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On the strategic importance of developing scientific and technical cooperation among BRICS members

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Abstract

The author examined the strategic importance and promising areas for the development of scientific and technical cooperation (STC) among the BRICS (and BRICS+) countries. The emergence of the New World Order (NWO) has created conditions for the expansion cooperation among the BRICS members, and the development and, in particular, deepening of the scientific and technical cooperation among the BRICS countries (BRICS+) should make it possible to create a sustainable strategic basis for the development of all BRICS members (and BRICS as a whole). The most important condition for the development of the international STC is the existence of innovative technological and scientific technical potential in the participating countries. Their study allowed the author to establish: 1) their presence in the BRICS countries; 2) the presence of interest of all BRICS countries in the development of STC and in the development of STC with Russia; 3) that the pace of development of STC of the BRICS countries is significantly inferior to the pace of trade and economic cooperation; 3) the presence of both intergovernmental documents and facts of implementation of joint events and programmes in the field of academic and university science, in the field of education. The directions for the development of the BRICS S&T cooperation agreed upon by the participating countries so far should be considered as justified, but it is advisable to develop and deepen them, especially in the direction of environmental protection and in response to the digital transformations taking place in the modern economy. However, for the development of the STC of the BRICS members, it is necessary to define the strategic significance and formulate the principles of understanding the strategic significance of the implementation of the ISTC at this stage of development of science, technology and economy, which is important for almost all BRICS members. For this purpose, the author has formulated the main points that determine the decisions that need to be made, including those related to the assumption of relevant risks, and has first recorded the stages of development of the STC of the BRICS members. The author also suggests considering the possibility of creating cross-border inter-firm innovation ecosystems. In conclusion, it is emphasised that the formation of the strategy of the STC of the BRICS members requires respect for their interests and the use of an ecosystem approach and fine-tuning.

Keywords: strategies for international scientific and technical cooperation, strategies for innovative development, scientific and technical cooperation, BRICS, new world order, deglobalisation.

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论金砖国家科技合作发展的战略意义

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简介

文章致力于研究金砖五国（和金砖五国+）科技合作的战略重要性和发展前景。正在形成的世界新秩序为扩大金砖国家之间的合作创造了条件，金砖国家（金砖+）之间科技合作的发展乃至深化，应能为每个金砖国家乃至整个金砖+的发展奠定可持续的战略基础。发展国际科技合作最重要的条件是成员国具备创新技术和科技潜力，本研究揭示了金砖国家具备这种潜力的情况，并确定了以下两点：第一，所有金砖国家都有兴趣发展科技合作以及与俄罗斯发展科技合作；第二，金砖国家间科技合作的发展速度明显低于与俄罗斯的经贸合作速度；第三，在学术和大学科学与教育领域开展联合活动和计划的国家间文件和事实。参与国迄今商定的科技合作发展方向应被视为是合理的，但最好发展和深化这些方　向，首先是在自然保护方面，以及在应对现代经济中发生的数字变革方面。为了发展金砖国家之间的科技合作，有必要确定战略重要性并制定原则，以理解现阶段国际科技合作在科技和经济发展中的战略重要性（这对几乎所有"金砖+"成员都很重要），制定决定所要采取的决策的要点，包括与承担适当风险有关的要点，并初步确定科技合作的发展阶段。文章建议考虑形成跨境企业间创新生态系统的可能性。文章强调，金砖国家科技合作战略的形成需要尊重各国的利益，采用生态系统方法并进行微调。

关键词： 国际科技合作战略；创新发展战略；金砖国家；国际科技合作；世界新秩序；去全球化。

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Introduction

The world community is faced with the need to solve (or at least mitigate the effects of) a number of problems caused by the so-called major challenges, the solution to which is beyond the capacity of any single country. Until recently, it seemed that humanity was ready to act together to solve these problems (including by achieving the Sustainable Development Goals, SDGs[1]), but the emerging world order is limiting the possibilities of solving global problems, because their solution is impossible without the consolidation of joint efforts and the development of international scientific and technological cooperation (hereinafter referred to as STC and ISTC) at various levels and in various forms, naturally taking into account aspects related to the observance of the interests of all countries of the international community. It is important to note that a characteristic feature of the emerging world order is not only the creation of conditions of disunity and confrontation, but also the fact that its ambassadors try in every possible way not so much to develop their innovative and technological potential, but to hinder the development of the scientific and technological potential of other countries, thus artificially maintaining their leadership. In the author's opinion, such a policy is counterproductive, not only in terms of solving global problems, but also in terms of developing such ambassadors themselves, and not only in the long term, but also in the medium term[2]. In this regard, given the growing innovative technological and scientific-technical potential of 'non-Western' countries, it can be assumed that efforts to develop ISTC between different groups of countries, including the BRICS (and BRICS+) countries, will be intensified in the near future. Of course, one should not expect BRICS (and BRICS+) to respond to all major challenges overnight, but it is highly advisable to act together, including in the direction of creating conditions for mutually beneficial cooperation. The reasons can be formulated in the following simple way: It is the ISTC that creates conditions for increasing the effectiveness of the scientific and technological activities of the association and of each of the participating countries, allowing them to solve together (and each individually) various problems related both to increasing the innovative and technological activity of the subjects of their economies, and to achieving technological leadership or technological sovereignty, depending on the goals that each country has set for itself, which is becoming particularly important given the growing importance, power, scale (and in some ways unpredictability) of the development of machine learning and generative artificial intelligence; it is the STC that is capable of creating absolute conditions for strengthening cooperation between the BRICS member countries and for the development and qualitative transformation of this international platform. In these conditions, the scientific and technological cooperation of the BRICS countries, which are becoming more and

[1] https://www.un.org/sustainabledevelopment/ru/sustainable-development-goals/.

[2] This has been noted in a number of the author's works devoted to the study of deglobalisation processes and the phenomenon of techno-nationalism, see, for example: [Matkovskaya, 2023a; 2022b].

more important players and successful in innovative-technological and scientific-technical development, is of strategic importance for the development of each of the countries included in the BRICS (BRICS+) and for the creation of a strategic basis for this association, which is aimed at ensuring the technological security of the participating countries, as well as facilitating the exchange of knowledge, the development of educational initiatives and a system for training highly qualified personnel and, of course, achieving sustainable development and improving the quality of life of the population. All these aspects characterise the content of the article's purpose, which is to explore and record the strategic importance of the development of scientific and technological cooperation among the BRICS countries.

The methodological basis for the study of the problem investigated in this article was a combination of general scientific methods (analysis and synthesis, scientific abstraction, generalisations, analogies), methods of economic analysis, classification and grouping, ranking and structuring, quantitative and qualitative analysis of data, methods of systemic, logical, structural, comparative and graphical analysis, and design methods.

1. New World Order

1.1. Facts

So what is the emerging new world order, and how destructive is it? And it is destructive, first of all, because of its lack of objectivity. Its characteristics, the new world order, can be very voluminous, but in this work only a few facts will be presented to outline it, highlighting the most important ones for the subject under study. So, fact one: 'new world order' has become a fairly stable term, but the meaning behind this concept is sometimes the opposite: from creating fair and equal conditions for all countries striving for development, to creating new conditions to maintain the previous proportions and support one's own superiority[3]. Fact two: the characteristics of the 'new world order' are characterised by processes such as the formation of a multipolar world, polarisation, deglobalisation, regionalisation, techno-nationalism, as well as 'glocalisation', 'friendshoring', etc. Fact three: the formation of trends that characterise the awareness of the depletion of their own sources of innovative development (for countries - ambassadors of techno-nationalism), in connection with which the rhetoric is changing: the concepts of 'third world countries', 'fourth world countries' are encountered less and less, they give way to the concepts of: countries with developing economies (not developing countries), high-income countries, middle-income countries, etc., for which 'green windows' are opening, etc., which is reflected in a number of reviews and reports[4]. Perhaps the change in rhetoric is largely due to the desire to preserve by all means the inflationary supranational institutions created after the Second World War, including the WTO, as demonstrated by the speech of its head in the autumn of 2024[5]. In addition, the proportion of foreigners among researchers in the United States is consistently high and even growing, although not yet dominant [Minate, Chepik, 2020; Petrovskaya, 2021][6], although a number of Chinese researchers are also returning home (although this trend has other causes, including the implementation of the personnel policies of the PRC government). Fact 4 is substantiated by the results of the regular monitoring conducted by the author, dedicated to the study of the nature and direction of globalisation (deglobalisation) processes occurring in the modern world, which allows us to assume that the modern world remains globalised, most economies of the world are 20-30% dependent on imports[7]. And finally, the fifth fact is the fact about the growing and developing BRICS. The formation and expansion of BRICS is truly the most reasonable response to the current situation - a situation in which the need has arisen to create conditions for the development of countries, including the countries of the global South and East, as well as countries whose rights are being trampled on by states that have appropriated the right to decide the fate of the entire world. Moreover, the policy of technological containment, together with digital transformation processes, creates conditions for understanding the strategic importance of the development of the scientific and technological complex of countries and BRICS+.

Thus, it is becoming more and more obvious that the established world order has a limiting effect on the possibilities of solving problems related to major challenges, since the solution of global problems is impossible without the consolidation of joint efforts and the development of ISTC at various levels and in various forms, naturally taking into account aspects related to the observance of the interests of all countries of the international community.

[3] The New World Order through the eyes of Putin and Biden. How will Russia and the United States divide the world? (2024). https://tsargrad.tv/articles/novyj-miroporjadok-glazami-putina-i-bajdena-kak-rossija-i-ssha-podeljat-mir_895260.

[4] Related links: The 2023/2024 human development report copyright (2024). https://report.hdr.undp.org/how-can-we-turn-things-around; Open green windows. Technology opportunities for low-carbon world: Technology and innovation report (2023). https://unctad.org/system/files/official-document/tir2023_en.pdf; The middle-income trap: World development report (2024). https://www.worldbank.org/en/publication/wdr2024?cid=ECR_E_NewsletterWeekly_EN_EXT&deliveryName=DM226534.

[5] WTO News items - DG Okonjo-Iweala calls for re-imagining of global trade system amid increasing challenges (2024). https://www.wto.org/english/news_e/news24_e/igo_31oct24_e.htm.

[6] Related links: The number of international scholars and students in the US has increased (2024). https://allterra.ru/news/v-ssha-stalo-bolshe-inostrannykh-uchyenykh-i-studentov/; Hamilton J. (2024). Foreign nationals propel U.S. science. If Trump limits immigration again, that could change. https://www.npr.org/sections/shots-health-news/2024/11/21/nx-s1-5187926/u-s-science-could-suffer-if-trump-limits-h-1b-visas-again.

[7] The complication of concentration in global trade (2023). https://www.mckinsey.com/mgi/our-research/the-complication-of-concentration-in-global-trade; KOF Globalization Index 2023 (2023). https://gtmarket.ru/ratings/kof-globalization-index?ysclid=ldbgd1lq7u96105360; The 2023/2024 human development report copyright (2024). https://report.hdr.undp.org/how-can-we-turn-things-around.

1.2. Review of sources dedicated to the study of the BRICS STC

An analysis of the level of research on the issues under study revealed a lack of studies in modern foreign scientific literature in recent years that are directly devoted to the study of scientific and technological cooperation among the BRICS countries. An analysis of publications in foreign peer-reviewed journals showed that the issue of the development of the STC of the BRICS countries is studied by authors mainly in the context of studying the prospects for the development of "green" energy and the economy, in which the STC are considered, but in a correspondingly subordinate context (much less often the STC of the BRICS countries are considered in the context of the development of financial institutions in general and the New Development Bank (hereinafter NDB) in particular), which, without being interpreted as a negative point, indicates a lack of independent, sufficiently effective studies devoted to the development of the STC (namely in foreign peer-reviewed publications of recent years, mainly for 2014-2024 and earlier). However, it is worth paying attention to the work of some researchers who have addressed the issues of the STC of the BRICS countries. Among them, the article [Andrew et al., 2024], devoted to the study of environmental aspects and the formation of the 'green economy', stands out. Its authors study the holistic production potential of the BRICS member countries (this is what 'economic complexity' consists of). By examining the moderating role of innovative technologies and 'economic complexity' in the relationship between financial development and environmental quality in the BRICS economies, these researchers conclude that, taken together, innovative technologies create much greater opportunities for reducing the carbon footprint of these economies than economic growth, and that the transfer of environmental technologies creates the conditions for increasing the environmental sustainability of the BRICS countries.

Magazzino et al. [Magazzino et al., 2024] analysed the transformation strategies in cereal production in the BRICS countries over a period of three decades (until 2021) and made several recommendations to improve policies aimed at achieving several SDGs by the BRICS countries: in the area of innovative technology development, land use management, ecology and crop diversification.

[Xu et al., 2022] find that green growth has an uneven impact on economic performance across BRICS countries, while [Gu et al., 2018] find that the concept of a green economy in BRICS countries 'should be seen as a means to achieve fundamental and overarching priorities, rather than an end in itself'. The same authors also point out the differences in potential among the BRICS countries and the fact that Russia and Brazil are characterised by technical and political limitations, while an important area of trade and economic relations between Russia and South Africa is the development of cooperation in the field of nuclear energy.

The authors [Özkan et al., 2024] note that the BRICS countries эhave become major players in the global economy over the past decadeэ, including in the field of green energy. They also point out that for countries such as Russia and Brazil, the development of green energy financial initiatives has a positive impact in the short and medium term, but turns negative in the long term, in contrast to South Africa, where the impact of financial development on green growth is predominantly negative.

It should be noted that the work of other authors, for example [Chen et al., 2023], also makes a significant contribution to the study of these issues.

Among the studies focused on the study of the NBR and issues of innovative development of the BRICS countries, it is worth highlighting [Rowlands, 2012; Abdenur, 2014; Chin, 2014; Schablitzki, 2014; Kan, 2015; Dixon, 2015].

In contrast to foreign researchers, Russian researchers are quite active in studying the possibilities and prospects for the development of S&T cooperation in the BRICS countries and try to cover a wider range of issues related to the development of BRICS and the ISTC within its framework. It is worth highlighting the work [Sokolov et al., 2017], which conducted a serious study and formulated 'a list of promising areas and fields of science and technology in which the BRICS countries may be interested in cooperation with Russia'. The authors rightly note that the effectiveness of interaction between the BRICS countries will be facilitated by such an approach, which is aimed at the implementation of STC by these countries throughout the entire cycle of innovation creation. Examining the prerequisites and prospects for cooperation between BRICS countries in the field of innovation, the author of the work [Sidorova, 2018] notes the 'uneven development and innovation gap of the national economies of the member countries', considers China's leadership as 'obvious' but 'not completely dominant', and concludes that 'further stimulation of the innovative development of the countries is necessary', calling for the creation of a 'single BRICS innovation space'.

It is also worth paying attention to other work. For example, [Govorova, 2018] examines the national innovation systems (NIS) of the BRICS countries, studies the prospects for cooperation among them, and suggests that China and South Africa may become leaders in the field of BRICS innovation. The authors [Luzina, Dudareva, 2019] believe that the condition for the development of integration processes between the BRICS countries, their science and business is 'the creation and support of the development of innovative infrastructure to attract scientists and highly qualified specialists'.

At the same time, Russian researchers are also studying other aspects of the development of the NIS, for example, legal issues of the formation of a global research infrastructure [Kozheurov, Teymurov, 2019]. A number of other Russian scientists have conducted in-depth studies in the field of the formation and development of the Russian ISTC. A significant contribution to the development of this issue is provided by the works of [Kotsemir et al., 2015; Balyakin et al., 2018; Danilin, 2019; Dezhina, Klyucharev, 2020] and others. The researchers also touch on issues of productivity and the choice of implementation directions, drawing attention to the similarities and differences in the scientific and technological potential of the BRICS countries.

Despite the fact that the interest of foreign authors in the study of the BRICS STC is somewhat subordinate, which is compensated by a broader definition of the object of research by Russian scientists, the trends emerging in the modern world make the study of the BRICS STC (and ISTC in general) increasingly relevant. This suggests that the study of S&T cooperation in the BRICS countries should be intensified, especially in the area of developing strategies for its implementation by the participating countries and developing integration strategies for S&T development, and that research on the development and implementation of infrastructure and institutional projects should be intensified, especially in the context of digital transformations and the formation of a new world order, developing models that allow creating conditions for the development of both the participating BRICS countries and the association as a whole.

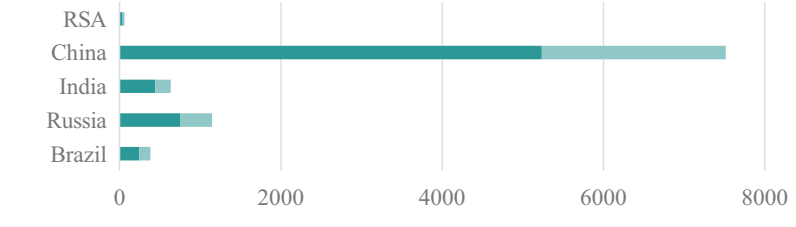
2. Assessing the innovative potential of the BRICS countries

Two important comments should be made at the beginning of this section. The first is that while much could be said about the importance of the development of the BRICS STC, any assessment should be based on numerical indicators. The second observation is the methodological complexity of the systemic nature of determining the innovative potential of a country (as opposed to the assessment of the innovative potential of organisations, although this is not close to perfection), which is due to many factors, such as the heterogeneity of data, the asynchronous nature of investments in research and development (R&D) and their returns, the differentiation between investments and returns in basic and applied science, the uncertainty of results, etc. Methodological shortcomings are recognised by researchers, statistical agencies and international organisations, but they all try to assess the innovation potential of a particular country. As a result, all assessments of the innovative potential of economies are imperfect, but a tradition has emerged that defines a set of parameters against which these assessments are made. These are usually estimates of the number of organisations performing R&D, the number of R&D personnel, internal R&D costs, budget allocations for civil science, available fixed assets, etc. (this attribution logic is mainly used by statistical organisations). The World Intellectual Property Organisation (WIPO) uses a system of indicators to construct a global innovation rating, grouped under the following headings: institutions, human capital and research, infrastructure, market sophistication, business sophistication, knowledge and technological outputs, creative outputs (the names of which can be translated as ‘institutions’, ‘human capital and research’, ‘infrastructure’, ‘market and business sophistication’, ‘knowledge and technological outputs’, ‘creative outputs’)[8]. At the same time, WIPO (like many other international organisations) presents relative results, while statistical bodies more often present absolute results.

There is no guarantee that the system of indicators used by statistical offices, WIPO or other organisations to calculate indicators reflecting the innovative activity or innovative potential of a given economy is sufficient, homogeneous, relevant and, above all, capable of providing comprehensive and reliable information. In this regard, the author presents only some of the most important indicators for this study: (1) adherence to the logic of statistical bodies, WIPO and other expert and international organisations; (2) attention to the most significant, comparable indicators; (3) emphasis that the study of the innovative potential of the BRICS countries is not the main objective of this work.

Let us first look at key indicators such as the number of persons employed in R&D and the number of researchers (Fig.1).

Fig. 1. Number of R&D personnel and researchers in BRICS countries in full-time equivalents, 2010–2021 (thousand person-years, median)



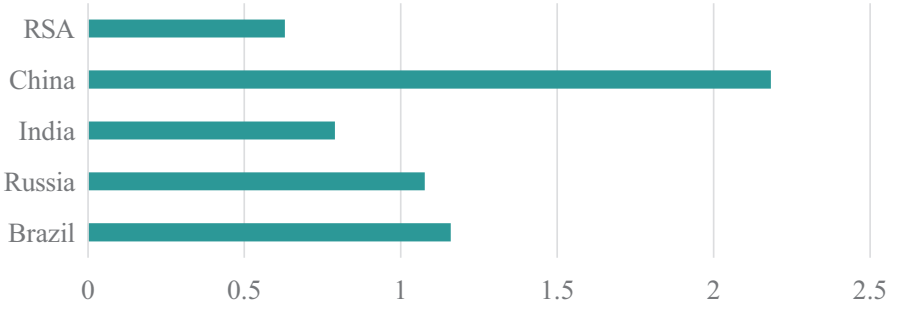
Source: compiled by the author on the basis of: Russian Statistical Yearbook (2023). Moscow, Rosstat: 689.

[8] Global Innovation Index 2024: Unlocking the promise of social entrepreneurship. https://www.wipo.int/documents/d/global-innovation-index/docs-en-2024-gii-2024-clusters-top100-ranking.pdf.

Fig. 1 shows that the absolute leader in both indicators is China, with Russia in second place among the BRICS countries. To estimate the ratio, the number of persons employed in R&D in the BRICS countries during this period should be taken as 100%. China's share will then be 78%, Russia's 11%, India's 7%, Brazil's 4% and South Africa's less than 1%. If we take the number of full-time equivalent researchers in the BRICS countries over the same period as 100%, China's share remains high at 75%, Russia at 13%, India at 6%, Brazil at 5% and South Africa at 1%.

The next important indicator is domestic R&D expenditure in the BRICS countries (Fig. 2).

Fig. 2. BRICS domestic R&D expenditure, 2010–2021 (% of GDP, median)

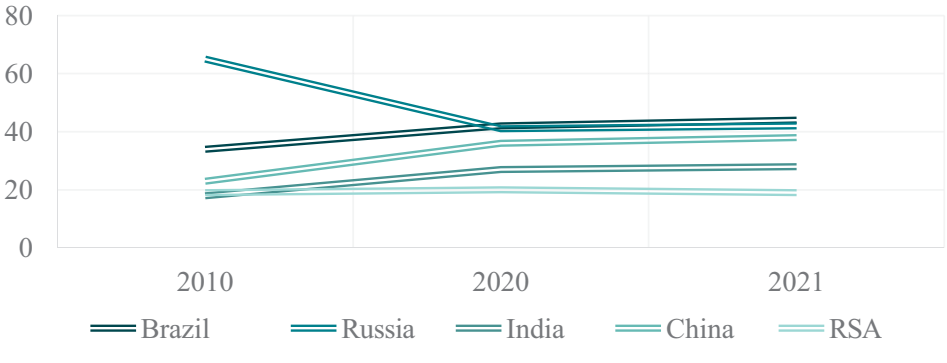


Source: compiled by the author on the basis of: Russian Statistical Yearbook (2023). Moscow, Rosstat: 690.

The data presented in Fig. 2 again show China's leading position in relation to other BRICS countries, but at the same time, with an indicator of 2.43%, China is well behind the world leaders, including the Republic of Korea - 4.93%, the United States - 3.46%, Belgium - 3.46% and Sweden - 3.4% (2021). In Russia, this indicator will be 1% in 2021[9].

The next indicator that the author considers worthy of attention is the dynamics of student numbers (Fig. 3).

Fig. 3. Dynamics of the number of students in the BRICS countries (per 1000 inhabitants)



Source: compiled by the author on the basis of: Russian Statistical Yearbook (2023): 656.

In addition to the data shown in Figure 3, it should be noted that the largest number of students among the BRICS countries in 2021 will be observed in Brazil - 44 people per 1000 inhabitants, the second place among the BRICS countries is taken by Russia with an indicator of 42 people, the third place belongs to the PR China - 38 people, in India - 28 people, in South Africa - 19 people. At the same time, the number of students in 2022 will increase to 43 per 1000 in Russia and 40 in China (data for 2022 are not available for the other BRICS countries). It should be noted that the world leaders in the number of students are Australia (67 students per 1000 inhabitants) and Kazakhstan (59 students per 1000 inhabitants), the USA (55 students) and Germany (40 students)[10].

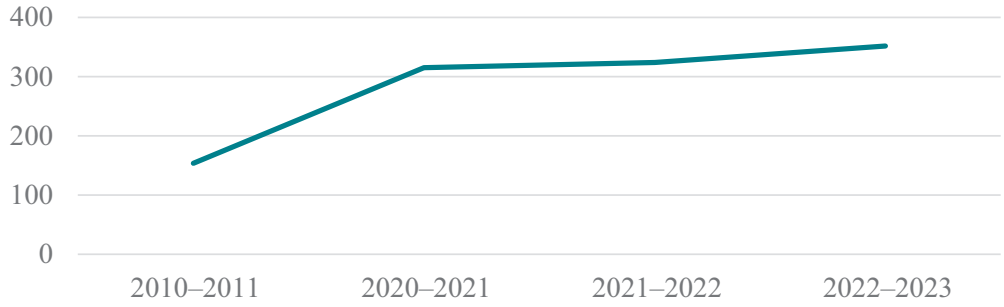
Statistical data also suggest that Russia leads the BRICS countries in the number of foreign students. The growth in the number of foreign students studying in various programmes at higher education institutions and scientific organisations in Russia is shown in Fig. 4.

It should be added that students from a significant number of countries around the world study in Russia (listed in descending order of number): from the CIS countries, the Baltic States, Georgia, Europe, Vietnam, India, China, the DPRK, Malaysia, Mongolia, the Republic of Korea, the Syrian Arab Republic, Central and South America, North America (USA and Canada), Zambia, Cameroon, Kenya, Morocco, Nigeria, etc. (stateless persons also study). Foreign students accounted for 8.4% of the total number of students in 2022-2023.

To further analyse the innovative potential of the BRICS countries, it is necessary to pay attention to the HDI (Human Development Index) indicator calculated by the UNDP (United Nations Development Programme). This index is calculated as a summary indicator of average performance in three main dimensions of human development: a long and healthy life, access to knowledge and a decent standard of living. The HDI estimate for 2023-24 shows that all BRICS (and BRICS+) countries, including

[9] Russian Statistical Yearbook (2023). Moscow, Rosstat: 690.
[10] Id.: 656.

Fig. 4. Dynamics of the number of foreign students studying in bachelor's, specialist's, master's degree programmes in higher education institutions and scientific organisations of the Russian Federation (at the beginning of the academic year), on average (thsnd people)



Source: compiled by the author on the basis of Russian Statistical Yearbook (2023): 215.

Russia, have experienced growth in this indicator. Let us add that Russia's HDI increased by almost 11% between 1990 and 2002, which, according to UNDP researchers, is due to growth in GNI per capita (up 25.8%), an increase in life expectancy in Russia of 3 years and an increase in the average length of education by 2.8 years[11].

Focusing on just a few of the most relevant indicators for this study to characterise the innovative potential of the BRICS countries, we can come to a fairly simple conclusion (expected and confirmed by the assessments of other indicators), according to which the leader among the BRICS countries is China, with Russia occupying a stable second place. However, this does not mean that the PRC is the unconditional leader among the BRICS countries, as each of them is characterised by the presence of strengths and weaknesses in their scientific and technological development and innovation potential, which further realises the importance of deepening scientific and technological cooperation among them[12] and determines the strategic directions of scientific and technological cooperation among the BRICS countries.

It should be added that, firstly, the realisation of innovative potential is facilitated by a dynamic competitive environment within the country, as well as the presence of infrastructure, an innovation-oriented business environment, etc., and in this respect the PRC appears to 'win' (but again, not fully). But this is what makes the STC so important for the development of the BRICS countries. Second, an important indicator of a country's innovation potential is the presence of high-tech products in its overall export structure. These estimates will not be presented in this article, but the author refers to some of her other works, in which the results of the study of the dynamics of Russian high-tech exports (positive) are presented in more detail, international comparative assessments of this parameter are carried out, and the results of the critical analysis of the state of scientific and technical potential are presented [Matkovskaya, 2022a; 2024].

3. BRICS NTS: current documents, programmes, events

The results of the analysis of the composition of current documents, programmes and events that form the basis for the implementation of the BRICS STC are presented in the form of a set of facts (as above). The first fact is that in 2019 Russia adopted a (new) Concept of International Scientific and Technical Cooperation of the Russian Federation (8 February 2019, No. TG-P8-952)[13], which defines its content, principles, activities and areas of implementation, and the Concept of ISTC of Russia, STC with the BRICS countries is highlighted as one of the priority areas. A comprehensive positive assessment and critical analysis of the concept of the International Scientific and Technical Council of Russia is presented in the works [Danilin, 2019; Dezhina, Klyucharev, 2020].

The second fact is that in 2015, a 'Memorandum of Cooperation in Science, Technology and Innovation between the Governments of the Federative Republic of Brazil, the Russian Federation, the Republic of India, the People's Republic of China and the Republic of South Africa' was signed[14].

[11] 2023–2024 human development report (2024). https://hdr.undp.org/data-center.

[12] The author does not present the results of the analysis of the number of articles indexed in international databases and the number of publications co-authored with foreign colleagues, given the difficulties that have been created, for example, for domestic researchers in recent years, but notes that the leader among the BRICS countries in the number of publications co-authored with foreign authors is South Africa. It seems that this aspect is a competitive advantage of this country and can be considered as one of the areas for deepening BRICS S&T cooperation.

[13] The concept of international scientific and technical cooperation of the Russian Federation (2019). https://нтр.рф/analytics/kontseptsiya-mezhdunarodnogo-nauchno-tekhnicheskogo-sotrudnichestva-rossiyskoy-federatsii/.

[14] Order of the Government of the Russian Federation dated 14.03.2015 No. 434-r 'On the signing of a Memorandum on cooperation in the field of science, technology and innovation between the Government of the Federative Republic of Brazil, the Government of the Russian Federation, the Government of the Republic of India, the Government of the People's Republic of China and the Government of the Republic of South Africa'. ttps://rulaws.ru/goverment/Rasporyazhenie-Pravitelstva-RF-ot-14.03.2015-N-434-r/?ysclid=m4h24bux2574991251.

The third fact is that the institutions of the BRICS STC are functioning. For example, the body that coordinates the initiatives and activities of the thematic working groups of the BRICS STC is the BRICS Steering Committee on Science, Technology and Innovation, which determines the priority areas for the development of cooperation[15]. Other institutes are also in operation, such as the BRICS Scientific Council (since 2013), the BRICS Network University (established in 2015 and operational since 2017), the BRICS Network Centre for Materials Science and Nanotechnology (since 2017), and the BRICS Baikal Institute (at the Irkutsk Scientific Research Technical University, since 2018). The BRICS Energy Research Platform meetings are being organised; in 2024, the BRICS Ministers of Labour and Employment adopted a joint declaration; in October 2024, the BRICS University Rectors Forum, 'the first event of this format'[16]; was held in Moscow; the BRICS Academic Forum and the BRICS Young Scientists Forum are in operation; flagship projects are being implemented; the BRICS GRAIN Platform [Kortunov, 2024] and other initiatives are in operation.

According to the work [Gerasimov, Kodaneva, 2023], referring to the report of I.E. Ilyina, within the framework of BRICS '93 projects in 11 scientific fields were supported, of which 59 projects were implemented with the support of the Russian side' (with the participation of Russia). This article also indicates that cooperation is developing in the area of access to scientific infrastructure. Thus, 'Russia is represented by 6 active infrastructure facilities, Brazil - 4, India - 6, China - 4, South Africa - 1; another 7 research infrastructure facilities are under development, of which 1 is in South Africa, 1 in India, 1 in Brazil, 4 in Russia'.

The fourth fact is that Russia is implementing scientific and technological cooperation with each of the BRICS countries. For example, in 2021 the 'Roadmap for Russian-Indian cooperation in science, technology and innovation' was signed, which should ensure the development of cooperation and the implementation of a number of programmes, including those related to innovative entrepreneurship, grant support for R&D, it also indicates the presence of initiatives in the field of forming technology parks and innovation clusters that can be localised in both countries. The areas in which cooperation is being developed are mainly medicine, nuclear physics and space geodesy, and joint research is beginning to be carried out in the Arctic and Antarctic regions[17].

Perhaps the most active development of S&T cooperation among the BRICS countries is taking place between Russia and China, which is largely explained by the structural proximity of our S&T cooperation and the presence of National Academies of Sciences in both countries (RAS and CAN, respectively). This creates an institutional basis for the implementation of quite active work aimed at interaction between the institutes of the Russian Academy of Sciences and the Chinese Academy of Sciences (and the Chinese Academy of Social Sciences), implying joint R&D; interactions also take place within the framework of university science. Some of the priority areas of the Russian-Chinese STC are joint research in the field of digital technologies, ecology, geology and geophysics, medicine, physics and astronomy (including a focus on cooperation in the field of space research, lunar exploration - the Memorandum of Understanding on cooperation in the field of creation of the International Scientific Lunar Station, in the field of improvement of optical devices), as well as joint research in hard-to-reach but promising regions (the Arctic, the Tibetan Plateau, deep-sea research). Of course, there is also the 'Roadmap for Russian-Chinese cooperation in science, technology and innovation'. It was developed for the five-year period 2020-2025 and defines the priority areas of scientific and technical cooperation between Russia and China, including: research and development activities and scientific and technical exchanges, innovative cooperation, scientific and technical cooperation in the implementation of mega-science projects, in the field of creating scientific foundations and world-class scientific and educational centres, etc. The roadmap also provides for the holding of scientific and technical congresses and exhibitions, etc[18].

The STC with Brazil is not very active, but is considered to be of interest to both parties. The website of the Ministry of Education and Science of the Russian Federation states that 'Russia and Brazil are expanding inter-university and scientific cooperation. The Brazilian Ministry of Science, Technology and Innovation has expressed interest in creating an exchange programme for Russian and Brazilian researchers in the field of quantum computing, communications and cryptography'[19]. The key areas of STC between Russia and South Africa are recognised as cooperation in higher education and astronomy[20]. The new members of BRICS (BRICS+) have also expressed interest in an STC with Russia.

[15] Scientific, technological and innovative cooperation within BRICS: from oceanology to astronomy (2024). https://minobrnauki.gov.ru/press-center/news/mezhdunarodnoe-sotrudnichestvo/82323/.
[16] What is known about BRICS and the stages of its expansion (2024). https://tass.ru/info/18558683.
[17] Russian-Indian cooperation in high technology: through thorns (2024). https://russiancouncil.ru/analytics-and-comments/analytics/rossiysko-indiyskoe-sotrudnichestvo-v-sfere-vysokikh-tekhnologiy-cherez-ternii/; Russia and India strengthen cooperation in science and technology (2024). https://minobrnauki.gov.ru/press-center/news/mezhdunarodnoe-sotrudnichestvo/63021; The future of innovation: Russian-Indian partnership in science and technology (2024). https://infobrics.org/post/41081/.
[18] Areas of cooperation: Russian-Chinese associations of specialised universities (2024). https://ruschinalliance.unecon.ru/napravleniya-sotrudnichestva/; Russia and China are implementing 80 investment projects worth almost 20 trillion roubles (2024). https://www.interfax.ru/business/937120.
[19] Russia and Brazil expand inter-university and scientific cooperation (2024). https://minobrnauki.gov.ru/press-center/news/mezhdunarodnoe-sotrudnichestvo/79652/.
[20] Russia and RSA are developing cooperation in astronomy and higher education (2024). https://minobrnauki.gov.ru/press-center/news/mezhdunarodnoe-sotrudnichestvo/50279/.

4. Prospective directions of development of BRICS STC cooperation, strategic choices and risk taking

The above analysis has shown that, firstly, the development of the STC between the BRICS+ countries is seen as promising by all participating countries, although the rate of development of the BRICS countries' STC lags significantly behind the rate of growth of trade between the countries. Secondly, a number of documents have been developed, some institutions or outlines of future institutions have already been formed, which creates conditions for the development of the STC of the BRICS countries. Thirdly, events and programmes related to the development of STC are being implemented.

The main and most promising directions of development of STC cooperation in the BRICS countries are determined by the presence of significant reserves in certain areas and/or the existing needs of the countries for interaction. As mentioned above, in Russia these areas are formulated in the concept of the ISTC. The agreed direction of development of the STC of the BRICS countries is cooperation in a number of areas[21]. These areas, taking into account the most advanced aspects defining promising areas, can be presented as follows ICT and digital technologies, including cybersecurity, data transmission, big data processing, machine learning (AI); mechanical engineering and robotics; energy development (including renewable energy sources); materials science; earth sciences; medicine; space research and peaceful exploration of space; education; agronomy, etc[22].

Of course, the listed areas do not exhaust the possibilities for the development of BRICS STC. Very important areas for the development of STC could be cooperation in the field of carbon capture and storage, development of environmental standards for the BRICS countries, development of hard-to-reach terrestrial and extraterrestrial territories, environmental protection and reduction of the anthropogenic burden on the planet[23].

At the same time, there are a number of factors hindering the development of scientific and technological cooperation in the BRICS countries, such as 'insufficient coordination of activities to determine cooperation priorities, taking into account the interests of the countries and the most promising areas'; 'problems with the protection of intellectual property rights'; 'uneven development of the scientific and technological sphere'; 'high cost of transportation'; 'the existence of visa regimes'; 'language barriers'. According to the author, the following problems are of great importance 'insufficiently intensive information exchange between national scientific, technical and innovation systems', lack of knowledge about 'scientific potential, strategic priorities, research programmes, allocated funds and interaction mechanisms' [Krasnova, 2024].

The author, who agrees with the opinion of the RIAC experts on the composition of factors hindering the development of the STC of the BRICS countries, believes that a more serious obstacle, a systemic obstacle, is the insufficient (but not the lack of) understanding of the strategic importance of the development of the STC of the BRICS+ countries. Therefore, it is very important to establish the strategic importance of ISTC at this stage of development of science, technology and economy in general, and to formulate principles for understanding its strategic importance and the importance of developing STC between BRICS+ countries. This is a serious undertaking, and we propose to begin by formulating certain points (the content of which is evidence of the strategic importance of the ISTC in general and the BRICS+ STC in particular) and by identifying the decisions to be taken, including those relating to the assumption of relevant risks.

1. There are a growing number of areas of knowledge where a country's resources are not sufficient to achieve results. In addition, the whole range of digital technologies, including the processing of large amounts of data and the operation of large language models, requires computing power, which in turn requires energy capacity for data processing. In addition, the energy supply for data processing will soon be impossible for individual countries to provide, and joining forces is an important step that opens up new prospects.

2. For each country participating in the ISTC, there are risks of losing R&D results, but also opportunities to gain access to information and R&D results that the country might not have received or that would have required more resources to produce. In most cases, the 'economies of scale' outweigh the opportunities.

3. The policy of technological containment will only become more active, and any participant in modern international relations may find themselves in the crosshairs of techno-nationalism[24]. However, in modern conditions (2020s), not every economy is able to withstand sanctions (here we mean sanctions primarily of a technical and technological nature), so it is necessary to create conditions for maintaining an independent position and access to advanced scientific achievements.

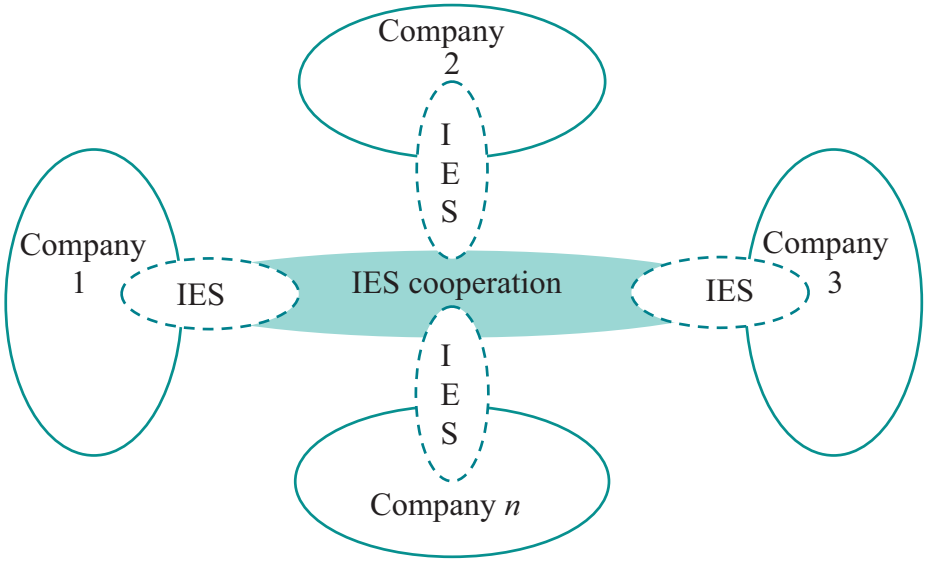
[21] Scientific, technological and innovative cooperation within the BRICS... https://minobrnauki.gov.ru/press-center/news/mezhdunarodnoe-sotrudnichestvo/82323/.

[22] The concept of international scientific and technological cooperation... https://нтр.рф/analytics/kontseptsiya-mezhdunarodnogo-nauchno-tekhnicheskogo-sotrudnichestva-rossiyskoy-federatsii/; Russia and China are implementing 80 investment projects worth… https://www.interfax.ru/business/937120; Areas of cooperation… https://ruschinalliance.unecon.ru/napravleniya-sotrudnichestva/.

[23] As suggested by [Matkovskaya, 2024].

[24] Thus, sanctions against Iran have been in place for several decades, sanctions against Russia have been in place since 2014 (the active phase, although they were in place before), and the trade war between China and the United States continues. Of the BRICS+ countries, only the United Arab Emirates and India have not yet been openly sanctioned, but such sanctions could be imposed on India if it becomes clear that its technological development threatens the interests of other countries.

Fig. 5. Inter-firm innovation ecosystem model



Источник: [Матковская, 2023b].

4. Technological, economic, financial and cybersecurity risks will only increase as the impact of major challenges on the development opportunities of individual economies, the economies of the BRICS+ countries and the global economy will grow.

5. A deepening of the STC between the BRICS+ countries may not take place, but this does not mean that the implementation of the STC is inappropriate.

6. The level of innovation-technological and scientific-technical development of the BRICS countries varies; the areas in which the countries have achieved success differ, as do the resources available to them and necessary for the further development of these areas. In addition to the conclusion on the feasibility of the implementation of the STC of the BRICS countries, it follows from this thesis that the STC should be mutually beneficial, the contributions should be proportionate (we cannot talk about donations, unless special international support programmes are meant), and the STC itself should bring significant innovative-technological and scientific-technical results for the participants, creating a basis for increasing the competitiveness of the BRICS+ countries and contributing to the achievement of the goals of technological and economic security of these countries.

7. It may be that the BRICS+ countries will have to take on the task of solving the problem of climate change, as well as the task of creating regulatory documents in the field of digital regulation (especially the part that affects everyone's concerns - in the field of AI).

In this regard, it is important.

1) to achieve an understanding of the strategic importance of the development of the STC by the BRICS+ countries (and for each of them);
2) to continue developing action programmes and gradual development of scientific and technological cooperation of the BRICS countries, including the development of mechanisms to protect the interests of the participating countries and the association as a whole (including the development of institutions for the protection of intellectual property), taking into account the legal status of the BRICS;
3) to strengthen actions to establish the infrastructure necessary for the implementation of scientific and technological cooperation by the countries of the Association, including digital infrastructure.

It is obvious that the list of tasks should only grow, but at the same time it should remain structured within the framework of mutually beneficial STC of the BRICS+ countries.

It has to be said that the work to solve these problems has already begun and is being carried out with varying degrees of productivity. In this regard, I would like to emphasise the importance of the announced decision on the formation by BRICS member countries of a 'single technological space, including on issues of the development of artificial intelligence (AI)', which is cited in the BRICS material[25], where it is also noted that the Chairman of the PRC already in 2023 'called for the creation of a common structure for the management of artificial intelligence'.

[25] https://www.tadviser.ru/index.php/Article:BRICS_(BRICS)#.2A_.D0.92_.D0.91.D0.A0.D0.98.D0.9A.D0.A1_.D0.BF.D0.BE.D1.8F.D0.B2.D0.B8.D1.82.D1.81.D1.8F_.D0.B5.D0.B4.D0.B8.D0.BD.D0.BE.D0.B5_.D1.82.D0.B5.D1.85.D0.BD.D0.BE.D0.BB.D0.BE.D0.B3.D0.B8.D1.87.D0.B5.D1.81.D0.BA.D0.BE.D0.B5_.D0.BF.D1.80.D0.BE.D1.81.D1.82.D1.80.D0.B0.D0.BD.D1.81.D1.82.D0.B2.D0.BE.

5. Prospects for the development of cross-border inter-enterprise innovation ecosystems of International Research Cooperation

Complementing his proposals for the development of S&T cooperation with the BRICS+ countries and revealing its microeconomic aspects, the author would like to draw attention to the prospects for the implementation of International Research Cooperation (IRC) between companies of the BRICS+ countries. First, however, it is necessary to consider the role of the state and intergovernmental agreements in the development of international scientific and technological cooperation. It can be qualified as 'initiative' or 'ensuring'. In the first case, states form relevant intergovernmental agreements and projects, combining efforts to create regulatory, institutional, technological, communication, infrastructural and other foundations for the implementation of ISTC, and also work to create incentives for the development of scientific, technical and innovative technological cooperation between their national business structures. In the second case, the governments of states, noting the activity in the development of the STC between their national companies and recognising its strategic importance for the development of their national economies, may enter into contractual relations and formulate appropriate policies in the field of the STC between these (two or more) countries. The purpose of such documents and related activities is to create more productive conditions for the development of scientific and technical cooperation between enterprises of these countries, as well as to structure and streamline the forms and methods of implementing such (in this case, scientific and technical) cross-border inter-enterprise cooperation. Of course, these 'strategies' are not diametrically opposed to each other, since no intergovernmental document, no matter how competently formulated, will be able to create the conditions for the real development of STC cooperation between certain countries if it is not supported by economic entities and, above all, if there are no objective prerequisites for its creation or if it does not create real conditions for the implementation of cross-border inter-enterprise cooperation in the field of STC cooperation. Finally, it should be emphasised that it is precisely the intensification of cross-border cooperation between companies, especially in the field of STC cooperation, that creates more dynamic relations in the field of ISTC cooperation.

More specifically, in relation to the development of international research cooperation between BRICS (and BRICS+) companies, it is necessary to propose for discussion the issue of the prospects for the formation of innovation ecosystems (IES) between BRICS companies, based on the proposal for the formation of intercorporate innovation ecosystems (ICIES) in Russia, which was presented in the author's previously published work [Matkovskaya, 2023b]. There is every reason to believe that the model proposed in it is also relevant for the development of cross-border ICIES (CBICIES) and can be implemented to form such innovative ecosystems between companies of the BRICS+ countries. In this respect, it should be noted, firstly, that the universality of the inter-enterprise IES matrix presented in Fig. 5 allows it to be used not only for ICIES but also for CBICIES (including the BRICS+ countries), due to the possibility of including an unlimited number of enterprises in ICIES (and CBICIES). However, in the case of the BRICS+ CBICIES, there are limitations due to the membership of the BRICS (BRICS+) countries whose CBICIES are included in the BRICS+ CBICIES. In other words, CBICIES can consist of n companies from m countries (currently $m \in [2, 9]$). Secondly, in the case of CBICIES, as in the case of ICIES, it can be assumed that the partial integration of two or more ICIES will make it possible to exploit the potential of the companies and obtain a synergy effect from inter-company cooperation. The development of CBICIES can both become one of the key factors in accelerating the innovative development of individual companies in the BRICS countries and create conditions for accelerating the innovative development of the BRICS countries whose companies become participants in such CBICIES[26].

At the same time, when developing such a practice, it is advisable to focus on the proposals made in [Gao et al., 2018]. The authors of the work point to the problem of corporate interference in the activities of foreign companies, including those implementing STC with companies on the territory of the host country, and propose two strategies, the first of which is that companies 'must demonstrate their legitimacy and usefulness to the host country'. At the same time, the researchers also point out that in the case of 'cross-border research alliances, the legitimacy of a foreign firm is partly based on its ability to develop and disseminate technologies that support the interests of the host country' and, referring to [Ge et al, 2021], they cite the example of the Chinese government 'forcing foreign automakers to establish R&D cooperation with domestic firms in order to facilitate the transfer of knowledge to local firms' (while the open exchange of technological knowledge can, according to these authors, 'meet government expectations' and help reduce the 'likelihood of government intervention'). Another strategy identified by these authors is based on 'engagement with host country politicians' [Gao et al., 2018; Jean et al., 2018].

[26] It is important to note that while this article was being prepared, an event occurred that confirmed the timeliness of such a question: on 11 December 2024, it was announced that 'the Russian Direct Investment Fund (RDIF), together with 20 companies from six countries, is creating the BRICS Alliance for the Development of Artificial Intelligence'. It is noted that this initiative was supported by 'more than 50 international companies'. https://www.gazeta.ru/tech/news/2024/12/11/24601442.shtml.

6. Conclusion: priority strategic guidelines

Despite the high rates of economic growth and development demonstrated by the BRICS countries (not to mention the rates of growth of mutual trade), our countries are still not interacting effectively enough; more precisely, the greatest effectiveness in interaction (in all areas) is achieved primarily by China, but even this country is extremely far from using the full potential of benefits from cooperation with the BRICS countries (including the STC).

Barriers to development are created by institutional constraints, primarily formed by the status of BRICS (BRICS is only a 'platform'), the differentiation of countries' positions on the direction in which BRICS should develop: expansion or deepening. Moreover, if the growth of mutual trade volumes contributes to the further development of integration processes, a number of other aspects (including those caused by the existence of long-standing territorial conflicts between individual BRICS countries, not to mention differentiation in ideology, religion, etc.) should have the opposite effect. However, the fact that the BRICS countries are intensifying their cooperation means that the integration processes between them are determined by the influence of a special deep-rooted factor, which is also innovative in relation to the factors that dominated in the industrial and previous eras, and that they are apparently guaranteed success in this integration. This is the phenomenon of the BRICS countries and it remains to be explored while continuing to work on the design and implementation of the STC strategy of the BRICS countries, including the use of an ecosystem approach and fine-tuning.

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