countries in relation to their economic growth in the last two years. A systematic review methodology was used, the innovation topic was investigated from the practice-based problem. Secondary data is collected from sources and institutions that use statistical data to build country rankings produced by the world intellectual property organisation (WIPO) and the World Bank. The findings show China is well-positioned in innovation ranking followed by Russia. Similarities in innovation evolution are observed among the other three BRICS- countries. Although these similarities exist, India portrays a slightly high prospect in innovation because of its information communication technology success, followed by Brazil and South Africa. The findings also show that their GDPs improve with the innovation ranking of the countries. This study recommends the member countries to strengthen their innovation cooperation and to revisit and adapt the education systems to their innovation aspirations through the production of relevant knowledge.

Keywords: BRICS, innovation outputs, GDP, knowledge economy, cooperation.

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1. Introduction

The transition from industrial economy to the innovation economy requires countries to adopt an innovative approach Ehlers and Lazenby [1]. To develop innovative approach, countries formulate policies that focus on knowledge and technological production in order to advance their economies. This paper looks into BRICS from the lenses of knowledge and technology innovation outputs in relation to the economic growth. It discusses the matters pertaining to critical perspectives on cooperation as far as the BRICS is concerned in the context of promoting economic development of its members. It also elucidates how innovation matters and affects the countries' economic development. Using a comparison, the authors analyse the trajectory of knowledge and technology innovation within the BRICS in relation to the economic growth.

Nel [2] states that innovation is in effect the application of knowledge, its effective acquisition, its impact and its application. In this context, BRICS countries commitment to innovation is likely to be observed through the ability for the block to create and diffuse knowledge. Furthermore, meaningful innovation effort should be translated into an improved GDP growth.

Based on the reviewed literature and using the systematic review design as a methodology, it tackles the issue of knowledge creation, impact, and diffusion and how these factors relate to the economic growth of BRICS countries. A selection of cases to be studied allows the information to be synthesised, evaluated and presented for decision-making purposes. The most relevant findings are presented before managerial and industry implications are presented.

2. Literature Review

This sectionreviews the literature on international innovation rankings and the economic growth of BRICS with regard to innovation. It will briefly look into the innovation trend of the three countries in relation to economic growth. Simpeh [3] reiterated that critical and dominant studies of entrepreneurship and innovation in the early 20th century such as [4], [5] and [6] emphasised on the role that knowledge production to support innovation played in the economic development of countries.

Potts [7] indicated that in a cooperative model of innovation, cooperation appeared essential to improve innovation performance. It was therefore critical to find out whether BRICS countries adopt a cooperative path in addressing and improving the innovation posture in terms of knowledge and technology outputs of the member countries. The question is whether innovation trends of BRICS-countries reflects their economic growth. To this note, it is paramount to compare and analyse the innovation outputs of BRICs countries in relation to their economic performance.

This paper aims to compare and critically analyse the trajectory of knowledge and technology innovation outputs of BRICS-countries in relation to economic growth

for 2018 and 2019. The aim of the study will be achieved through comparing innovation outputs of the BRICS-countries in terms of knowledge creation, knowledge impact and knowledge diffusion; and in addressing the implications of global innovation ranking and innovation cooperation in the economic growth trajectory of BRICS-countries.

Several studies acknowledged that knowledge was practised to support innovation [8]; [9]. Innovation was viewed by economists as an economic factor. To this note, innovation performance became a major policy focused on the cooperation of many economic blocks in the international sphere such as European Union, BRICS, SADC. Although BRICS-countries showed the determination to improve their innovation positions at the beginning of the decade, from 2013, China showed the highest rank among the BRICs countries on the 35th place globally, there are no large differences in terms of global ranking between the rest of BRICs countries, South Africa stood on the 58th place followed by Russia on 62nd, Brazil on place 64 and India on the 66th place [10]. At the end of the decade, in 2018 and 2019, China and Russia showed a great improvement in their innovation standing with China occupying 17th and 14th positions in 2018 and 2019 respectively. In the same context, Russia kept the same 46th position in 2018 and 2019 [10]. On the other hand, Brazil, India and South Africa share similar characteristics in their economies that were likely to impact their innovation outputs. For instance, domestic economic and political uncertainty in South Africa and Brazil presented a challenge for innovation activities. With a focus on knowledge and technology as innovation outputs, individual countries of the block were likely to prioritise cooperation to achieve sustainable economic development goals. In this context, systematic and well-managed innovation became a core focus area for high performing economic development. The fact that BRICS-countries were still categorised as an efficiency-driven economies rather than an innovation-driven economies [10] might hinder the achievement of their innovation goals. An innovation-driven economy was regarded as focusing on innovation, with most organisations producing their products with well-designed processes and launching them as new to the market and within their respective industries. Consequently, economies of innovation-driven countries were likely to improve their gross domestic product (GDP). This means that BRICS' countries would therefore not be expected to improve their GDP. The next section evaluates the innovation profile of BRICS-countries.

2.1 BRICS Innovation Profiles

The Global Innovation Index [10] showed that the beginning of the decade portrayed a bleak innovation trend as Brazil, Russia, India, China and South Africa (BRICS) became a lot less innovative dropping the ranking positions of previous years. With more focus on South Africa, Brazil and India, the following situation may be observed in the last two years in terms of knowledge and technology.

2.2 South Africa, Brazil and India

Although South Africa focused on the collaboration between universities and industry, the country appeared to create many powerful innovation linkages, which revealed that the higher education was weak, just as the ecological sustainability of its economy [10]. Brazil also had a lot of high-tech manufactures and a quite strong R&D environment overall, but its higher education sector was still ranked lower in comparison to other innovative countries, this was the weak point in innovation improvement of the country [11].

India presented a very efficient innovation sector, but that in most cases could not result in a high ranking. India's education sector needed to catch up with the top 100 instutitions in the world. India's environmental performance and economic goals constituted another dilemma in the country's innovation strategy [10].

2.3 Knowledge and Technology as Innovation Outputs

Fu, Li, and Johnson [12] pointed out that experience and learning mattered for knowledge to generate innovation. Laudon and Laudon [13] clarified that knowledge needed to be actionable and shared. Based on the theory of knowledge creation, the spiral process of socialisation, externalisation, combination and internalisation (SECI) could be used to connect and arrange new and existing knowledge [14]; [15]. This section analyses knowledge and technology as innovation outputs pillar with regards to international ranking of innovation. Reviewing the global ranking of the three factors that include knowledge creation, knowledge impact, and knowledge diffusion are regarded as the measurement of knowledge and technology innovation outputs. Gackstatter, Kotzemir, and Meissner [16] reiterated that powerful knowledge base, often centred on technology and innovation, as an important precondition to build and develop an innovation-based economy. To this note, knowledge creation and its impact and diffusion become critical to the innovation performance of BRICS countries.

However, maintaining the process of knowledge creation might result in improvement in innovation [17]. Knowledge creation factors included variables that were traditionally thought to be the fruits of inventions and/or innovations. The five indicators that covered were the result of inventive and innovative activities such as patent applications filed by residents both at the national patent office and at the international level through the PCT; utility model applications filed by residents at the national office; scientific and technical published articles in peer-reviewed journals; and an economy's number of articles received and citable documents [18].

Furthermore, global Innovation Index referred to Knowledge impact as a representation of the impact of innovation activities at the micro- and macro-economic level or related proxies and measured by the increases in labour productivity, the entry density of new firms, spending on computer software, the number of certificates of conformity with standard ISO 9001 on quality management systems issued, and the

measure of high- and medium-high-tech industrial output over total manufactures output.

Lastly, knowledge diffusion was key to innovation such as intellectual property receipts measured by percentage of total trade; high-tech net exports as a percentage of total exports; exports of ICT services as a percentage of total trade; and net outflows of foreign direct investment (FDI) as a percentage of [18].

2.4 China and Russia in Knowledge Management

Ramesh [19] studied knowledge generation and systems put in place innovatively to address the phenomenon in China, in comparison to what happens in India. Research and development (R & D) play a vital role in generating and distributing knowledge in China. China had a particularity of disparity between the City and the rural areas when it came to knowledge creation, impact, and diffusion. Burrows, Drummond, and Martinsons [20] profoundly assessed knowledge management in China and confirms Ramesh [19] on the fact that China approaches knowledge production, management, and output informally, personally and with limiting technological creativity and business excellence. Since the cultural revolution of the Mao Zedong era, culture and social tradition influence the thinking around knowledge systems in this country.

Table 1. Three views of knowledge

Characteristic	Context	Description
Knowledge viewed as an object	The primary aim of the Chinese partner in a Sino-foreign a joint venture is to receive both technical knowledge and business knowledge (technology transfer)	Knowledge viewed as explicit, codifiable, and replicable; joint venture contracts are structured to extract maximum knowledge from foreign partners
Knowledge viewed as a process, albeit a top-down process (one-way information flow)	Chinese firms with complex manufacturing operations must manage and continually upgrade their technical knowledge	Knowledge creation is viewed as the purview of senior management and of trusted, long-serving supervisory staff in whom tacit knowledge resides
Knowledge viewed as a valuable asset forgoing global but locked in the minds of foreigners	Chinese firms seeking to gain access to foreign markets, expanding beyond mainland China, must access international business knowledge	Knowledge, specifically market knowledge viewed as a function of language and cultural understanding; boundary-spanning Chinese recruited to act as a cultural/linguistic bridge

Source: Adapted [21]

China used more personal interactions for knowledge transfer than

technology. State-owned firms were not doing better on the aspect of organisational learning. It was known that IT often provided a platform for Knowledge production and management-knowledge managed in context and not according to rules [20].

The characteristics of knowledge are threefold depending on the context or the situation as shown in Table 1, as far as the Chinese knowledge hub is concerned. This synoptic table presents how knowledge is viewed and how to transfer could be done in manufacturing and the operations in mainland China and abroad. In this context, China's innovation success is based on the early efforts and commitment in terms of knowledge creation and diffusion. This has also been translated into many years of China's economic growth. Table 1 should, therefore, serve of a standard for other BRICS-countries especially Brazil, India and South Africa.

Husted and Michailova [21] looked into the issue of knowledge distribution in Russia. In the same context, Mingaleva and Mirskikh [22] analysed the issue of creation of knowledge and related innovation and how knowledge and skills could be transferred throughout Russia. These studies concluded that innovation in Russian economy was lagging behind despite showing an improvement among the BRICS countries. However, Russia integration into BRICS was emphasising on participation in order to facilitate the innovation development and improve its competitiveness. Maslova and Popova [23] stated that Russia national innovation strategy should be based on current situation in the world in terms of technological leadership and the socio-political context.

3. Research Methodology

This study used the systematic review design to synthesise information on the question of innovation in BRICS-countries. As noted by Briner and Denyer [24], a systematic review as a particular methodology aimed at identifying existing studies about a well-defined topic of investigation as derived from practice-based problems. The design entails selecting and critically evaluating the contributions of different identified studies, analysing and carefully synthesizing the data, and reporting the evidence in a way that facilitates clear conclusions about what is and is not known. A systematic review is considered different from a traditional literature review because it appears as a self-contained research project that explores a clearly defined research problem using existing studies [25].

Being categorised as emerging countries, it is imperative for BRICS members to catch up with other economic blocks such as European Union and North America. The secondary data was used according to the procedure and standards of international datasets used. This systematic review aims to formulate evidence-based perspectives of the innovation ecosystem of BRICs countries.

Purchasing Power Parity **(**PPP) was used to standardise data. Regarded as an economic theory, the purchasing power parity approach served to compare different countries' currencies through a "basket of goods" [26].

However, data-based evidence and innovation metrics were increasingly at the centre of formulating, deploying, and evaluating innovation policies of countries and their economies. The countries and relevant economies were classified according to the World Bank Income Group. Furthermore, data for GDP and GDP per capita were collected by the global innovation Index from the International Monetary Fund World Economic Outlook 2018 database.

In this context, data stringency requirements were used in the attribution of strengths and weaknesses at the sub-pillar level of innovation outputs. These levels were revised in 2019. When economies did not meet a data minimum coverage (DMC) requirement at the sub-pillar level (for sub-pillars with two indicators, the DMC is 2; for three it is 2; for four it is 3, and for five it is 4), they were not attributed a strength or weakness at the sub-pillar either. Furthermore, if the economy in question did not meet the DMC requirements at the sub-pillar level, but it could still obtain a ranking higher than or equal to 10 or a ranking equal to or lower than 100 at the sub-pillar level, for caution this rank was put in brackets. This procedure use by Global Innovation Index was to ensure that incomplete data coverage did not lead to erroneous conclusions about strengths or weaknesses, or particularly about strong or weak sub-pillar rankings. The analysis was based on existing results, review of trends allowed to achieve the objectives of this study.

4. Results and Discussion

It is important to point that Brazil and South Africa are classified as upper-middle-income countries, in contrast, India is regarded as lower-middle-income country. Although the size of the population can justify this classification, it is relevant to indicate that this aspect falls outside the scope of this study.

4.1 Knowledge and Technology Outputs

This section will critically evaluate strengths and weaknesses in terms of indicators that are used to measure the innovation profile of BRICS-countries. The innovation outputs are grouped into two pillars: knowledge and technology outputs, and creative outputs [10]. The first justifies the purpose of this study.

Knowledge creation could be seen as a cornerstone to innovation improvement of any country's economy, Table 2 shows the scores of each measurement variable of innovation outputs and the overall ranking of each country under study. To this note, the scores, and ranking of Brazil, India, Russia, China, and South Africa in terms of knowledge creation. Knowledge creation includes the patents produced and patents in application, utility models, scientific and technical articles published, and citable documents index.

The table 2 further shows that China dominates this category of innovation outputs and similarities are observed in knowledge creation among Brazil, India, and South Africa. The results portray that Brazil produces a high number of patents in

comparison with India and South Africa. However, the patents produced are not necessarily used for economic benefits as there are less patents in application compared to the two countries. Furthermore, South Africa shows a positive posture and leads the two countries in numbers of scientific and technical articles produced.

Table 2. Knowledge Creation

	Brazil		India		South Africa		Russia		China	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Knowledge Creation	**19.8**	**47**	**20.9**	**42**	**19.3**	**48**	**29.9**	**30**	**68.1**	**4**
Patents by origin/bn PPP$ GDP	1.7	50	16	52	0.9	63	5.8	20	53.7	1
PCT patent applications/bn PPP$ GDP	0.2	53	0.2	51	0.3	44	0.2	47	2.1	17
Utility models by origin/bn PPP$ GDP	0.9	25	N/A	N/A	N/A	N/A	2.5	8	72.4	1
Scientific & technical articles/bn. PPP$ GDP	9.7	50	5.3	77	10.3	45	6.9	63	11.9	42
Citable documents H index*	36.3	24	38.9	21	28.4	32	37.4	22	54.2	13

Source: Global Innovation Index [10]

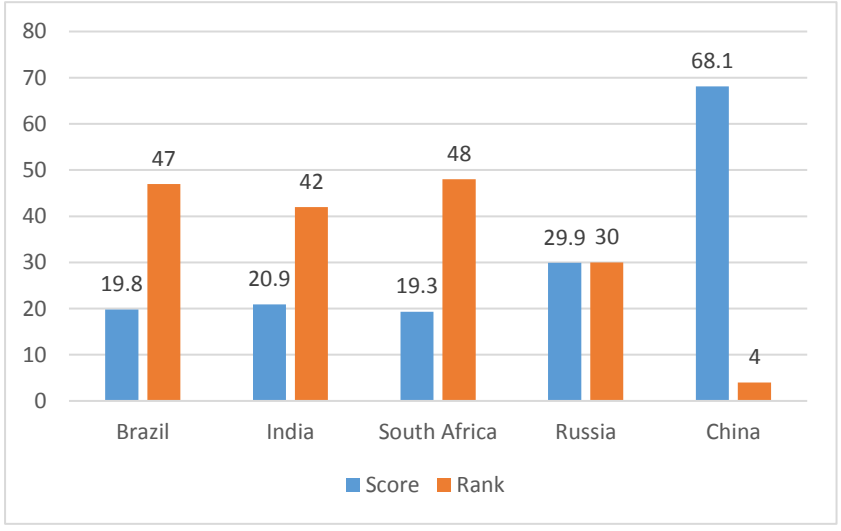

Figure 1. Knowledge creation (Innovation output)

In contrast, India leads articles citations, followed by Brazil and South Africa. In this context, it can be argued that India articles produced have a high impact in the economic advancement of the country. The Figure 1 depicts that China followed by Russia has an improved aggregate ranking among the BRICS countries. The next section will critically analyse knowledge impact.

Table 3. Knowledge Impact

	Brazil		**India**		**South Africa**		**Russia**		**China**	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Knowledge Impact	**31.9**	**86**	**43.4**	**35**	**37.9**	**58**	**33.9**	**77**	**66.6**	**1**
Growth rate of PPP$ GDP/worker, %	-0.3	96	5.9	4	-0.4	97	10	63	7.1	1
New businesses/pop.	0.1	98	0.1	100	10.2	12	4.3	29	N/A	N/A
Computer software spending, % GDP.	0.2	74	0.2	65	0.3	48	0.2	63	0.4	24
ISO 9001 quality certificates/bn PPP$ GDP	5.4	58	3.8	65	5.5	56	0.9	111	16.9	20
High- & medium-high-tech manufactures, %	0.6	32	0.3	33	0.3	40	0.3	43	0.5	12

Source: Global Innovation Index [10]

Table 3 shows the knowledge impact in terms of innovation activities and the manpower involved. This affects economic variables such as growth rate of GDP per worker, new business created per population, computer software spending as a percentage of GDP, ISO 9001 quality certificate produced, and high-tech manufactured. Based on the results provided in Table 3, China is ranked number one, India shows a more improved position with regard to knowledge impact compared to the other two countries, followed by Brazil and South Africa. China and India seem to increase its GDP growth rate in relation to its manpower or worker as they rank number 1 and 4 globally in terms of GDP/worker as depicted in Table 2. Brazil and South Africa show disparities between their GDP growth rate and the quality of human capital. It seems that economic growth is challenged by labour productivity. In addition, South Africa is ranked high with regards to new business creation occupying the 12th position as compared to Brazil 98th and India 100th. In contrast, the failure rate of small and medium enterprises (SMEs) created is over 70% [27]. The findings support the Organization for Economic Co-operation and Development (OECD) [28] that generating employment, contributing to innovation and promoting inclusive growth vary widely across firms and across countries and sectors.

As shown in Figure 2, China ranked number in the world. This is aligned with higher Chinese GDP. The Figure 2 also shows that India is improving its ranking in terms of knowledge impact.

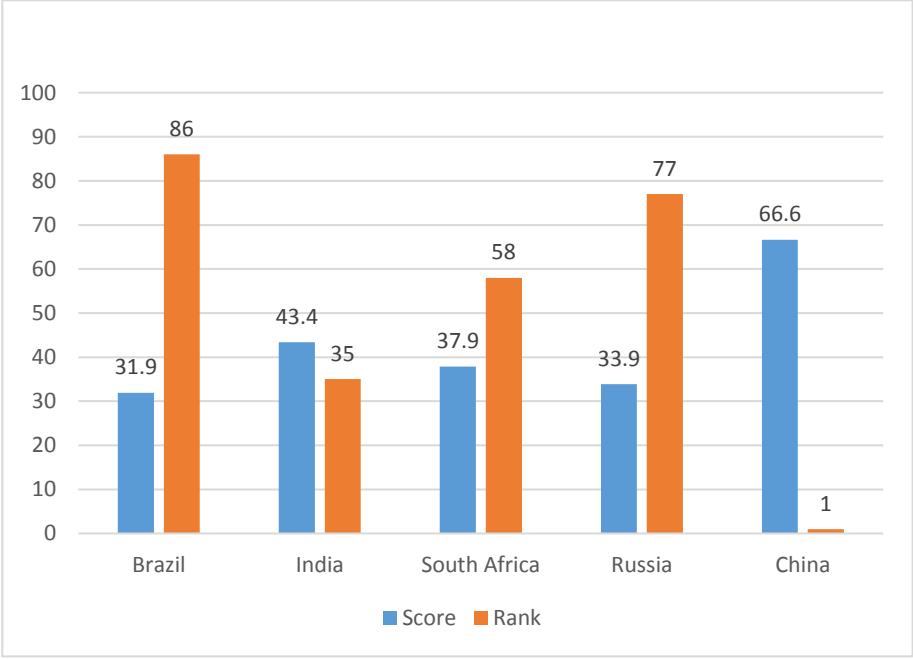

Figure 2. Knowledge Impact (Innovation output)

The results in Table 4 show that to the exception of China, India is leading Russia, Brazil, and South Africa in terms of knowledge diffusion. India ranked high in BRICS and in the world in terms of information and communication Technology (ICT) services exports. It is recognized as one of the leading countries in the world in information and communication Technology. This position provides a big boost to the economic growth of the country. In the same context, South Africa has shown great strength in terms of foreign direct investment (FDI) net outflows in relation to GDP. Although China does more business on the African continent, South Africa remains one of the biggest economies on the African continent. The results in Table 4, show that according to global innovation ranking, South Africa occupies the lowest position in terms of knowledge diffusion in comparison to other BRICS members. This can also be observed in Table 4 in terms of low percentage in total trade. Any attempt of South Africa and other members of BRICS to enter the African and international markets in order to benefit from international trade must revisit the ability to diffuse knowledge and improve the GDP.

The Figure 3 proves that China and India have strong position in terms of knowledge diffusion in comparison with the rest of BRICS counterparts.

Table 4. Knowledge Diffusion

	Brazil		India		South Africa		Russia		China	
	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Knowledge Diffusion	**17.4**	**66**	**36.1**	**23**	**14.4**	**80**	**17.6**	**63**	**37.0**	**22**
Intellectual property receipts, % total trade	0.3	31	0.1	50	0.1	49	0.2	39	0.1	56
High-tech exports less re-exports, % total trade	4.5	32	2.8	46	2.0	55	2.6	49	27.9	1
ICT services exports, % total trade	0.9	84	10.4	1	0.7	91	1.3	71	1.2	75
FDI net outflows, % GDP	0.6	63	0.3	76	18	32	1.9	30	1.4	42

Source: Global Innovation Index [10]

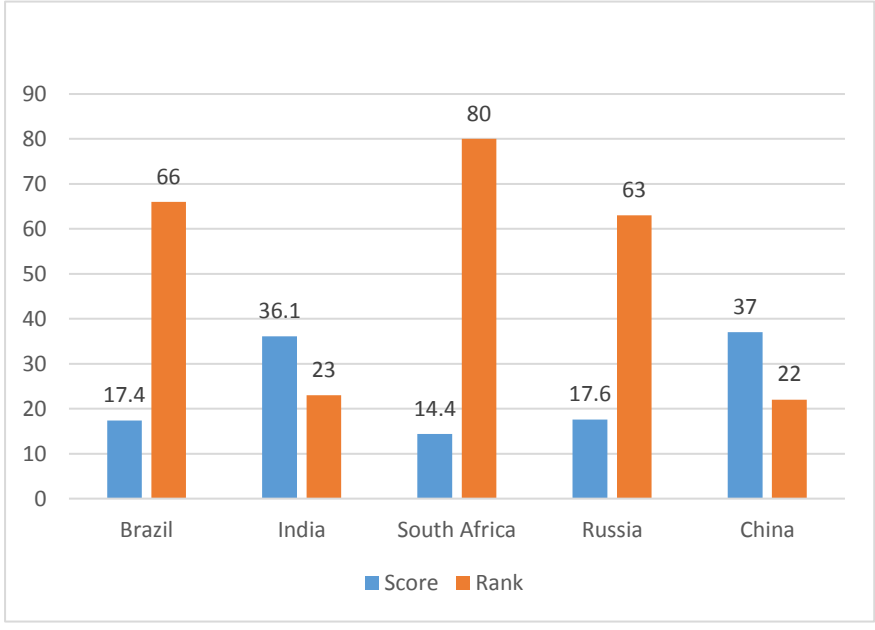

Figure 3. Knowledge diffusion (Innovation output)

Table 5. Economic Profile and Innovation international Rankings for BRICS countries

	Brazil Upper middle Income	**India** Lower middle Income	**South Africa** Upper middle Income	**Russia** Upper middle Income	**China** Upper middle Income
Global innovation ranking 2018	64	57	58	46	17
Global innovation ranking 2019	66	52	63	46	14
GDP (Bn)	3,370.6	10,401.4	790.9	4,179.6	25,313.3
GDP per capita	16,154.3	7,873.7	13,675.3	29,266.9	18,109.8
Population (Mn.)	210.9	1,354.1	57.4	144.0	1,415.0

Source: Global Innovation Index 2019 [10]

Brazil and South Africa innovation positions have dropped two and five places respectively, as shown in Table 5. In contrast, India has shown a great improvement from 57 in 2018 to 52 in 2019. Furthermore, India shows that the improvement of innovation ranking has translated into a greater GDP, but poor GDP per capita is likely the evidence of the large size of the population. However, it is observed that South Africa's serious drop in innovation ranking has a negative impact on its GDP as depicted in Table 5. Russia also shows a greater GDP per capita because of its lower population size in comparison with China, India, and Brazil. In summary of the findings above, China dominates the block in terms of knowledge and technology outputs. More about the knowledge generation and management is discussed in the table below.

5. Conclusion and Managerial Implications

The study compared and critically analysed the international rankings in innovation outputs in terms of knowledge and technology outputs measured by factors such as knowledge creation, knowledge impact, and knowledge diffusion among the three BRICS-countries with regards to their economic growth in the last two years. India performs better in knowledge diffusion with its dominance with ICT export. In terms of knowledge creation, we observe a similar position, though South Africa shows a slightly improved posture. Furthermore, South Africa seems to innovate better with regards to new business created in the economy, but the failure and death rate of SMEs overshadowed the prospect to focus on innovation [29]. Cincalova [30] pointed that any economic policy of the state should be designed to support innovation through sharing knowledge and know-how, as well as activities that promote intensive

knowledge, high skills and adaptability of the workforce. South Africa's innovation policy success lies in how it incorporates both the economic and social environment of innovation [31].

One of the key sectors for a country's innovation strength is higher education. In contrast, the three BRICS countries have their higher education as a shared weakness. South Africa needs the utilisation of efficient local and global knowledge networks in order to deliver the required innovations and to sustain their businesses, improve global ranking scale and to boost economic development [32]. Knowledge was viewed from different perspectives and a variety of ways to produce and disseminate it was discussed. The country innovation policy success lies in how it incorporates both the economic and social environment of innovation [33]. South Africa is in the 141st position in the world and it is found to be the lowest in the regions of this ranking on education system among the BRICS-countries. Mobility among the BRICS countries is to be improved urgently to boost these higher education sectors [10]. Holistically, a knowledge-based growth strategy for innovation should be an important integral part of economic cooperation. A strategy has to be framed to redesign alternative ways to improve innovation through the improvement of input and the appreciation of output dimensions. To this note, Smith [34] asserts that the process of innovation is directly linked to innovation policy. BRICS being a new organisation, Chan and Daim (2012) [35] technology realisation and the selection of appropriate technology from a local perspective; and the support of more elaborated innovation strategies may pose a challenge. As emerging countries, the differences in their aspirations concerning their future role in the global economy, political will, availability of economic resources, technological positions, and social conditions should be considered.

In this context, different strategic orientations of BRICS-countries may hinder innovation. The extent of innovation improvement attracts individual countries of the block is to improve BRICS countries' innovations through a well-defined innovation path embraced by all members.

This study recommends the member countries or the economic leadership to strengthen their innovation cooperation.

It further recommends to revisit and adapt education systems to innovation aspirations of member countries in order to produce knowledge that is relevant to innovations and economic development.

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