Innovation Role in Driving Sustainable Industrial Development: Evidence from BRICS

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Abstract

This study aims to explore the role of technological innovation in supporting the sustainability of industrial development in the BRICS countries. To achieve this, the study used panel data for the five BRICS countries (China, India, Brazil, Russia, and South Africa) over the period 2007-2023, for a total of 80 annual observations. To express sustainable industrial development, the study focused on the ninth Sustainable Development Goal (SDG) called “Industry, Innovation, and Infrastructure” through three main dimensions: developing economic competitiveness, creating shared prosperity, and protecting the environment. This resulted in five indicators that provide an overall view of the sustainability of the industrial sector. The study also relied on the Global Innovation Index to express the level of technological innovation. The study used the panel data fixed effects approach, and the most important results it reached were the ability of the industrial sector in BRICS countries to increase the competitiveness of the economy by increasing the share of industrial value added in the GDP. However, this increase is in favor of traditional industries compared to advanced technological industries, as a result of the relatively low originality of patents in BRICS countries compared to developed countries. These innovations also support the creation of shared prosperity by providing equal opportunities for all with a fair distribution of benefits, as the industrial sector supports increasing the productivity of industrial labor and thus their share of industrial value added through the transformation of the industrial sector from a labor-intensive sector to a technology-intensive sector.

Keywords: Innovation, Sustainable Industrial Development, Environmental Sustainability, BRICS Countries, Panel Data-Fixed Effects Model.

Introduction

According to the Industrial Development Report of 2020, technologically advanced countries that occupy the top positions in Global Innovation Index (GII) dominate global markets. Ten economies produce (70%) of all exports related to these advanced technologies, and 40 other economies actively participate in their development, while The rest of the world does not participate in the creation and use of these technologies at the global level, which has prompted all countries to accelerate their adoption of technology and innovation. As a result, innovation has become a competitive advantage for all advanced and developing economies alike. It leads to a massive increase in production, the creation of new jobs and products, and the achievement of environmental sustainability, which leads to long-term sustainable development (Ge, Y., 2022).

As investment in research and development (R&D) in universities and research institutions is not only a facilitator of industrial innovation, but also one of its most essential requirements (Li, M, et al, 2023: 5). In 2020, China’s R&D spending reached 2.4% of its GDP, the highest among BRICS countries compared to India, Brazil, Russia, and South Africa, which had R&D spending ratios of 0.7%, 0.7%, 1%, and 0.6% of their respective GDPs. In comparison, Egypt’s R&D spending ratio was 0.96% of its GDP. The United States spent 2.99% of its GDP on R&D, which exceeded its average GDP growth rate of 2.3%. so, this study employs panel data-based
econometric modeling approaches to investigate the relationship between innovation, sustainable industrial development, high-tech exports, and the share of R&D expenditures in GDP (Gross Domestic Product), with total patents as the dependent variable in BRICS countries from 2007 to 2023 based on available data.

**Literature Review**

Given the significance of innovation as a mechanism for achieving economic and trade growth, numerous studies have addressed this topic. A few examples are highlighted below:

**Gao (2023)** investigated the relationship between corporate technological innovation, export product quality, and manufacturing value chain upgrading. By using panel data from Chinese manufacturing firms through (2000 – 2013), The study showed that technological innovation significantly promotes manufacturing value chain upgrading, that upgrading the manufacturing value chain results in a 0.28% rise for every 1% increase in firm-level technical innovation. Additionally, Gao found that improving export product quality has a significant positive effect on manufacturing value chain upgrading.

**Xu et al. (2023)** examined the impact of bidirectional foreign direct investment on manufacturing innovation in China. They posit that inward foreign direct investment can enhance technological development, industrial linkage, and technology exposure, thereby promoting industrial structure upgrading in the host country.

**Ge (2022)** explored the influence of innovation activities on the expansion of high-tech firms. The study's findings suggest that industrial transformation is crucial for achieving long-term sustainable economic development.

Overall, these studies suggest that technological innovation is a key driver of the development of China's advanced industrial technology innovation system and manufacturing sector.

Additionally, a study by **de Oliveira, B. F. et al. (2022)** aimed to investigate the relationship between innovative capability and the deindustrialization process. The researchers employed data collected from 80 countries between 1995 and 2016. To assess the extent of deindustrialization, they also utilized a unique dependent variable linked to export quality and industrial competitiveness. According to the data, there is a direct relationship between the share of manufacturing GDP and industrial employment as a percentage of total employment and the quality of industrial exports. With rising income levels, the study found that the impact of the creative process on the dependent variables decreases. However, innovation continues to have a positive effect on industrial strength.

In addition to the studies, several other works have examined the relationship between innovation and sustainable industrial development in BRICS countries. **Solovieva and Mingjun (2021)** aimed to identify and analyze technology transfer systems in BRICS countries to establish specific mechanisms for regulating innovation processes that deliver highly interactive and competitive technological products.

**Durmaz, Atakan, and Ümit Yıldız (2020)** investigated the relationship between innovation and advanced technology exports in BRICS countries from 1999 to 2018. Their findings revealed a strong positive relationship between the number of patents and advanced technology exports in BRICS countries.

**Contributions of the Study**

This study contributes to the existing body of knowledge by addressing three key gaps:

1. **Temporal Gap:** The study examines the relationship between variables during the period 2007-2022, a timeframe not covered by previous studies.
2. **Spatial Gap:** The study focuses on the BRICS group of countries, whereas previous studies have investigated other regions and blocs.
3. **Study Variable Gap (Measurement):** The study employs innovation as an independent variable and analyzes its relationship with sustainable industrial development, measured using three indicators aligned with Sustainable Development Goal 9:
- Developing industrial competitiveness: Expressed as the share of industrial value added in GDP.
- Creating economic prosperity: Measured by the share of workers in the industry and industrial value added per worker.
- Protecting the environment: Represented by the share of carbon dioxide emissions from the industry in total carbon dioxide emissions from fuel combustion.

The study utilizes panel data with fixed effects to analyze the relationship between these variables during the period 2007-2022.

**Theoretical Framework:**

Manufacturing serves as a primary engine of economic growth for developing countries and emerging economies. Technology plays a crucial role in enhancing production efficiency, boosting national competitiveness, and reducing vulnerability to market fluctuations (UNIDO, 2015: 1). Between 1990 and 2014, global manufacturing value added doubled from $4.753 trillion to $9.228 trillion in constant 2005 prices. Since 1992, the growth rate of manufacturing value added in developing countries and emerging economies has consistently outpaced GDP growth (total economic output). By 2014, manufacturing value added in developing countries and emerging economies had increased 2.4 times from its level in 2000 in constant 2005 prices, while their GDP doubled. In contrast, industrialized countries experienced an increase in manufacturing value added of only 51.3% (UNIDO, 2015: 1).

The world has undergone significant changes that have amplified the focus on sustainable manufacturing and innovation. COVID-19 pandemic has fundamentally transformed the global manufacturing landscape, accelerating the transition towards digitalization, green industries, and global rebalancing. The post-pandemic era is characterized by a heightened emphasis on environmental sustainability and social inclusion, aligning with Sustainable Development Goals (Industrial Development Report 2022: 1). Innovation serves as a primary engine of sustainable development, contributing to job creation, improved quality of life, environmental protection, industrial modernization, infrastructure resilience, sustainable technology development, equitable access to information and financial markets, and the creation of safe and prosperous societies (WIPO Report, 2019: 6).

**Concept of Innovation:**

Innovation can be defined as the introduction of new ways of doing things. This definition encompasses aspects such as new organizational structures, products, or processes. (Prieto, 2017: 1). Oyedele further defines innovation as the ability to create and utilize imaginative skills to venture into and invest in new spaces. It is the process of transforming the best creative ideas into reality, thereby generating a series of innovative events that lead to the creation of new value. (Oyedele, 2018: 11). The Organization for Economic Co-operation and Development (OECD) defines investment in innovation as expenditure on research and development (R&D) and software investment. These indicators influence productivity and, consequently, economic growth. (OECD, 2003: 23)

A fundamental distinction exists between innovation and invention. Invention represents the initial step in the innovation process, encompassing the discovery of a novel idea. In contrast, innovation entails the development of a new technology, product, service, or work method (Karol Sledzik, 2015). Schumpeter further defines invention as the discovery and practical application of a new technique, while innovation involves the introduction of new technologies into products and industrial organizational forms (R. Ingles, Lotz).

**Global Innovation Index (GII):**

Global Innovation Index (GII) has been published annually since 2007 by INSEAD, a leading business school, in collaboration with the World Intellectual Property Organization (WIPO) and Cornell University. The index is supported by the Australian government and released on the sidelines of the G20 summit. The GII measures both the inputs and outputs of innovation processes and policies. It also assesses the level of
innovation that emerges from industry-science collaboration and the diffusion of knowledge. The GII is based on two main sub-indices: The Output Sub-index and the Input Sub-index.

**Input Sub-index:**

The Input Sub-index measures the factors that enable innovation. These factors can be broadly categorized into four groups:

1. **Human Capital:** This includes indicators such as quality of education, the number of researchers, and the skills of the workforce.
2. **Infrastructure:** This includes indicators such as access to broadband internet, the quality of roads and transportation, and the availability of energy.
3. **Institutions:** This includes indicators such as the protection of intellectual property, the rule of law, and the government’s support for innovation.
4. **Market Sophistication:** This includes indicators such as the size of the market, the presence of venture capital, and the intensity of competition.

**Output Sub-index:**

The Output Sub-index measures the results of innovation activities. These results can be broadly divided into two main categories:

1. **Knowledge and Technology:** This includes indicators such as the number of patents, trademarks, and scientific publications.
2. **Creative Goods and Services:** This includes indicators such as exports of creative goods and services, and the number of people employed in creative industries.

**Innovation Models:**

Numerous models exist for implementing innovation. These include:

1. **Linear Innovation Model:** This is considered one of the most prevalent innovation models, where the innovation process consists of a series of sequential steps beginning with a scientific invention, followed by its progression to commercialization. It represents one of the most dominant innovation models.
2. **Coupled Innovation Model:** This model represents a dynamic approach to innovation, recognizing the interaction between various elements of the innovation process. It commences with a new need, leading to the creation of a novel idea followed by a new technology. Continuous feedback and evaluation occur at each stage. Additionally, interaction exists between the different phases of the innovation cycle, market requirements, and modern production technologies.
3. **Innovation Activities Model:** This model is considered a fundamental component for successfully marketing ideas and generating social and economic benefits. (Alaa El-Din, 2012: 4-8)

**The Reality of the Global Innovation Index:**

INSEAD(1) has long been a leading reference point in the field of innovation, and since 2007, it has become a working tool for decision-makers seeking to improve their countries’ innovation performance. (Dutta, 2019:36)

According to the 2007 Global Innovation Index report, United States topped the global innovation list among 107 countries with a score of 5.80 out of 10 possible points. Germany followed in second place with 4.89 points, United Kingdom in third place with 4.81 points, Japan in fourth place with 4.48 points, and France in fifth place with 4.32 points. In 2009, the global ranking saw a new change, with Iceland topping the list of 130 countries with a score of 4.86 points, followed by Sweden with 4.85 points, Hong Kong with 4.83 points, Denmark in fifth place with 4.72 points, and Finland with 4.66 points (The Global Innovation Index, 2008/2009:1).

(1) Global innovation index developed by European Institute of administration Affaires.
According to the 2022 Innovation Report (WIPO, 2022: 50), Switzerland topped the list of 132 countries with a score of 64.6 points, followed by the United States with 61.8 points, Sweden in third place with 61.6 points, the United Kingdom with 59.7 points, and the Netherlands and Korea sharing fifth and sixth place with 58.0 and 57.8 points, respectively.

In Global Innovation Index 2023 (WIPO, 2023: 19), United Arab Emirates and Turkey emerged as the top innovators in North Africa and the Middle East with scores of 43.2 and 38.6, respectively. Brazil, Chile, and Mexico held the top three positions among Latin American countries with scores of 33.6, 33.3, and 31, respectively. India secured the first place among South and West Asia with a score of 38.1. In East Asia, Singapore, Korea, and China led the pack with scores of 61.5, 58.6, and 55.3, respectively. Notably, the BRICS countries have demonstrated significant progress in global innovation indicators.

Overview of the BRICS Group:

In 2000, a Goldman Sachs report highlighted the world’s most prominent emerging economies, proposing an economic alliance among them, known as “BRIC.” The concept gained significant traction in 2006 when the foreign ministers of Brazil, Russia, India, and China held a series of conferences and meetings, leading to the official establishment of the BRICS alliance in 2009. South Africa joined in 2010, and more recently, Saudi Arabia, the United Arab Emirates, Egypt, Iran, Argentina, and Ethiopia joined in January 2024.

The BRICS countries represent some of the world’s most important emerging economies. With a combined population of over 3.2 billion, they account for more than 40% of the world’s inhabitants. Their collective GDP exceeds $27 trillion, approximating one-quarter of the global GDP. BRICS nations are also members of the G20, the world’s most powerful economies. Projections indicate that BRICS countries will continue to experience rapid growth in the coming decade, with their combined GDP potentially surpassing that of the G7 (United States, United Kingdom, France, Japan, Germany, Canada, and Italy) by 2030. Playing a pivotal role in the global economy, the BRICS group is poised to exert significant influence on the world in the years to come.

Economic Significance of the BRICS Group:

The growing importance of BRICS group to the global economy is evident through several economic indicators:

- **Rising Share of Global GDP:** BRICS group’s share of global GDP has increased significantly over the past decades, from just over 10% in 1990 to over 25% in 2022, representing a growth of over 150% in two decades.

- **Increasing Share of World Trade and Trade Openness:** BRICS countries have become major players in global trade, with their trade volume expanding considerably and their economies opening more to foreign trade.

- **Growing Foreign Exchange Reserves:** BRICS countries have witnessed substantial growth in their foreign exchange reserves over the years, strengthening their financial stability and ability to withstand economic crises.

- **Inflows and Attraction of Foreign Direct Investment:** BRICS countries have become significant destinations for foreign direct investment, both inbound and outbound, indicating their growing economic attractiveness.

Overall, the rise of the BRICS economies represents a significant shift in the global economic landscape, contributing to increased multipolarity in the international economic system. The importance of this group is expected to continue growing in the coming years, and it will play a pivotal role in shaping the future of the global economy.
In 2015, the BRICS group established an organization called the New Development Bank (NDB) with an authorized capital of US$50 billion and equal shares among the five founding countries. The bank aims to support infrastructure projects in these countries and has successfully financed 70 infrastructure projects worth over US$25 billion in the past five years.

**Assessing Innovation Landscape in BRICS Countries:**

Goldman Sachs’ 2001 report predicted that China would become the world’s largest economy by mid-century, with India, Brazil, and Russia among the top ten. While BRICS nations are not considered global innovation leaders, with China ranking 12th, India 40th, Brazil 49th, Russia 51st, and South Africa 59th globally according to the 2023 Global Innovation Index (WIPO, 2023: 19), they have achieved notable progress regionally. China ranks third in East Asia, India leads South and Central Asia, Brazil tops Latin America and the Caribbean, and South Africa leads Africa (WIPO, 2023: 18).

**Evolution of the Innovation Index in BRICS Countries (2007-2022):**

Figure 1: Remarkable Progress in the Innovation Index of BRICS Countries (2007-2022). Where BRICS countries have experienced significant progress in innovation performance over the period 2007-2022. They have consistently outperformed their innovation inputs, particularly in competitiveness and innovation infrastructure. India and China rank among the top 10 globally in terms of competitiveness and innovation infrastructure. India ranked 42nd out of 107 countries in the 2007 Global Innovation Index with a score of 3.57 points (Dutta, S., & Caulkin, S., 2007). Its ranking declined to 56th in 2009 with a score of 3.10 points. In response, the Indian government launched its “Decade of Innovation” initiative under Vision 2020-2010 (Ministry of Communications & IT, Department of Electronics & Information Technology, 2012). This initiative began to yield results in 2016, with India ranking 66th globally in the Global Innovation Index with a score of 33.61 points.

- India has continued to progress, reaching 40th place in 2022 among 132 countries (WIPO, 2022: 1) and maintaining this position in 2023 (WIPO, 2023: 19).
- This progress is attributed to factors such as increased investment in research and development (2% of GDP), infrastructure development, the establishment of a national science, technology, and innovation agency as a public-private partnership, and the growth of the technology sector (Basu, S. D., 2014).

As China has made significant strides in innovation, rising to 12th place in the 2022 Global Innovation Index compared to its 29th position in 2007. This progress can be attributed to several factors, including increased investment in research and development (R&D), improved education and training, and infrastructure development. The private sector in China has played a crucial role in financing and supporting R&D. However, it is important to note the influence of the government on influential companies in these countries. Both Russia and China own or have stakes in numerous companies whose R&D activities are counted as commercial R&D. Consequently, their industrial R&D activities should be considered driven by political agendas rather than following an individual innovation strategy for any given company. (p:299 Meissner, 2014) R&D spending has reached 2.4% of GDP.

In contrast to the steady progress of China and India, Brazil’s innovation performance has been characterized by fluctuations. In the 2007 Global Innovation Index, Brazil ranked 55th out of 107 countries with a score of 2.84 points (Dutta, S., & Caulkin, S., 2007). Brazil’s innovation performance has been characterized by fluctuations over time. After ranking 55th globally in the 2007 Global Innovation Index, Brazil made a slight improvement to 50th place in 2008 with a score of 3.25 points out of 130 countries. However, the global financial crisis of 2009 took a toll on Brazil’s innovation ranking, causing it to drop to 68th globally with a score of 2.97 points out of 132 countries.
Despite this setback, Brazil demonstrated resilience and made a comeback in 2011, rising to 47th place globally with a score of 37.75 points out of 132 countries (WIPO, 2011). This resurgence can be attributed to several factors, including implementing numerous policies by Government and programmes to promote innovation, and Brazilian companies have responded by developing new technologies and products, which have also contributed to the country’s success in innovation. Some notable examples of Brazilian innovation include Petrobras, the leading external oil exploration company, Ambrair, the world’s first jet manufacturer, and the Brazilian ethanol industry, which produces more than 33% of the world’s ethanol. In 2013, it regressed to Centre 64 by a balance of 36.33 points. The arrangement continued to fluctuate between improvement and decline during that period, reaching Centre 54 in 2022, with a balance of 32.5 points out of 132 States. (WIPO, 2022: 19).


The ranking of 51 globally declined in 2023 with a balance of 33.3 (WIPO, 2023: 19), due to weak institutions, political risks (economic sanctions imposed by United States and Western countries on Russia after its invasion of Ukraine in 2014), tense investment climate and age structure of the population (increased proportion of older persons); this led to a weakening of Russia’s innovative potential, resulting in only 8% of Russian companies being interested in innovation, compared with 41% in China, 51% in Turkey and 64% in India. Its weak R & D spending has also reduced its innovative capacities; its R & D spending amounted to 1.1 per cent of GDP in 2020, and an arrangement of 38 globally, compared to China, which spent 2.4 per cent of GDP on R & D, and 13 globally. (WIPO Intellectual Property Statistics profile for Russia)

Africa’s performance was similar to that of Brazil; the figure also shows that South Africa’s innovation index was between the increase and the decrease during the period (2007-2022), with 38 global rankings, with a balance of 28.7 in 2007 out of 107 countries, increased to 43 worldwide by a balance of 34.1, decreased to 51 in 2010 with a balance of 32.2 in relation to the global financial crisis, and continued to progress until 2014, after which it declined to 61 in 2022 with a balance of 29.8, owing to several factors, including political and economic instability in South Africa, weak research and technological infrastructure and low investment in innovation by small and medium-sized enterprises. South Africa is expected to continue to strengthen its industrial innovation efforts in the coming years, which will help it to achieve its economic and social objectives.

We conclude from this analysis that, despite this marked improvement in the ranking of the global innovation index, the BRICS States continue to face several innovation challenges, including:

- Weak cooperation between the public and private sectors.
- Brain drains.
- Weak intellectual property protection

**Concept of Sustainable Industrial Development:**

The concept of inclusive and sustainable industrial development is embedded within the ninth Sustainable Development Goal (SDG), which calls for focusing on infrastructure that can withstand challenges, promoting industrial practices that are fair and environmentally responsible, and nurturing a culture of innovation. This goal emphasizes achieving industrial growth, economic strength, and inclusivity in a sustainable and resilient manner. It necessitates the effective integration of the economic, social, and environmental dimensions of sustainable development. Sustainable industrial development must embrace social inclusivity and equity. It should promote inclusivity and opportunity for all individuals and communities to participate in and benefit from industrial activities. This includes ensuring fair labor practices, promoting decent work environments, and fostering social dialogue among stakeholders. Yong also defined it as emphasizing the transition towards cleaner and more resource-efficient production methods. He suggests that this approach can gradually decouple economic growth from environmental deterioration. (Yong Li, 2015: 449). Overall, sustainable industrial development seeks to harmonize economic growth, social, and environmental considerations. It strives to achieve economic prosperity while ensuring social equity and environmental sustainability.

**The Role of Innovation in Achieving Sustainable Industrial Development:**

The significance of industry in the growth of emerging economies cannot be overstated. Manufacturing serves as a catalyst for sustainable growth, generating productive employment opportunities, decent jobs, and lifting millions out of poverty. The manufacturing sector also plays a pivotal role in fostering technological advancement and innovation. It holds the majority of research and development investments, which have been proven to generate positive externalities in terms of productivity growth and spillover effects that enhance overall economic growth (UNIDO, 2022: 5). In addition to the impact of innovation, technology-enhanced products hold a greater comparative advantage in exports (Frankel and Romer, 1999).

Mounting evidence supports the notion that industry can steer economies towards a sustainable growth trajectory (UNIDO, 2014b: 14). Industry serves as a natural breeding ground for entrepreneurship, commercial investment, and technological advancement. It enhances technical skills, creating jobs, and shifting the focus from basic survival farming to a more productive and profitable agribusiness sector, it strengthens the rural economy. (Technical Support Team, 2013: 8). This perspective is reflected in Sustainable Development Goal 9, which calls for building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation.

The inextricable link between innovation and socioeconomic advancement is clearly evident, as innovation has been a driving force behind increased capital investment, expanded workforces, enhanced productivity, rising income levels, improved public health, accessible transportation, and better-quality education, all of which underpin strong economic structures and more prosperous societies (World Intellectual Property Organization Report, 2019: 6).

In addition to the three critical elements identified by Altenburg et al. (2021), which can be described as transformative shifts influencing industrial development across social, economic, and political spheres, the future of manufacturing is further shaped by the following:

1. **Digitalization and Automation of Industrial Production:** Technological innovation is permeating all aspects of business development, enhancing the competitive edge of companies and nations. This includes advancements in artificial intelligence (AI), robotics, and Internet of Things (IoT), which are revolutionizing production processes, supply chains, and customer interactions.
2- **Global Economic Power Shifts**: The emergence of new economic powers, particularly in Asia, is re-shaping the global manufacturing landscape. These regions are attracting significant investments in manufacturing infrastructure and are becoming major hubs for production and innovation.

3- **Transition to Green Manufacturing**: The growing global call for carbon emission reduction and ecosystem preservation is driving a shift towards sustainable manufacturing practices. This includes adopting cleaner technologies, reducing waste generation, and promoting circular economy principles.

According to the Industrial Development Report 2022 (UNIDO, 2022: 19), three key indicators reflect the progress of industrial development:

1. Rise of Industrial Robot Density in Manufacturing.
2. Growing Share of Industry’s Value Added in Global Output.
3. Transition towards Sustainable Green Manufacturing.

The pervasiveness of robotics in manufacturing has witnessed a remarkable surge, with a fourfold increase in number of robots deployed between 2000 and 2020, as highlighted by the World Robotics report 2023 (p:11). This trend is further accentuated by the staggering density of robots, reaching an estimated 3.9 million operational robots in 2022.

According to the World Robotics report 2023 (World Robotics report, 2023: 11), there is increasing reliance on robotics in industry in 2000-2020 and that it had quadrupled in 2020 over 2000, and the International Robotics Union Report 2023 had revealed a massive robot density of about 3.9 million active robots in 2022. According to the World Robotics Report (2023), The most robotic-intensive States are: The Republic of Korea (1.012 robots per 10,000 employees), Singapore (730 units) and Germany (415 units). The value added of industry in domestic output, especially for developing and emerging industrial economies, has also increased, particularly in Asia from about 15% in 2000 to about 45% in 2020. (UNIDO, 2022: 20). The shift towards green and sustainable manufacturing, which entails reducing carbon dioxide emissions from industrial activities, has witnessed a promising trajectory. While industrial gas emissions were on the rise since 2000, a downward trend emerged post-2010. By 2018, industrial gas emissions were 15% lower than 2000 levels. Global gas emissions further declined by 5.8% in 2020, primarily driven by the pandemic’s impact on reduced demand for oil and coal (traditional energy sources) and a shift towards renewable energy sources. This reduction represents the largest decline on record, surpassing the 2009 financial crisis reduction by nearly fivefold. Notably, in 2020, carbon dioxide emissions declined at a faster rate than energy demand, highlighting the need for intensified efforts to achieve carbon neutrality goals by 2050 (IEA, 2021).

**Assessing BRICS Countries’ Performance in Achieving Sustainable Development Goal 9 (2007-2020):**

Sustainable Development Goal 9 (SDG9) stands as a pivotal objective within the 2030 Agenda, emphasizing innovation, sustainable industrial development, and resilient and sustainable infrastructure. As such, it serves as a cornerstone for sustainable development across nations (U.N. General Assembly, 2017). Innovation has gained widespread acceptance, aiming to enhance production efficiency and bolster industrial competitiveness, although its primary application lies in developed countries (Afzal, Lawrey, & Gope, 2019). Additionally, promoting international competitiveness through innovation has been recognized as a crucial strategy for attaining sustainable development (Zhang, 2019).

It is clear from the previous figure that the BRICS have achieved advanced positions in the indicators of the ninth sustainable development goal; Brazil has shown remarkable progress towards sustainable development, with 73.689 points in the Sustainable Development Goal Index, particularly with regard to the ninth sustainable development goal (innovation, industry and infrastructure), with 68.969, indicating significant advances in industry, innovation and infrastructure, with Internet use reaching a high of 80.256, indicating widespread access to the digital world. Country excels around road infrastructure, scoring 90.519
points, indicating a well-developed transportation network. Mobile phone usage is also remarkably high at 95.842 points, demonstrating widespread access to mobile technology. Furthermore, university access is impressive, reaching 86.366 points. However, research and development (R&D) activities present an area for growth, with a score of 32.649 points. Nevertheless, the country actively contributes to research, as evidenced by its score of 36.833 points for the number of published research papers.

Figure 2: Evolution of indicators of the ninth BRICS sustainable development goal during the period (2007-2020)

China demonstrates a strong commitment to sustainable development, as evidenced by its high Sustainable Development Goals (SDG) Index score of 72.008. This reflects notable progress across various goals. Within the context of SDG 9, China excels with a score of 80.274, indicating significant strides in industry, innovation, and infrastructure. Internet usage stands at 72.444, demonstrating that a substantial portion of the population has access to the internet. The country also boasts a well-developed road infrastructure, scoring 77.549, while mobile phone usage is widespread, reaching a perfect score of 100. Additionally, logistics and transportation efficiency are exemplary, with a Logistics Performance Index score of 97.864. University access is also excellent, with a score of 100. Investments in R & D are significant at 64.892, and China contributes significantly to global research by 49.167 in published research papers.

In addition, Russia has made significant strides towards achieving sustainable development, as evidenced by its overall Sustainable Development Goals (SDG) Index score of 73.786. Focusing specifically on SDG 9, the score of 75.945 indicates notable progress in the areas of industry, innovation, and infrastructure. Internet usage in Russia is robust and sophisticated, with a user penetration rate of 80.949%, demonstrating ease of access to the digital world and excellence in this domain. Additionally, the country boasts excellent road infrastructure, scoring 92.253, highlighting a well-resourced transportation system. Similarly, mobile phone usage is extremely high and well-developed, reaching a score of 100, indicating significant progress in this area and widespread adoption of mobile technology. Research and development (R&D) activities present an area for improvement, with a score of 29.676, despite excellent university access (100), which positions Russia as a leader in higher education and scientific research to fully capitalize on this field. However, the country makes substantial contributions to global research, with a score of 68.333 for published research papers.

India has also made notable progress towards achieving sustainable development, as evidenced by its overall Sustainable Development Goals (SDG) Index score of 63.449. The SDG 9 score of 50.96 indicates progress in the areas of industry, innovation, and infrastructure, with a focus on this goal. Internet usage remains relatively low at 45.102%, suggesting that a significant portion of the population lacks access to the internet. However, the country boasts a robust road infrastructure, scoring 76.284, highlighting a strong...
and efficient transportation system. Mobile phone usage stands at 53.773%, indicating that a substantial number of people do not have access to mobile technology. Research and development (R&D) activities score 13.083, while university access is excellent, with an overall score of 91.434. Despite this, the country actively contributes to research, as evidenced by the number of published research papers (17.73).

South Africa has also made notable progress towards achieving sustainable development, as evidenced by its overall Sustainable Development Goals (SDG) Index score of 64.003. Focusing specifically on SDG 9, the score of 70.8 indicates significant progress in the areas of industry, innovation, and infrastructure. Internet usage is robust at 71.687%, demonstrating widespread access to the digital world. The country excels in road infrastructure, scoring 92.417, highlighting a well-developed transportation network. Mobile phone usage is also excellent, reaching 100%, indicating widespread adoption of mobile technology. While university access is a remarkable achievement with a score of 100, research and development (R&D) expenditure presents an area for growth, with a score of 16.622. Despite this, the country actively contributes to scientific research, as evidenced by a respectable number of published research papers (42.75).

The BRICS countries’ emphasis on innovation, infrastructure, and technology has led to increased productivity and supported the industrial sector, particularly advanced technology industries. This will be discussed in more detail below.

**Evolution of Industrial Value Added in BRICS Countries: 1990-2022**

Growth of the industrial sector has been a significant contributor to the economies of BRICS countries. Over the past three decades, industrial value added has accounted for a substantial share in the gross domestic product (GDP) of this economic bloc. As illustrated in the following figure, China has consistently held the highest value added during this period. While this share has fluctuated, rising from 41.03% in 1990 to reach a peak of 47.5574% in 2006, it has subsequently declined to 39.92% of GDP in 2022. China's dominance extends beyond the BRICS region, as it has topped the global ranking for industrial value added since 2010, with a share of 46.49% of GDP, surpassing the United States' 19.26% in the same year, the year China became the world’s second-largest economy (UNCTAD, 2022: 20). The decline in industrial value added for BRICS countries is attributed to a shift from manufacturing-based economies to service-oriented economies and the growing demand for services from a rising population.

![Fig (3) The value added of the industry sector as a percentage of GDP in BRICS countries during the period (1990-2022)](https://data.albankaldawli.org/)

Structural transformation is a defining feature of development in BRICS countries, as aptly stated by Rodrik (2007:6): “Development is fundamentally about structural transformation.” This transformation is evident to varying degrees across the group, with China being the only member where industrial value-added accounts for a significant share of GDP. In contrast, the remaining BRICS countries have witnessed a decline in the share of medium and high-tech industry value added, giving way to the service sector. Services have emerged as the dominant sector in South Africa, Russia, Brazil, and India, while China remains the only BRICS nation where services do not constitute more than 50% of GDP. (Naudé. W. et al, 2015: 17)

In contrast to China’s notable growth in industrial value added, Russia’s share of industry in GDP remained relatively stagnant between 1995 and 2008. During this period, South Africa experienced a decline in its share of manufacturing by over three percentage points, while the share of its service sector increased by more than ten percentage points. Interestingly, South Africa witnessed a significant drop in the relative share of mining during a period that encompassed one of the strongest commodity booms since World War II.

Despite differences in their manufacturing shares, all BRICS countries experienced relatively high manufacturing growth from at least 1999 until the financial crisis. Given its strong backward linkages to local economies compared to other sectors, the manufacturing sector made a strong contribution to their growth over the past decade. Within the manufacturing sector, there was a gradual (and sometimes uneven) shift from labor-intensive to capital-intensive (and higher-skill) manufacturing. Consequently, important industries such as food processing, textiles, leather and footwear, wood and wood products (which are typically labor-intensive and low-skill industries) showed only moderate changes in output, while output grew fastest in the most capital-intensive industries such as chemicals, machinery and electrical equipment, optics, transport equipment, and metals and metal products. (Naudé. W. et al, 2015: 18)

**Evolution of Medium and Advanced Industry Value Added as a Share of Total Industry in BRICS Countries**

The focus of BRICS countries on different types of industries reflects their varying labor and capital endowments. China, for instance, has maintained a relatively stable share of value added in high-tech industries, partly due to its preference for employing moderately skilled labor, which is more cost-effective compared to expensive machinery.

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**Advanced Technology Exports of BRICS Countries: A Glimpse into the Growth Trajectory (2007-2021)**

The landscape of advanced technology exports in BRICS countries underwent a remarkable transformation during the period 2007-2021, marked by significant growth and evolving dynamics. China emerged as the frontrunner in this domain, establishing itself as a global powerhouse in advanced technology exports. Its exports in this sector soared to an impressive $9.42315E+11 billion in 2021, outpacing its BRICS counter-
parts by a considerable margin. In contrast, the advanced technology export figures for Russia, Brazil, South Africa, and India stood at $1.06E+10, $6.35E+09, $1.84E+09, and $2744653652, respectively, for the same year. Notably, China’s average share of advanced technology exports as a percentage of total exports reached 30.76%, the highest among BRICS nations. Brazil followed with an average of 12.94%, while Russia’s average stood at 10.68%. India and South Africa recorded the lowest average shares of advanced technology exports as a percentage of total goods exports within BRICS, at approximately 8.74% and 6.05%, respectively.

Source: Prepared by researchers based on World Bank development indicators data

Figure (5) Evolution of technological exports as a proportion of total exports to BRICS during the period (2007-2021)

The variations among BRICS countries in prioritizing technology exports as a share of total exports stem from a confluence of factors:

- **Differences in Industrial Structure**: The composition of each country’s industrial base significantly influences its focus on technology exports. Nations with established manufacturing sectors and a strong foundation in technology-intensive industries are better positioned to excel in this domain.

- **Research and Development Investments**: The level of investment in research and development (R&D) plays a crucial role in driving technological advancements and fostering innovation. Countries that dedicate substantial resources to R&D are more likely to develop cutting-edge technologies and establish a competitive edge in technology exports.

- **Government Policies**: Supportive government policies, such as tax incentives, research grants, and regulatory frameworks, can significantly influence the development and export of advanced technologies. Countries with comprehensive and well-structured government policies that promote innovation and facilitate technology commercialization tend to witness stronger growth in technology exports.

**R&D Expenditure Trends in BRICS Countries**

BRICS nations have embarked on a concerted effort to bolster their research and development (R&D) capabilities, recognizing the pivotal role of technology in driving industrial growth and economic competitiveness. To achieve this objective, BRICS governments have implemented a range of policy measures, including, Formulation of Long-Term Technology Development Plans, Investment in Basic Scientific Research, Promotion of R&D Commercialization, and Establishment of High-Tech Industrial Parks. (UNCTAD, 2022: 28)

The following figure illustrates the evolution of research and development (R&D) expenditure as a percentage of GDP in BRICS countries during the period from 1996 to 2020. It is evident that all BRICS nations experienced an increase in R&D spending during this period, with China recording the highest average share of 1.53%, followed by Brazil and Russia at 1.09% and 1.08%, respectively. India and South Africa exhibited the lowest average shares, at approximately 0.73% and 0.68%, respectively. China stands out as the leading BRICS country in terms of R&D expenditure as a percentage of GDP. In 2020, China’s R&D spending reached 2.4%, followed by Russia at 1.09%, Brazil and India at 0.655%, and South Africa at 0.615%. China’s substantial R&D investments have been instrumental in driving its technological advancements and economic competitiveness.
The notable progress in R&D expenditure and technological advancements witnessed by BRICS countries can be attributed to several key factors:

1. **Rapid Economic Growth**: The rapid economic growth experienced by BRICS nations has led to an increase in the financial resources available for research and development activities. This growth has enabled governments and private sectors to allocate more funds to R&D initiatives, fostering innovation and technological progress.

2. **Growing Recognition of R&D's Importance**: There has been a growing awareness among BRICS governments, businesses, and the general public about the crucial role of research and development in driving economic growth, competitiveness, and societal well-being. This recognition has fueled support and investment in R&D endeavors.

3. **Governmental Support for R&D**: BRICS governments have played a pivotal role in promoting R&D through various measures, including:
   - **Financial Support**: Providing direct funding and tax incentives to R&D institutions, researchers, and private companies engaged in innovative activities.
   - **Regulatory Frameworks**: Establishing supportive regulatory frameworks that facilitate research collaborations, technology transfer, and the commercialization of R&D outcomes.
   - **Infrastructure Development**: Investing in the development of research facilities, laboratories, and technology parks to create a conducive ecosystem for R&D activities.

**Study Problem**

The world is developing at a rapid pace, especially in the field of technology and innovation. These innovations act as catalysts for sustainable development. Countries that lack access to emerging technologies risk falling behind. According to the Industrial Development Report 2020 (UNIDO, 2020), 10 economies produce 70% of all exports directly linked to these advanced technologies, and 40 other economies actively participate in their development. The rest of the world does not participate in the creation and use of these technologies on a global level. These new technological transformations also pose challenges for countries seeking to recover from multiple crises and accelerate progress towards achieving the Sustainable Development Goals (UNIDO, 2024: 18).

Therefore, the current research problem can be summarized in three main points:

- **First**: The dominance of technologically advanced countries in a large share of global markets, which creates an incentive for other less technologically advanced countries to compete to build a scientific and technological innovation systems to enhance their position in this field. Innovation has become a key competitive advantage (Li, M, et al, 2023: 1). In addition to the continuous challenges that force developing economies to create their own high-value-added industries and use innovation as a weapon to achieve all economic, commercial, and environmental benefits.

- **Second**: The dominance of the industrial sector’s value added in the GDP of most countries around the world. The industrial sector contributes the largest share to the GDP and job creation in most
countries worldwide. However, it also causes environmental and ecological pollution due to its reliance on traditional energy sources such as coal, oil, and natural gas. Global emissions raised of 29% between 1995 and 2009, with the industrial sector contributing 16% of this increase. This demonstrates the vital role of the industrial sector in causing environmental pollution and accelerating climate change. This has led to a global increase in calls for environmental protection and carbon emission reduction, with most countries shifting towards clean energy and Industrial Sustainability that preserves the environment (UNIDO, 2015: 25).

- **Third**: The challenges facing the transition of countries to adopting industrial technological innovation (sustainable industrial development), transitioning to green manufacturing, and preserving the ecosystem.

Based on the above, the research problem can be summarized in one question:

Can innovation and technology support sustainable industrial development to increase high-tech exports in BRICS countries and attain the Sustainable Development Goals?

**Study Objectives**

This study aims to:

- Recognize what innovation is in the BRICS countries
- Identify the role of innovation in increasing industrial value added in the BRICS countries
- Identify the role of innovation in supporting sustainable industries and reducing carbon emissions
- Recognize the role of innovation in increasing high-tech industries
- Draw conclusions and applicable recommendations.

**Study Hypotheses**

This study revolves around one main hypothesis:

H1: It is expected that there is a statistically significant positive effect of innovation on achieving sustainable industrial development in BRICS countries during the period (2007/2022).

**Research Justifications**

The Justifications of this study stems from the critical role of the industrial sector in accelerating economic growth, fostering innovation, creating employment opportunities, promoting societal equality, and combating climate change. The industrial sector plays a pivotal role in alleviating poverty and reducing hunger by providing sustainable livelihoods, improving living standards, and attaining the Sustainable Development Goals (UNIDO, 2024: 22). Innovation aims to minimize environmental impacts (such as carbon dioxide emissions) by adopting green manufacturing practices, which enhance the environmental sustainability of industrial production.

Furthermore, the study’s significance lies in the profound impact of innovation not only on industrial and economic development but also on international trade. Innovation leads to an increase in advanced technological products, which in turn enhances export competitiveness (Frankel and Romer, 1999). Moreover, technologies associated with the Fourth Industrial Revolution, such as artificial intelligence (AI), advanced robotics, Internet of Things, additive manufacturing (FIR), big data analytics, and cloud computing, are reshaping the way we live, consume, and produce (UNIDO, 2024: 18).

**Standard Model and Variable Description**

This section delves into the construction of the model, including the estimation strategy and the data employed to estimate the targeted relationship.
Study Methodology

This study employed a multifaceted research approach, encompassing the following methodologies:

1. Descriptive Method: This method was utilized to review previous studies and identify critical research gaps.
2. Deductive, Inductive, and Descriptive-Analytical Methods: These methods were employed to analyze the study variables from an economic perspective.
3. Modern Scientific Method for Building Econometric Models: This method involved employing the panel data approach with fixed effects to examine the relationship between Variables.

Building the Study Model

Innovation serves as a fundamental driver of productivity and growth across various economic sectors. Establishing effective, modern, and sophisticated industries in all fields proves challenging in the absence of innovation. The Lima Declaration, adopted at the 15th General Conference of United Nations Industrial Development Organization (UNIDO) in 2013, outlined a new vision for comprehensive and sustainable industrial development. This vision encompasses development and manufacturing aimed at transforming the economic structure, transitioning from a labor-intensive economy to a technology-intensive one. Thus, the role of vital and critical innovation in achieving this structural change becomes evident.

Considering the foregoing, this study endeavors to examine the role of innovation in fostering sustainable industrial development in BRICS countries. Innovation plays a pivotal role in propelling this group of nations towards technological advancement, particularly as they hold prominent positions in the Global Innovation Index (GII) within their respective regions (WIPO, 2024). Consequently, drawing upon the existing literature and study hypotheses, the following general linear model will be employed to elucidate the relationship, as represented by the following equation:

$$\ln \text{SID}_{it} = \alpha_0 + \alpha_1 \ln A_{it} + \alpha_2 \ln PC_{it} + \alpha_3 \ln H_{it} + \alpha_4 \ln EXC_{it} + \alpha_5 \ln RIR_{it} + \alpha_6 \ln G_{it} + \alpha_7 \ln TO_{it} + \alpha_8 \ln FO_{it} + \alpha_9 \ln GE_{it} + \epsilon_{it}$$

Where, $(\text{SID}_{it})$: The natural logarithm of sustainable industrial development for country $i$ at time $t$. $C$: Represents the constant term of the function. $A_{it}$: Represents the independent variable of interest, which is the level of technological innovation in country $i$ at time $t$. $(X_{ik})$: Represents a vector of control variables, which capture potential determinants of sustainable industrial development other than innovation. Based on the previous literature, the physical capital of each factor $(pc)$, human capital $(h)$, exchange rate $(exc)$, real interest rate $(rer)$, economic growth $(g)$, trade openness $(to)$, financial openness $(fo)$, and finally government effectiveness $(ge)$ will be included as controlled variables. And finally, it represents the limit of error in its usual qualities. The pilot model is therefore determined in its final form in the logarithmic formula as follows:

$$\ln \text{SID}_{it} = \alpha_0 + \alpha_1 \ln A_{it} + \alpha_2 \ln PC_{it} + \alpha_3 \ln H_{it} + \alpha_4 \ln EXC_{it} + \alpha_5 \ln RIR_{it} + \alpha_6 \ln G_{it} + \alpha_7 \ln TO_{it} + \alpha_8 \ln FO_{it} + \alpha_9 \ln GE_{it} + \epsilon_{it}$$

Based on the preceding discussion, it is anticipated that an increase in technological innovation will contribute to achieving sustainable industrial development goals in BRICS countries. Consequently, a positive sign for the coefficient $(\alpha_1)$ is expected. Additionally, an increase in the level of human capital accumulated by workers will support industrial development. Trade openness serves as the second most significant channel for technology transfer between countries, while financial openness facilitates the provision of the necessary financing for establishing new productive projects, regardless of their size (small, medium, or large), which enhances industrial production. Moreover, an increase in economic growth leads to an expansion of the domestic market, providing opportunities for the industrial sector to expand. Undoubtedly, enhancing government effectiveness will create a sound and supportive institutional environment for...

(1) The logarithm formula is used to reduce data dispersion, and to obtain long-term flexibility for variables.
fostering industrial growth. Therefore, a positive sign for the coefficients (β3, β6, β7, β8, β9) is anticipated. For the rest of controlled variables, namely, the physical capital of each worker, the exchange rate and the real interest rate, their impact is ambiguous and determined by the economic structure of the BRICS and the stage of economic development in which they are going, the high financial base required for the employment of a labour unit can slow down the growth of industrial sector. In addition, if there is flexibility in the production apparatus, the appreciation of the exchange rate will lead to an expansion of the industrial sector, as it increases domestic demand, increases external demand as a result of the depreciation of the national currency denominated in foreign currency, and vice versa in the event of the stagnation of the production apparatus. A trend in studies also suggests that higher interest rates do not encourage increased investment in the industrial sector, while another trend suggests it include a lower volume of domestic investment expansion, which gives an opportunity for foreign investment with foreign financing.

Data Sources

To implement the study model, balanced panel data for the five BRICS countries (China, India, Brazil, Russia, and South Africa) will be utilized, covering the period from 2007 to 2022, with a total of 80 annual observations. This period was chosen based on data availability, particularly the Innovation Index. Data was collected from the following sources:

- World Development Indicators (WDI) from the World Bank for the period 2004-2022.
- United Nations (UN) reports up to 2020.
- World Economic Forum (WEF).
- Global Innovation Index (GII) reports.

Study Variables: this study examines the relationship between Variables innovation (independent variable) and sustainable industrial development (dependent variable) during the period 2007-2022. Sustainable industrial development was measured using three indicators aligned with Sustainable Development Goal 9:

- Developing industrial competitiveness: This was expressed as the share of industrial value added in GDP.
- Creating economic prosperity: This was measured by the share of workers in the industry and industrial value added per worker.
- Protecting the environment: This was represented by the share of carbon dioxide emissions from the industry in total carbon dioxide emissions from fuel combustion.

A wide range of variables will be drawn from this sample and period, obtained from the World Bank’s World Development Indicators and other databases. Regarding sustainable industrial development (the dependent variable), the United Nations Industrial Development Organization (UNIDO) in 2016 (UNIDO, 2016) identified the elements of comprehensive and sustainable industrial development as:

(1) Based on the «statistical power analysis,» which is used to estimate optimal sample size to be collected that minimizes type I and type II error and increases the expected impact in condition and quality. It is clear that the available sample of study meets the statistical strength requirements based on a small, expected impact scale, 90 per cent statistical strength and 5% moral standard. As can be seen from table A of the annex to the study.

(2) https://databank.worldbank.org/source/world-development-indicators


(4) https://www.weforum.org/publications/the-global-cooperation-barometer-2024/?gad_source=1&gclid=CjwKCAiA2py uBhBKEiwApLaO_90wmdinvUAEFGMgp2WGrPHEtZoajDwDbjtUj7jS8ZnFbiug8AAQF3BoCH-OQAvD_Bwe


- Long-term and sustainable manufacturing as a driver of economic competitiveness.
- Creating shared prosperity by providing equal opportunities with fair distribution of benefits.
- Promoting a sustainable future for industry by separating economic gain from excessive resource use and environmental harm.

Accordingly, Sustainable Development Goal (SDG) 9, titled “Industry, Innovation, and Infrastructure,” identifies the most important indicators related to the sustainability of industrial development in any country. Suitable indicators from each dimension will be used, as shown in Fig1.

Independent variable, innovation, will be represented by the Global Innovation Index (GII) published by the World Intellectual Property Organization (WIPO). The GII aims to provide the most comprehensive picture possible of the innovation landscape. It encompasses approximately 80 sub-indicators, including measures to assess the political environment, education, infrastructure, and knowledge creation mechanisms in each economy. Finally, for controlled variables, the study was based on the Penn World Table database on per capita physical capital at the constant prices of the US dollar of 2017, human capital index calculated from average years of schooling and expected return from education. World Bank World Development Index study also relied on the average official exchange rate as a domestic currency against the United States dollar to capture the cost of production, the real interest rate index (%), as a monetary policy representative, and the real GDP growth index, as a representative of the extent of market expansion. Trade index as a percentage of total output to express the level of openness of traders, and government effectiveness to capture the institutional aspect.

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The study used the Financial Openness Index (Chinn-Ito) database to capture the free movement of capital and profits between BRICS countries. And here before the model is adopted, we should first make sure that it’s properly described, that is, whether the independent variables are in their relationship with the following variable takes the linear or non-linear form; therefore, the Auxiliary regulation test for non-linearity test - squared terms for the non-linear test and model description test were used. It showed that all independent and disciplined variables follow the linear form of their relationship to sustainable industrial development, excluding the relationship of innovation to sustainable industrial development (1.1) and (2.1) as well as the relationship of the foundation of material money of each worker to indicators (1.1), (2.2) and (2.2) for sustainable industrial development, where it was not linear, and will therefore be expressed in the quadripartite form. Finally, table B of the annex to the study provides a brief description of the variables used in the analysis, their symbols and data sources. Table 1 shows a summary statistical summary of all study variables, and table C in the annex to the study shows the correlation matrix between variables.

The main features of the study variables can be seen here in table 1, which shows that there are clear structural differences between the five BRICS countries, whether in sustainable industrial development variables, innovation levels or even controlled variables, although these differences are in China’s best interest. For the dimension of developing the economy’s competitiveness, China’s industrial value added is 29.6 percent of output, and 41.4 percent of this industrial value added belongs to medium- and advanced technological industries. India, which has an industrial value added of 15.4% of output, and like China, 41.1% of this value is for technical industries. South Africa is ranked last with an industrial value added of 13% of output, and 23.9% for technical industries.
At the level of creating shared prosperity, 31.1 percent of the Chinese workforce works in the industrial sector, compared to 27.4 percent in Russia, 23.7 percent in India, 22.1 percent in Brazil, and 20.7 percent in South Africa. At the level of industrial value added per capita, the offer comes in favour of South Africa by $21,910 per worker, followed by Russia by $21,370 and China by $20,930, and Brazil, while India’s industrial value-added per capita falls significantly to $5,157 per worker. At the level of environmental protection, the lowest carbon-emitting industry in Russia was 4.2% of total emissions, followed by South Africa by 10%, Brazil by 16.6%, which is much higher in India to 21.7%, and peaking in China to 26.3%.

Table (1): Descriptive summary statistics, 2007-2022

<table>
<thead>
<tr>
<th>Dependent Variables:</th>
<th>Unit</th>
<th>Total sample</th>
<th>BRICS countries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Development of economic competitiveness</td>
<td>(%) of GDP</td>
<td>16.41</td>
<td>11.38</td>
</tr>
<tr>
<td>Industrial value added</td>
<td>(%)</td>
<td>33.68</td>
<td>41.09</td>
</tr>
<tr>
<td>Medium &amp; high-tech VA</td>
<td>(% of total empl.)</td>
<td>25.00</td>
<td>31.13</td>
</tr>
<tr>
<td>3) Environment protection CO₂ emissions from industry</td>
<td>(%) of total fuel</td>
<td>15.82</td>
<td>26.32</td>
</tr>
<tr>
<td>Independent Variables: Innovation Index</td>
<td>(scale 0 -1)</td>
<td>36.84</td>
<td>43.65</td>
</tr>
<tr>
<td>Control Variables: Physical capital per worker</td>
<td>constant US$</td>
<td>131.6</td>
<td>144.4</td>
</tr>
<tr>
<td>Human capital</td>
<td>(scale)</td>
<td>2.704</td>
<td>2.795</td>
</tr>
<tr>
<td>Official exchange rate</td>
<td>(LCU per US$)</td>
<td>25.88</td>
<td>48.19</td>
</tr>
<tr>
<td>Real interest rate</td>
<td>(%)</td>
<td>8.126</td>
<td>1.834</td>
</tr>
<tr>
<td>GDP growth</td>
<td>(annual %)</td>
<td>3.769</td>
<td>3.917</td>
</tr>
<tr>
<td>Trade openness</td>
<td>(%) of GDP</td>
<td>44.59</td>
<td>3.366</td>
</tr>
<tr>
<td>Financial openness</td>
<td>(scale 0 -1)</td>
<td>0.263</td>
<td>0.16</td>
</tr>
<tr>
<td>Government Effectiveness</td>
<td>(scale 0 -1)</td>
<td>5.393</td>
<td>4.98</td>
</tr>
</tbody>
</table>

Note: - * Values are in thousand US$.

The analysis reveals that China boasts the largest and most technologically advanced industrial sector among the BRICS nations. This sector absorbs a larger share of the workforce (leading to a lower per capita share of industrial value added) but is also the most environmentally polluting, not only among BRICS countries but potentially worldwide.

The remaining BRICS countries exhibit relatively similar levels of sustainable industrial development. Regarding innovation, the pattern mirrors sustainable industrial development. China possesses the strongest innovation system among BRICS countries, with a value of 46.35. The remaining BRICS nations have comparable national innovation systems, ranging from 29.35.

For controlled variables, the Russian industrial sector is the most capitalist with an average capital per worker of $240,600, followed by a large margin by South Africa, Brazil, a sharp drop in China to $110.89, and my brother India $770.54. This demonstrates that the Indian and Chinese industrial sector depends on human density compared to the capital-intensive Russia and South Africa, which is why the Chinese industrial sector can absorb the largest proportion of the labour force compared to the rest of BRICS countries. Similarly, we find that the human capital accumulated by workers is the highest in Russia for 3.366, followed by Brazil, China, South Africa and, finally, India for 2.068. We also note that China and India have achieved a high average annual growth over the period of 7.7%, 5.97%, respectively. The rest of BRICS have
only a 2% annual average growth barrier. Regarding institutional features, BRICS are relatively close to the effectiveness of their governments (the least effective of Russia’s 40.93, the largest of which is China 64.47). The remaining control variables exhibit variations among BRICS countries, reflecting their respective economic structures and economic orientations. This highlights the diversity of the BRICS economies and the need to consider country-specific factors when formulating policies and strategies.

Table (C) reveals a positive and statistically significant correlation between the innovation index and all sustainable industrial development indices at the 1% level. This indicates that higher levels of innovation are associated with a strong performance across all dimensions of sustainable industrial development. The strongest correlation is observed between the innovation index and the share of industrial value added in GDP, with a correlation coefficient of 60.5%. This highlights the critical role of innovation in driving industrial productivity and economic growth. The remaining indices also exhibit strong positive correlations with innovation, suggesting that innovation contributes to job creation, increased per capita value added, growth of technology-intensive industries, and reduced carbon emissions from the industrial sector. This is followed by Share of workers in industry (45.6%), then per capita value added (43.2%), Share of value added from technology-intensive industries (41.6%), and finally Share of carbon emissions from industry (39.6%). This implies that increased innovation will be accompanied to a large extent by an increase in the level of sustainable industrial development.

**Estimation Methodology:**

Given that the study sample represents BRICS countries, which differ significantly from each other in terms of their level of sustainable industrial development, innovation, and other economic and institutional structure variables, this could raise the problem of individual differences or effects of each country when analyzing the data. Therefore, the fixed effects model (FEM) or the least-squares dummy variable (LSDV) model was used, as it deals with individual effects by showing them and taking them into account in the analysis. This is done by adding dummy variables for each country, as shown in the following equation:

\[ y_{it} = \beta_{0i} + \beta_{1}x_{it} + u_{t} \]

Here, we notice that we have placed the subscript i on the intercept of the y-axis, which allows it to vary across countries. These differences may be due to country-specific characteristics, such as economic, technological, and institutional structures, or other characteristics (e.g., level of culture, human capital, colonial history, and religion). This requires us to consider the individual differences of each country in the analysis, but we still assume that the slope coefficients are constant for each country. Here, the time test showed that time influences the regression, and therefore the estimation method changes to a two-way fixed effects model (two-way FEM), which means that the intercept of the y-axis varies across countries and time. As shown in the following equation:

\[ y_{it} = \beta_{0it} + \beta_{1}x_{it} + u_{t} \]

Thus, the term “fixed effects” refers to the fact that although the intercept of the y-axis varies across observations and time, the slope coefficients are constant for all countries (Gujarati, 2003)\(^1\). Before estimating the study’s regressions, it is first necessary to ensure the quality of the applied regressions and

\(^1\) The fixed effects model was chosen based on Hausman test. This test compares it with the random effects model, as shown in Table (D) in the study appendix. Although the calculated F value for the Pagan and Breusch-Pagan (Residual variance) test was statistically significant, indicating a preference for the fixed or random effects model over the pooled least squares model, the calculated F value for the Hausman test was also significant, indicating a preference for the fixed effects model over the random effects model.
Data Analysis

As shown in Table 2, several interesting results emerge. In the first regression, Reg (1), which focuses on the share of industrial value added in GDP, there is a non-linear relationship between the level of technological innovation and industrial value added. This non-linear relationship takes the shape of a U-curve, meaning that low technological innovation will have a negative impact on the share of industrial value added, but this impact turns positive at high levels of technological innovation. In other words, a national innovation system with low innovation efficiency will lead to a decrease in the share of industrial value added in GDP, and vice versa, as the increase in the efficiency of the national innovation system and the resulting density of patents that serve the industrial sector will lead to an increase in the contribution of the industrial sector to GDP.

To verify the nonlinearity of this relationship, the Sasabuchi–Lind–Mehlum test was conducted, as shown in Table 3. The test statistic was statistically significant at the 1% significance level, indicating a rejection of the null hypothesis of an inverse U-shaped relationship and acceptance of the alternative hypothesis of a U-shaped relationship. Additionally, the turning point fell within the range of the actual data, at 3.621. This suggests that the relationship is a true U-shape rather than a spurious one. Therefore, the effect of technological innovation below 3.621 (in logarithmic form) is negative on industrial value added, but this effect turns positive when the level of technological innovation exceeds the threshold of 3.621 (in logarithmic form).

Moving on to the second regression (Reg (2)), which focuses on the share of value added of medium and high-tech industries in total industrial value added, we observe the most intriguing result in the findings, which is the presence of an inverse effect of technological innovation on the value added of technology industries. According to the regression coefficient, a one-unit increase in the logarithm of the level of technological innovation leads to a 0.3% decrease in the logarithm of the share of value added of high-tech industries on average. This could be due to the fact that technological innovations in BRICS countries are mostly designed to serve traditional industries in order to capture a larger market share in the global market, which leads to an increase in the share of value added of traditional industries in total industrial value added, and consequently a decrease in the share of value added of technology industries.

Another possible reason is that high-tech industries rely on high-tech patents that require research originality in complex technological sciences. The main monopolists of these industries are traditional developed countries, led by the United States, the other G5 countries, and most of the European Union. These countries have research originality in these complex technological sciences that enable them to innovate on the global stage (as innovation is their fuel for development). These industries also represent the comparative advantage and, in some cases, the absolute advantage of these countries.

In contrast, BRICS countries are still in the early to middle stages of these advanced technological sciences. Consequently, their patents are not original enough to support their advanced technology industries compared to developed countries (and therefore innovation in BRICS countries still relies on the concept of “new to the country”). Therefore, BRICS countries focus more on traditional industries to capture larger international market shares, while pursuing competition in advanced technology industries in the long term.

As for the ability of the industrial sector to create shared prosperity, the third regression (Reg (3)) which focuses on industrial employment shows a nonlinear relationship between the level of technological in-
Innovation Role in Driving Sustainable Industrial Development... 

Innovation and industrial employment. However, unlike the relationship between innovation and industrial value added, we find here that this nonlinear relationship takes the form of an inverted U-shape. This means that low technological innovation will lead to an increase in the proportion of industrial workers in the total workforce, but this effect turns negative at high levels of technological innovation. The Sasabuchi–Lind–Mehlum test in Table 3 confirmed the validity of this nonlinear relationship, as the test statistic was statistically insignificant, indicating acceptance of the null hypothesis of an inverse U-shaped relationship. Additionally, the turning point fell within the range of the actual data, at 3.4804, reflecting that it is a true inverted U-shaped relationship rather than a spurious one. Therefore, the effect of technological innovation below 3.48 (in logarithmic form) is positive on industrial employment, but this effect turns negative on industrial employment when the level of technological innovation exceeds the threshold of 3.48 (in logarithmic form).

Table (2): Innovation and Sustainable industrial development: Econometrics results

<table>
<thead>
<tr>
<th>Dependent variables:</th>
<th>Reg (1)</th>
<th>Reg (2)</th>
<th>Reg (3)</th>
<th>Reg (4)</th>
<th>Reg (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln Sustainable industrial development</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln Innovation Index</td>
<td>[-9.0599]</td>
<td>[-0.3025]</td>
<td>7.8762</td>
<td>0.2405</td>
<td>-0.4720</td>
</tr>
<tr>
<td>ln Innovation Index squared</td>
<td>1.2512</td>
<td>-1.1315</td>
<td>[-6.897]***</td>
<td>[-0.746]***</td>
<td>[-6.092]***</td>
</tr>
<tr>
<td>ln Physical capital per worker</td>
<td>2.3039</td>
<td>-0.0801</td>
<td>4.2822</td>
<td>-2.0723</td>
<td>-1.5445</td>
</tr>
<tr>
<td>ln Physical capital per worker squared</td>
<td>-0.1109</td>
<td>-0.1758</td>
<td>0.1151</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln Human capital</td>
<td>-1.0199</td>
<td>-1.3587</td>
<td>-0.6530</td>
<td>-1.7020</td>
<td>-8.3556</td>
</tr>
<tr>
<td>ln Official exchange rate</td>
<td>0.0497</td>
<td>0.1237</td>
<td>0.1022</td>
<td>-0.0994</td>
<td>-0.7911</td>
</tr>
<tr>
<td>ln Real interest rate</td>
<td>0.0173</td>
<td>0.1113</td>
<td>0.0144</td>
<td>0.0335</td>
<td>-0.0739</td>
</tr>
<tr>
<td>ln GDP growth</td>
<td>0.0115</td>
<td>-0.1957</td>
<td>0.0651</td>
<td>0.0015</td>
<td>0.2847</td>
</tr>
<tr>
<td>ln Trade openness</td>
<td>0.1182</td>
<td>-0.2491</td>
<td>0.0655</td>
<td>0.0018</td>
<td>1.3411</td>
</tr>
<tr>
<td>ln financial openness</td>
<td>0.0197</td>
<td>-0.0117</td>
<td>-0.0278</td>
<td>-0.0607</td>
<td>0.3157</td>
</tr>
<tr>
<td>ln Government Effectiveness</td>
<td>0.0489</td>
<td>0.1921</td>
<td>0.0529</td>
<td>0.0232</td>
<td>-0.3731</td>
</tr>
<tr>
<td>Constant</td>
<td>7.3836</td>
<td>6.9056</td>
<td>-36.609</td>
<td>18.499</td>
<td>34.925</td>
</tr>
</tbody>
</table>

Key Regression Statistics

| Adjusted R-squared | 97.7% | 98% | 94.8% | 99.7% | 97.8% |
| Fisher test (F-stats.) | (206.44)*** | (142.82)*** | (49.107)*** | (797.32)*** | (125.47)*** |

Practical significance for Innovation Index: Effect Size

| ln Innovation Index | -2.098 | -1.600 | 1.730 | 1.859 | -0.822 |
| ln Innovation Index squared | 1.991 | | | | -1.766 |

Interpretation: Large effect | Large effect | Large effect | Large effect | Large effect | Large effect |

Note: ***, **, * indicate significance at 1%, 5% and 10% respectively. – t-Statistic in parentheses.

Therefore, this result confirms the ability of innovation to support the vision of the United Nations Industrial Development Organization (UNIDO), which states that comprehensive and sustainable industrial development means development and manufacturing to change the structure of the economy, by transitioning from a labor-intensive economy to a technology-intensive economy. This is evident in the nonlinear relationship in the third regression, as a decrease in the level of technological innovation will support an...
increase in the reliance of the BRICS countries’ industrial sector on labor-intensive production methods, but with an increase in the intensity of technological innovations, it will support the transformation of the industrial sector to the use of capital-intensive production methods, which will lead to a decrease in the proportion of industrial workers in the total workforce.

Regression 4 (Reg (4)), which focuses on the worker’s share of industrial value added, shows a positive effect of technological innovation on industrial value added per worker. According to the regression coefficient, a one-unit increase in the logarithm of the level of technological innovation leads to a 0.241 dollar increase in the logarithm of the individual’s share of industrial value added on average. Therefore, this result confirms what was inferred from Regression 3: since technological innovations work to change the structure of the economy by transitioning from a labor-intensive economy to a technology-intensive economy, this leads to a decrease in labor intensity in the industrial sector compared to an increase in the intensity of physical capital. This, in turn, supports an increase in worker productivity in the industry, which leads to an increase in their share of industrial value added.

**Table (3): Sasabuchi–Lind–Mehlum test for an inverse U-shaped relationship**

<table>
<thead>
<tr>
<th></th>
<th>Reg (1)</th>
<th>Reg (3)</th>
<th>Reg (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Innovation Index</strong></td>
<td>-9.0599 [***]762.7</td>
<td>2.3039 [2.408]**</td>
<td>7.8762 [5.991]***</td>
</tr>
<tr>
<td><strong>Physical capital per worker</strong></td>
<td>2.0723</td>
<td>-0.1758 [-***]742.6</td>
<td>4.2822 [7.175]***</td>
</tr>
<tr>
<td><strong>Physical capital per worker</strong></td>
<td>2.3039 [2.408]**</td>
<td>-1.1315 [-**]115.2</td>
<td>7.8762 [5.991]***</td>
</tr>
</tbody>
</table>

Interval: $X_i (min) = 3.2581$; $X_i (max) = 4.0079$; $X_h (min) = 3.2581$; $X_h (max) = 10.358$.

Slope at $X_i$: $\beta + 2\hat{\gamma}X_i = -0.9069 [***]910.5$; $0.5031 [3.017]***$; $-0.4565 [-***]105.2$; $0.7922 [1.042]$. Slope at $X_h$: $\beta + 2\hat{\gamma}X_h = 0.9694 [4.932]***$; $-1.1937 [-***]105.2$; $0.6397 [5.104]***$; $-0.0945 [-***]140.3$.

Sasabuchi test (t-value): $0.9069 [0.295]$; $0.5031 [2.943]***$; $-0.4565 [0.892]$; $0.7922 [1.042]$.

Note: - ***, **, * indicate significance at 1%, 5% and 10% respectively.

**Results:**

As for the ability of the industrial sector to protect the environment (environmental sustainability), Regression 5 (Reg (5)), which focuses on industrial carbon emissions, shows an inverse effect of technological innovation on the proportion of industrial carbon emissions. According to the regression coefficient, a one-unit increase in the logarithm of the level of technological innovation leads to a 0.47% decrease in the logarithm of the proportion of carbon emissions from total carbon emissions on average. This confirms the ability of technological innovations to transform the BRICS industrial sector into a more sustainable and environmentally friendly production sector, by supporting green technology and increasing the efficiency of the industrial sector in its use of natural resources.

Summarizing the results of five regressions provides a general overview of relationship between innovation and sustainable industrial development in BRICS countries. The regressions confirm the ability of the BRICS industrial sector to increase the economy’s competitiveness by increasing the share of industrial value added in output, but this increase is in favor of traditional industries compared to advanced technology industries, due to the relative lack of originality of patents in BRICS countries compared to developed countries. These innovations also support shared prosperity by providing equal opportunities for all and
fair distribution of benefits, as the industrial sector supports increased productivity of industrial workers and thus their share of industrial value added by transforming the industrial sector from a labor-intensive to a technology-intensive sector. These innovations also work to transform the industrial sector into a more sustainable sector, by supporting green technology and increasing the efficiency of natural resource use.

As for the control variables, their effect was consistent with economic theory and the expected implications. For physical capital per worker, the effect was nonlinear on industrial value added, industrial employment, and the worker’s share of industrial value added. We find that the relationship between physical capital per worker and both industrial value added, and industrial employment takes the form of an inverted U-shape. This is logical, as increasing the capital per worker involves increasing the capital cost required to hire a new worker, and therefore, as this cost increases significantly, the ability of the industrial sector to expand decreases. While the relationship between physical capital per worker and the worker’s share of industrial value added takes the form of a U-shape, which is natural because a significant increase in the physical capital available to each worker will greatly increase his productivity and thus increase the share of each worker in the industrial value added.

While the effect of physical capital per worker on the value added of technological industries and industrial carbon emissions is negative (linear), this supports the fact that increasing capital intensity in BRICS countries is more environmentally sustainable, and it is also in traditional industries, which reduces the proportion of value added in medium and advanced technology industries. As for human capital, its effect was negative on the five indicators of sustainable industrial development, which is expected, because the increase in the accumulated human capital of workers makes them move to other economic sectors that need their high skills more, and therefore higher appreciation for these skills, unlike the industrial sector, which requires medium-pattern skills as a result of the pattern of manufacturing processes.

It is also observed that economic growth in BRICS countries supports the increased sustainability of industrial development, by increasing the share of industrial value added in output, industrial employment, and productivity, while reducing industrial carbon emissions. While financial openness works in the opposite direction to economic growth, trade openness has no impact on sustainable industrial development. In addition, the effectiveness of BRICS governments is currently focused on the industrial sector on increasing the share of value added in medium and advanced technology industries, while reducing industrial carbon emissions. The impact of the remaining control variables (exchange rate, interest rate) varies depending on the industrial development variable used and the economic structure of each country.

Finally, as for the general statistics, the value of the adjusted coefficient of determination (R2) for the regressions is high, as the study model explains between (94.8% - 99.7%) of the changes that occur in the sustainability of industrial development in BRICS countries. The remaining percentage is due to random error as a result of the existence of other variables that were not controlled for within the model. Also, the Fisher test indicates the rejection of the null hypothesis and the acceptance of the alternative hypothesis that there is statistical significance for the regressions at a significance level of 1%.

Given that statistical significance is the least interesting thing about the results, statistical significance (p-value) is not enough because it only tells us that there is a stronger relationship between innovation and sustainable industrial development (rejecting the null hypothesis), which simply tells the reader that it is unlikely that the relationship between innovation and sustainable industrial development is due to pure chance. Therefore, the effect size will be relied upon, which provides a quantitative measure of the magnitude of the association between the variables. Thus, it provides an assessment of the strength of the results that statistical significance tests alone do not provide, in other words, it clarifies the magnitude of the practical significance of the relationship between innovation and sustainable industrial development.
in real life. Accordingly, effect size brings us additional information for the inferential decision to accept or reject the null hypothesis.\(^{(1)}\)

Effect size is calculated here from the partial correlations between the Global Innovation Index and the five sustainable industrial development indicators. This measures the correlation between the dependent and independent variable, controlling for the other variables in the model (assuming they also affect the dependent variable). It is clear from the Cohen (1988) statistic at the bottom of Table 2 that there is a large effect size of technological innovation in supporting the sustainability of industrial development in BRICS countries. This provides strong support for the development of the theory and the formulation of policies to increase the sustainability of the industrial sector through innovation.\(^{(2)}\)

**Study Limitations:**

This study encompasses two main frameworks:

- Spatial limits: The study focuses on the BRICS countries (Brazil, Russia, India, China, and South Africa).
- Temporal limits: The study covers a time period of (2007/2022) according to the available data.

**Recommendations:**

Based on the previous analyses and results:

- Due to the differences in the economic structures and policies of the BRICS countries, each country should adopt industrial innovation in a way that is compatible with its own nature and resources. This will lead to maximizing industrial added value and increasing the competitiveness of the economic bloc’s countries.

- Governments in BRICS countries should implement policies that encourage and support innovation in all sectors of the economy, particularly in the industrial sector. This could include providing tax breaks, subsidies, and other incentives for businesses that invest in research and development.

- Governments in BRICS countries should increase investment in sustainable industrial development technologies, such as renewable energy, energy efficiency, and pollution control. And implement policies that promote the adoption of these technologies by businesses.

- BRICS countries should increase their spending on research and development and adopt original research that contributes to increasing the added value of medium and advanced industries in addition to traditional industries and increasing their global market share.

- Despite the increase in technological exports of BRICS countries, their proportion of total industrial exports is decreasing. This is explained by the reliance of these countries on traditional industries. Therefore, attention should be paid to attracting researchers to root advanced sciences and encourage patents.

- Based on the positive impact of innovation in BRICS countries in reducing carbon emissions by 0.47% when innovation is increased by one unit, BRICS countries should continue to increase their reliance on technological methods in manufacturing and production until the industrial sector becomes environmentally friendly. And Provide support to businesses to comply with environmental regulations.

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\(^{(1)}\) There is a wide debate under the name (Null Hypothesis Significance Testing (NHTS)). Therefore, the American Psychological Association (APA) recommended in Chapter 1.01 Design and Reporting of Research; That all published statistical reports should also include effect size) Section of the Fifth Edition Guide. APA (2002).

\(^{(2)}\) The sample size used only supports confirming a small effect size in the presence of goodness of fit, as is clear from Table A in the study appendix. Therefore, the large effect size of innovation on the sustainability of industrial development in BRICS countries that is shown by the results of the study cannot be definitively confirmed except by confirming it using a larger sample.
References:


- Global Innovation Index 2021 Tracking Innovation through the COVID-19 Crisis, WIPO.

- Global Innovation Index Database, Cornell, INSEAD, and WIPO, several years. https://thegedi.org


https://dashboards.sdgindex.org/rankings


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Solovieva, Yuliana & Mingjun He(2021), National systems of technology transfer of BRICS countries: features of formation, *SHS Web of Conferences* 114, 01023 (2021 NTSSCEM 2021) https://doi.org/10.1051/shsconf/202111401023


The full WIPO Intellectual Property Statistics profile for Brazil ,p:6 ,can be found at: https://www.wipo.int/ipstats/en/statistics/country_profile/profile.jsp?code=BR.

The full WIPO Intellectual Property Statistics profile for China, P: 9, can be found at: https://www.wipo.int/ipstats/en/statistics/country_profile/profile.jsp?code=CN.

The full WIPO Intellectual Property Statistics profile for Russia can be found at: https://www.wipo.int/ipstats/en/statistics/country_profile/profile.jsp?code=RU.
- UNIDO. (2024). Industrial Development Report 2024: In search of a new paradigm. Vienna:
- World Bank Economic Development indicators https://data.albankaldawli.org/
- Naudé.W. et al (2015), Structural transformation in Brazil, Russia, India, China and South Africa (BRICS), Publisher: Oxford University Press, 2015, P: 17.
Appendices:

Table (A): Statistical power analysis (A-priori sample size for multiple regression)

| Anticipated effect size ($f^2$): | 0.035 | 0.035 | 0.035 |
| Desired statistical power level ($p$): | 0.90 | 0.90 | 0.90 |
| Number of predictors: | 8 | 9 | 10 |
| Probability level ($\alpha$): | 0.05 | 0.05 | 0.05 |
| Minimum required sample size: | 66 | 69 | 72 |

Table (B): Description of the study variables

<table>
<thead>
<tr>
<th>Source</th>
<th>Description</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBI</td>
<td>Manufacturing, value added of manufacturing (% of GDP); Manufacturing is defined as industries classified under ISIC sections 15-37.</td>
<td>SID1</td>
</tr>
<tr>
<td>WBI</td>
<td>Value added of medium and advanced technology industries (% of total value added of industry);</td>
<td>SID2</td>
</tr>
<tr>
<td>ILO</td>
<td>Industry workers (% of total employment); This refers to persons of working age who have participated in productive activities in the industrial sector. Here, the industrial sector is defined as mining and quarrying, manufacturing, construction, and utilities (electricity, gas, and water), according to ISIC sections 2-5 (ISIC 2), ISIC divisions C-F (ISIC 3), or ISIC divisions B-F (ISIC 4).</td>
<td>SID3</td>
</tr>
<tr>
<td>WBI</td>
<td>Industrial value added per worker (in constant US dollars);</td>
<td>SID4</td>
</tr>
<tr>
<td>IEA</td>
<td>Carbon dioxide emissions from manufacturing and construction (% of total fuel combustion); This includes emissions from coal inputs for blast furnaces in the iron and steel industry. Manufacturing and construction also include emissions from the combustion of fossil fuels for energy generation and industrial processes.</td>
<td>SID5</td>
</tr>
<tr>
<td>WIPO</td>
<td>Global Innovation Index: This includes 80 sub-indicators to capture the political environment, education, infrastructure, and knowledge creation mechanisms in each economy, in order to provide a comprehensive picture of the national innovation system on a scale of (0-100)</td>
<td>A</td>
</tr>
<tr>
<td>PWT</td>
<td>Physical capital per worker; Calculated by dividing total physical capital (at constant 2017 prices) in the country by the number of workers.</td>
<td>PC</td>
</tr>
<tr>
<td>IMF</td>
<td>Human capital per capita”. Official exchange rate (local currency vs. US dollar, average period); refers to the exchange rate determined by the national authorities or the rate determined in the legally sanctioned exchange market. It is calculated as an annual average based on monthly averages (local currency units relative to the US dollar). Real interest rate (%). The real interest rate is the nominal interest rate adjusted for inflation as measured by the GDP deflator.</td>
<td>H</td>
</tr>
<tr>
<td>WBI</td>
<td>% of GDP (annual); Annual growth rate of GDP at market prices based on constant local currency prices. Aggregates are based on 2010 US dollars.</td>
<td>G</td>
</tr>
<tr>
<td>WBI</td>
<td>Trade (% of GDP); This is the sum of exports and imports of goods and services measured as a share of GDP.</td>
<td>TO</td>
</tr>
<tr>
<td>Chinn &amp; Ito</td>
<td>Financial openness index: This is an index that measures the degree of openness of a country’s capital account. It is based on dummy variables that codify the schedule of restrictions on cross-border financial transactions reported in the International Monetary Fund’s Annual Report on Exchange Arrangements and Restrictions. This index is normalized between 0 and 1, with higher values indicating that the country is more open to capital transactions.</td>
<td>FO</td>
</tr>
<tr>
<td>WGI</td>
<td>Government effectiveness; This captures perceptions of the quality of public services, the quality of the civil service and its degree of independence from political pressures, the quality of policy formulation and implementation, and the extent to which the government is credible in its commitment to those policies.</td>
<td>GE</td>
</tr>
</tbody>
</table>

**Table (C): Correlation matrix between study variables**

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
<th>(10)</th>
<th>(11)</th>
<th>(12)</th>
<th>(13)</th>
<th>(14)</th>
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</thead>
<tbody>
<tr>
<td>Industrial value added</td>
<td>1</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium &amp; high-tech VA</td>
<td>0.561*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employment in industry</td>
<td>0.753*</td>
<td>0.430*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Industrial VA per worker</td>
<td>0.052</td>
<td>-0.458*</td>
<td>0.089</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂ emissions from industry</td>
<td>0.645*</td>
<td>0.863*</td>
<td>0.279*</td>
<td>-0.353*</td>
<td>1</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Innovation Index</td>
<td>0.605*</td>
<td>0.416*</td>
<td>0.456*</td>
<td>0.432*</td>
<td>0.396*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical capital per worker</td>
<td>-0.457*</td>
<td>-0.649*</td>
<td>-0.024</td>
<td>0.678*</td>
<td>-0.783*</td>
<td>-0.037</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human capital</td>
<td>-0.307*</td>
<td>0.207*</td>
<td>0.041</td>
<td>-0.467*</td>
<td>-0.107</td>
<td>-0.156</td>
<td>0.100</td>
<td>-0.057</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real interest rate</td>
<td>-0.354*</td>
<td>0.052</td>
<td>-0.386*</td>
<td>-0.035</td>
<td>0.067</td>
<td>-0.245*</td>
<td>-0.075</td>
<td>0.002</td>
<td>-0.389*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP growth</td>
<td>0.60-1*</td>
<td>0.492*</td>
<td>0.476*</td>
<td>-0.323*</td>
<td>0.508*</td>
<td>0.141</td>
<td>-0.529*</td>
<td>-0.469*</td>
<td>-0.012</td>
<td>-0.311*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trade openness</td>
<td>0.107</td>
<td>-0.392*</td>
<td>0.048</td>
<td>-0.037</td>
<td>-0.289*</td>
<td>-0.142</td>
<td>0.052</td>
<td>-0.009</td>
<td>0.253*</td>
<td>-0.756*</td>
<td>0.151</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial openness</td>
<td>-0.345*</td>
<td>-0.318*</td>
<td>0.165</td>
<td>0.199*</td>
<td>-0.502*</td>
<td>-0.158</td>
<td>0.632*</td>
<td>0.506*</td>
<td>0.141</td>
<td>0.129</td>
<td>-0.226*</td>
<td>-0.181</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Government Effectiveness</td>
<td>0.579*</td>
<td>0.387*</td>
<td>0.199*</td>
<td>0.028</td>
<td>0.537*</td>
<td>0.535*</td>
<td>-0.506*</td>
<td>-0.586*</td>
<td>-0.137</td>
<td>-0.306*</td>
<td>0.337*</td>
<td>0.156</td>
<td>-0.482*</td>
<td>1</td>
</tr>
</tbody>
</table>

Note: - a, b, c indicate significance at 1%, 5% and 10% respectively.

**Table (D): Diagnostic & Identity Tests used:**

<table>
<thead>
<tr>
<th>Tests used</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identity Tests:</td>
<td></td>
</tr>
<tr>
<td>Residual variance test</td>
<td>Test for differing group intercepts (Pooled OLS versus FEM) 190.18 (0.000)***</td>
</tr>
<tr>
<td>Breusch-Pagan test</td>
<td>Test for differing group intercepts (Pooled OLS versus REM) 83.994 (0.000)***</td>
</tr>
<tr>
<td>Hausman test</td>
<td>To compare between (REM versus FEM) 214.48 (0.000)***</td>
</tr>
<tr>
<td>Time test</td>
<td>Wald joint test on time dummies 41.722 (0.000)***</td>
</tr>
<tr>
<td>Diagnostic Tests: Heteroskedasticity</td>
<td>White’s test 50.326 (0.106)</td>
</tr>
<tr>
<td>Serial Correlation</td>
<td>Wooldridge test 0.5889 (0.588)</td>
</tr>
<tr>
<td>Normality</td>
<td>Jarque-Bera 0.1388 (0.933)</td>
</tr>
<tr>
<td>Cross-Section Dependence</td>
<td>Pesaran CD -3.0027 (0.003)***</td>
</tr>
<tr>
<td>Breakpoint</td>
<td>Chow test 1.8112 (0.079)</td>
</tr>
<tr>
<td>Function Form</td>
<td>Ramsey RESET Test 13.988 (0.000)***</td>
</tr>
<tr>
<td>Linearity</td>
<td>Auxiliary regression for non-linearity test (squared terms) 38.178 (0.000)***</td>
</tr>
<tr>
<td>Collinearity</td>
<td>Auxiliary regression for non-linearity test (log terms) 32.802 (0.000)***</td>
</tr>
<tr>
<td>Variance Inflation Factors (VIF)</td>
<td>All values &lt; 10</td>
</tr>
</tbody>
</table>