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National Innovation Systems: A Case Study of the Leading Developing Countries

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Abstract:

The main aim of this study is an analysis of the world practice of developing national innovation system of Brazil, India, China and Republic of South Africa. The article presents the results of comparative analysis on the level of the development of innovation systems of the countries based on quantitative data.

It characterizes the level of development of science, technology and innovation, in the final part of the article, where there is an analysis of the current and prospects for the future development of Russia's innovation system.

The analysis showed that for creation and functioning of an effective innovation system, is important and it can be based on the trajectory of the country's strategic development, to competently build an innovative and technological business policy, oriented for a long-term perspective, as well as to create necessary conditions for the development of science and technology.

In addition, it is necessary to stimulate market mechanisms for independent financing of universities and research institutes, as well as to develop the practice of private initiatives and investment in the development of innovative activity.

Keywords: *Innovation, Science, Technology, State program, Innovative Development Strategy, National Innovation System, Developing Countries.*

JEL code: *O30, O38*

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1. Introduction

Development of an innovation system is an integral part of the strategic development of most of the BRICS (abbreviation for Brazil, Russia, India, China and South Africa) countries, and an opportunity to diversify the economy in conditions of the formation of a new technological paradigm. The national innovation system (NIS) is defined by researchers as a set of interacting institutions of the public and private sectors as part of creation, registration, storage, transfer, modification, distribution and transformation of new knowledge into technologies, goods and services consumed by the society.

2. Literature Review and Methodology

2.1 Theoretical aspects of the concept of the national innovation system (NIS)

2.1.1. The concept of "innovation" ("novelty") was introduced in economics by Austrian and American economist, political scientist, sociologist and historian of economic thought Joseph Schumpeter (1911), and was associated with the publishing of his work "The Theory of Economic Development". Innovations according to Schumpeter were "new combinations, changes in development".

2.1.2. The term "innovation system" was introduced in 1985 by Lundvall (1985). Subsequently, there were other interpretations of definition of the innovation system.

2.1.3. In 1987 Freeman *introduced the concept of "national innovation system".*

2.1.4. The concept of national innovation systems was developed in the 1980-1990s by English economist Freeman (1987), Danish scientist Lundvall (1985; 1992) and American researcher Nelson (1993).

2.1.5. The concept of NIS is determined by leading researchers as follows:

- ✓ Lundvall (1992): "elements and relationships that affect each other in the production, dissemination and use of new economically useful knowledge that are located in one country or come from it";
- ✓ Freeman (1995): "a network of public and private sector institutions whose activities and interactions contribute to the creation, transfer, modification and dissemination of new technologies";
- ✓ Nelson (1993): "a number of institutions whose interaction determines the results of companies in the field of innovation".
- ✓ OECD (Organization for Economic Cooperation and Development) (1997): "networks of institutions in public and private fields affecting the innovative potentials of the economy". It is the most commonly cited definition.

2.2The list of priority areas of innovation development for BRICS member countries

The list of priority areas of innovation development for BRICS member countries is:

1) power generation, 2) information technology, 3) biotechnology, 4) ecology and health.

Countries are taking measures to stimulate the participation of business in financing R&D (research and development). The basis of modern NIS are partnerships and cooperation. Supporting SMEs (small and medium-sized enterprises), state develops special programs for SMEs and opens the required number of public lending lines. Support of science by the state is carried out through opening the scientific centers, the grant-making, restructuring of universities, expanding the amount of funding for R&D, implementation of the state targeted programs to support innovation activities. Institutional support of the innovation strategy, in turn, is provided by the specialized structures for the consolidation of finance and support of priority directions for the implementation of innovative capacity (Belikova, 2011; Belikova and Akhmadova, 2012).

3. Results and Discussion

3.1 Fields of state policy of BRICS countries due to experience

The fields of state policy of BRICS are the following:

– creation of favorable conditions for attracting foreign investment in the country's innovation sectors, financing of research and development, building the innovative infrastructure;

– increase in the volume of R&D financing, including per employee;

– support of small and high-risk ideas, as well as of the promising innovative enterprises;

– popularization of science among youth in order to improve the human resources capacity of the country.

– increasing an attractiveness of the scientific sphere career, state support of young scientists and specialists,

– integration of scientific research with business processes,

– structural transformations of the research and production complex through improving the quality of social and institutional conditions.

3.2 Comparative analysis of the BRICS countries based on available statistical data

At the BRICS summit in 2012, an innovative specialization of the countries was determined in accordance with their achievements and competitive advantages (Larionova and Kirton, 2012).

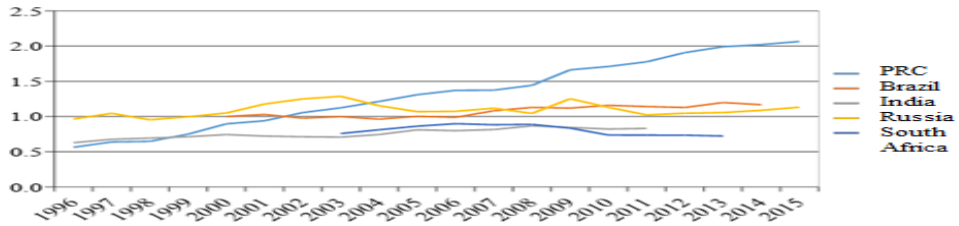
- *Brazil* has relatively low level of population education and low quality of education, but significant results in research in the field of agriculture, use of biofuels for vehicles, high-tech aircraft.
- *Russia* is strong in the development of space, nuclear and defense technologies, programming, sectors of nano- and biotechnology.

- *India* has a promising information and communication technologies sector.
- *China*'s innovation development is the policy of "open doors" – initially innovative technologies were attracted from abroad. The Chinese NIS has such strengths as high mobility of resources, large volumes of investments, favorable investment environment (especially for foreign investors), with a notable lack of staff and a slow return on investment.
- *South Africa* (ZAF) has insufficient educational level of the population, but developed financial system and the resource potential. The government of this country is forced to allocate significant funds for development of primary and secondary education, which limits the possibilities of financing the innovative projects. ZAF contributes to active investment into innovative sectors of the foreign countries economies for purpose of technology transfer.

3.3 Indicators of the level of development of NIS

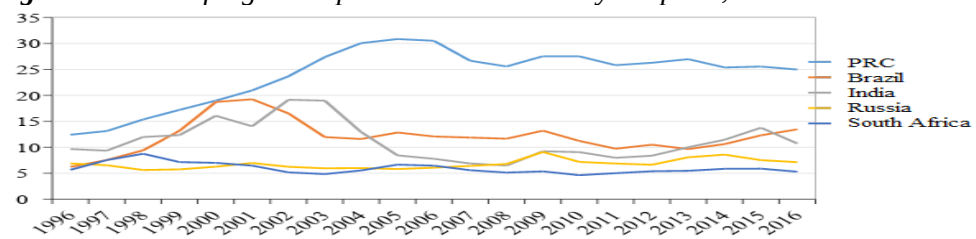
3.3.1 *Due to the share of expenditure on research and development in the GDP*. It is one of the most frequently used indicators, which characterizes the activity of the state and the private sector in the field of R&D. For 1996-2015, the greatest increase in expenses for science and technology was achieved in the PRC (see Figure 1). China became a leader. The lowestshare of GDP for R&D in period of 1996-2015 was allocated in South Africa and India.

Figure 1. *Expenses for research and development as % of GDP*



3.3.2 *Due to the share of high-tech products in the country's total exports.* China is the leader here (see Figure 2). Export of South Africa is the least innovative among the BRICS countries. The advantage of PRC is associated with the feature of its production structure – a greater focus on the production of high-tech products.

Figure 2. *Share of high-tech products in the country's exports, %*



3.3.3 *Due to the data on the turnover of intellectual property rights*. The payments in all countries analyzed significantly exceed the amount of funds received from non-residents (see Figures 3-4). China leads here, in particular with regard to the use of foreign intellectual property.

Figure 3*. The amount of funds paid to the non-residents by the residents of the country for the use of intellectual property, billion US dollars*

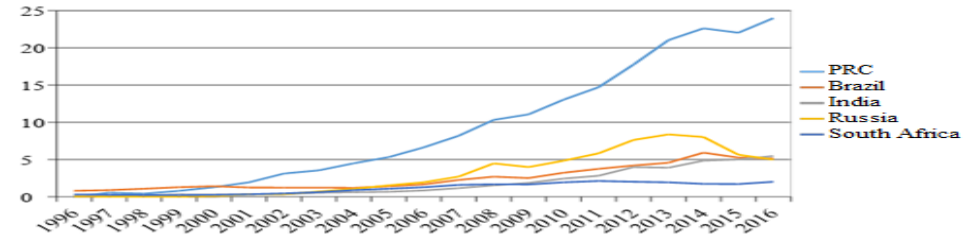
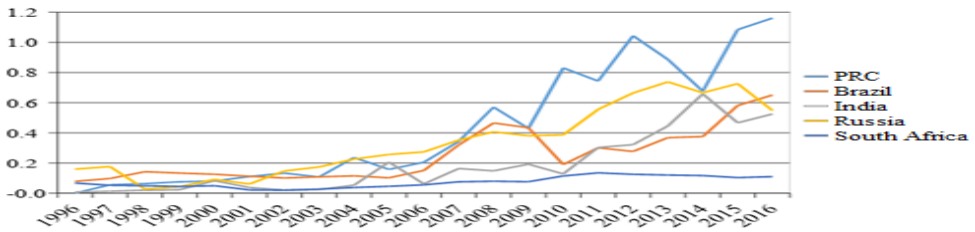
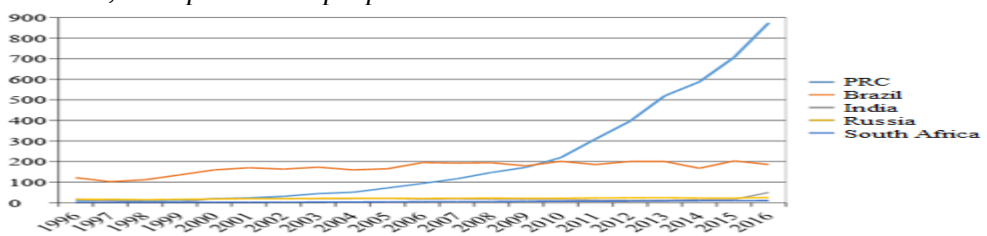


Figure 4. *The amount of funds received by the residents of the country from the non-residents for the use of intellectual property, billion US dollars*



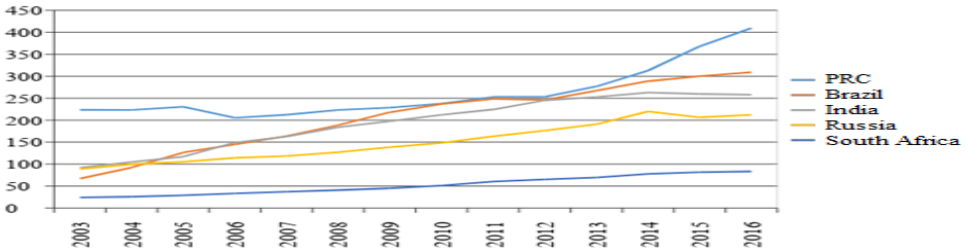
3.3.4 *Due to the number of the patents registered by the residents of the country per head of population.* Since 2009, China is leading here (see figure 5) while Brazil's, India's, Russia's and South Africa's figures changed insignificantly. Also the largest number of the patents is annually registered in Russia.

Figure 5. *Number of the patents registered by the residents per year in the BRICS countries, units per million people*



3.3.5 *Due to the number of articles published by the residents of the country in scientific and technical journals per capita.* Russia is leading here (see Figure 6), the least active is India.

Figure 6. *Number of articles published by the residents of the country in scientific and technical journals, units per million people*



3.3.6 *Due to the dynamics of the number of researchers and technical specialists in R&D per head of population* (Figures 7-8). A negative trend in these indicators in Russia should be noted. Nevertheless, throughout the decade, our country is the leader among the analyzed countries in terms of the number of research personnel. In terms of the number of the technical specialists, Russia in 2010 was second only to Brazil (data on the PRC for the entire period of time is absent). The lowest number of researchers and technicians in 2000-2015 was observed in Brazil.

Figure 7. *Number of researchers in the field of R&D, units per million people*

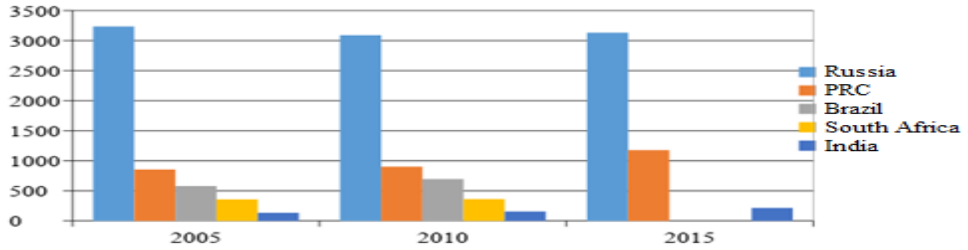
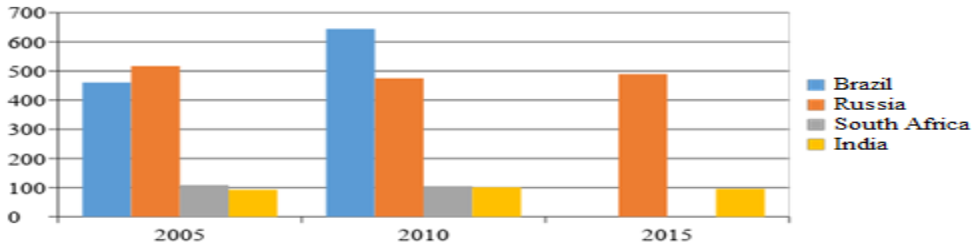


Figure 8. *Number of technical specialists in the field of R&D, units per million people*



The results of the analysis of statistical data characterizing the level of development of innovation systems of the BRICS countries showed:

✓ in the last decade the highest level of development of NIS and the most active growth of indicators of innovative development are observed in China. This country is a leader in almost all reviewed indicators, except for the indicators of the publication of articles by the residents in scientific and technical journals, and availability of scientific and technical personnel.

✓ Russia has the largest number of researchers in R&D per capita; level of availability of the technical specialists is also rather high. Our country is ahead of other BRICS states in terms of specific number of the articles published, but it is inferior in the number of the patents being registered. This situation indicates a high level of education of the population of the country and the development of science and technology in general, but also – the low patent activity of Russian scientific and technical specialists. In general, Russia occupies an intermediate position among the BRICS countries in the most of the indicators analyzed.

✓ For the majority of the indicators presented above, South Africa and India lag significantly behind other analyzed countries.

3.3.7. Global Competiveness Index & Hirsch index. In the rating of the World Economic Forum (2018), based on calculations of the Global Competiveness Index for 2017–2018, China is ahead of the rest of the BRICS countries and takes 27-th place, Russia – 38-th place, India – 40-th place (see table 1). The positions of South Africa (61-st place) and Brazil (80-th place) are comparatively lower in the rating. As an indicator of the level of development of NIS, the Hirsch index (H-index) (Scimago Journal & Country Rank) is also applied – scientometric indicator taking into account the number of publications by the researcher, and the level of their citedness. The highest value of this index in 2016 among the BRICS countries was reached by China (14-th place in the rating), the lowest – by South Africa (ZAF) (34-th place). India (21-st place), Russia (22-nd place) and Brazil (23-rd place). China is a leader not only in the number of published articles in scientific and technical journals, but also in the level of citedness among the BRICS countries.

Table 1. *Position of the BRICS countries in the world innovation development ratings*[*]

Competitiveness index for 2016			**Hirsch index for 2016**			**Index of innovation development for 2017**			**Index of human development for 2016**		
Country	Place in the rating	Index value	Country	Place in the rating	Index value	Country	Place in the rating	Index value	Country	Place in the rating	Index value
CPR	27	5,0	CPR	14	655	CPR	22	52.54	Russia	49	0.804
Russia	38	4,6	India	21	478	Russia	45	38.76	Brazil	79	0.754
India	40	4,6	Russia	22	467	ZAF	57	35.80	CPR	90	0.738
ZAF	61	4,3	Brazil	23	461	India	60	35.47	ZAF	119	0.666
Brazil	80	4,1	ZAF	34	361	Brazil	69	33.10	India	131	0.624

***Source:** By the authors according to (World Economic Forum 2018; Cornell University, INSEAD and WIPO 2017; UNDP 2016) and the data of Scimago Journal & Country Rank.*

3.3.8. Global Innovation Index (Cornell University, INSEAD and WIPO. 2017). It is developed by Cornell University, the European Institute for Business Management (INSEAD) and the World Intellectual Property Organization (WIPO). The index includes 81 indicators and reflects, among other things, such aspects of innovative development as the political environment, education, infrastructure and business complexity. In the rating of 2017, South Africa, India and Brazil occupied 57-th, 60-

th and 69-th places respectively, being inferior to CPR (22-nd place) and Russia (45-th place), which entered the number of 50 (out of 127 in total) of the most developed countries in the rating. In general, China's position is significantly higher than the positions of other BRICS countries on most of the indicators included in the index.

3.3.9. Human Development Index (UNDP, 2016), calculated by the United Nations Development Program (UNDP) annually since 1990, deserves an attention. The index characterizes three main aspects of human potential: living standard, literacy, education and longevity. The highest value for this index among the BRICS countries in 2016 was awarded to Russia, the lowest – to India. The results show that in Russia the most favorable situation is observed in terms of living standards and education of the population compared to other BRICS countries, which is one of the fundamental resources for the country's innovative development.

According to the analysis from sections 3.3.7–3.3.9, the leader among the BRICS countries in terms of innovative development is China, its "open doors" policy proved to be the most effective. Having started from the regulated planned economy, where the creation and implementation of research and development results took place within the framework of strict state planning and implemented through the state order, this country has managed to create favorable conditions for the development of high-tech industry, attraction of foreign investments, location of production facilities and research centers of multinational companies. Most indicators indicate that the NIS of South Africa is the least developed among the analyzed countries.

Russia is the leader among the BRICS countries in such aspects as the living standard, literacy, education and longevity, in terms of innovation development, in general, China is ahead of Russia. Despite the previously noted Russian championship among the BRICS countries in terms of the number of research personnel per capita, Russia is inferior to CPR and India in the level of citedness of the scientific papers, which indicates the need to stimulate and increase the productivity of Russian researchers.

3.4 Development of the national innovation system of Russia

The main efforts are supposed to be focused on priority areas, among which are the following: digital production technologies, new materials, systems processing large data amounts, artificial intelligence and machine learning, environmentally friendly and resource-saving energy sources, personalized health care. The share of domestic expenditure on research and development in Russia's GDP in 2017 was 1.1%. In accordance with the Strategy, it is expected that this indicator will reach 2% by 2035 (1.7% by 2030).

The development of the sphere of science, technology and innovation in our country is determined by a number of strategic documents, the key of which is the Decree of the President of the Russian Federation No. 642 (2016) "On the Strategy for Scientific and Technological Development of the Russian Federation" (hereinafter – the

Strategy). According to the Strategy, in the coming decades the country's scientific potential will be focused on resolving the following series of problems:

1. deterioration of the environment;
2. exhaustion of opportunities for economic development as a result of extensive exploitation of resources;
3. need for additional power capacities.

The main source of financing for Russian R&D is still the state; according to 2015 data, its contribution to research and development was about 69.5% of the total amount of funds invested in R&D, contribution of the business – 26,5%, educational institutions – 1.2%, private non-profit organizations – 0.2%, from foreign countries 2.6% is attracted (Eurostat, 2016). This cost structure differs significantly from the practice of world leaders in innovative development and China. The State Program of the Russian Federation "Development of Science and Technology" for 2013-2020 (Decree … No. 301 2014) is a key tool here. Due to which the share of publications of Russian researchers in the scientific journals of the database WEB of Science reached 2.5% by 2017 (Decree … No. 204, 2018; Report … for 2013-2020, 2018) and the share of young researchers under age of 39 has exceeded 41%. But increasing the investment attractiveness of scientific, scientific, technical and innovative activities, expressed in the volume of investments into R&D, have not yet been resolved.

Currently, Russia is developing a new State program "Scientific and technological development of the Russian Federation", designed for the period until 2030. Implementation of the Program involves the following measures:

– allocation of additional funding for R&D;
– creation of the new institutes engaged in research and development;
– providing the scientific and technological communication;
– creation of an advanced infrastructure for research and development, innovation (installations of the "mega science" class, centers for collective use and unique scientific installations, centers for experimental and small-scale production);
– creation of a network of world-class science centers;
– updating at least 50% of the instrument base (Decree … No. 204 2018) and provision of equipment to new institutes;
– support for manufacturers of high-tech products;
– creation of digital platforms for participants of scientific and technological development;
– creation and support of the functioning of the centers of the National Technological Initiative;
– attraction of the foreign leading scientists and young promising researchers, targeted improvement of working conditions for Russian leading scientists and young researchers (including programs to support targeted mobility and grant support).

4. Conclusion

The results of the research showed that for the creation and operation of an effective NIS it is important to competently build an innovative and technological business policy, oriented to a long-term perspective, as well as to create conditions necessary for development of science and technology in universities and research institutes, involving young scientists and specialists into this process. In addition, it is necessary to stimulate market mechanisms for independent financing of universities and research institutes, as well as to develop the practice of private initiatives and investments in the development of innovative activity.

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