Sustainable Economic Growth: Challenges and Opportunities

Identification of Priorities for S&T Cooperation of BRICS Countries[1]

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This article presents a methodology for the selection of priorities for science and technology (S&T) cooperation among the BRICS countries of Brazil, Russia, India, China and South Africa based on an analysis of international and national strategic documents of BRICS countries and a bibliometric analysis of joint publications by researchers from BRICS countries indexed in the Scopus database. The national S&T priorities for countries are systemized and a comparative assessment of capacities for S&T development in BRICS countries is developed.

Indicators of publication activity of all BRICS countries have significantly increased since 2000. Analysis shows that Russia must pay particular attention to the development of cooperation with China, which is already one of the leaders on the global S&T stage. Cooperation with India, Brazil and, in some research areas, with South Africa could also have a positive impact on the performance of research and development in Russia.

A list of 14 thematic priorities for S&T cooperation for BRICS countries is presented in the paper based on the analysis of a set of national, bilateral and multilateral strategic and forward-looking documents. Priorities of S&T development create a basis for more efficient and mutually beneficial cooperation between BRICS countries and allows individual scientists to broaden the range of research, use new tools for S&T cooperation and share best practices.

Key words: science and technology cooperation; international partnership; priorities for STI cooperation; bibliometric analysis; BRICS

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Introduction

One of the key principles formulated in the Russian Federation's S&T Development Strategy is striving for leadership in specific S&T areas, in conventional and innovative technology, product, and service markets alike, and creating a full-scale integrated innovation system [President of the Russian Federation, 2016]. In recent years, cooperation with BRICS countries in a wide range of subject areas, including science and technology, is increasingly becoming a high priority. Popular tools commonly applied to promote this development model include international S&T cooperation, international R&D integration, establishing efficient partnerships with international R&D centres, and agreeing S&T cooperation priorities with them [BRICS, 2014, 2015, 2016, 2017].

Meeting long-term socio-economic challenges requires the application of a systemic, integrated approach to identify key S&T development areas – those with the potential to make the biggest contribution to solving emerging problems on the national and international levels. Meanwhile, international priorities define the S&T areas, and research and innovation-related goals and objectives particularly important to groups of countries, which require joint effort to accomplish.

Most of the developed and developing nations, including BRICS countries, have been devoting considerable attention to S&T priority setting for quite a while now, since such priorities serve as a basis for their science, technology, and innovation (STI) policies [OECD, 2010; BILAT-USA, 2010; Gassler et al., 2004; Gokhberg et al., 2016; Grebenyuk et al., 2016; Cagnin, 2014; Kuwahara et al., 2008; Li, 2009; Pouris, Raphasha, 2015]. Relevant efforts are mainly focused on solving strategic socio-economic problems, and making efficient use of national competitive advantages [OECD, 2012, 2014; European Forum on Forward Looking Activities, 2015; Meissner et al., 2013; Shashnov, Poznyak 2011; Sokolov, Chulok, 2016]. S&T priorities are currently being set through a comprehensive assessment of their possible contribution to achieving sustainable socio-economic development, and strengthening the country's competitiveness.

Accordingly, identifying S&T priorities shared by BRICS economies becomes increasingly relevant for planning their cooperation [Kahn, 2015; Kotsemir et al., 2015]. This objective is partially accomplished in the scope of various bilateral S&T cooperation programmes implemented by BRICS countries. Developing joint approaches to setting S&T cooperation priorities is becoming particularly important, followed by their successful practical implementation. Especially interesting are cooperation areas where joining forces can potentially produce major synergies. The partner countries' long-term goal is turning BRICS into a full-fledged platform for ongoing and strategic interaction on key issues, including science and technology.

A long-term objective is turning BRICS into a reliable and efficient mechanism for current and strategic cooperation in key areas, including science and technology. Participating in drafting a common agenda for international cooperation, to obtain competitive advantages through S&T and innovation cooperation with foreign countries, is important to Russia and other BRICS nations. Such advantages include identifying promising S&T development areas, and stepping up relevant research through international cooperation; sharing risks and costs in the scope of promising large-scale S&T projects, and pooling resources required for their implementation; participating in meeting global challenges (energy efficiency, climate change, etc.); establishing long-term relations with leading R&D centres to create new knowledge and building infrastructure for joint activities, etc.

Putting in place a reliable information basis for designing a relevant agenda that is meaningful to all BRICS countries requires conducting a comprehensive analysis of S&T potential and the socio-economic objectives of specific countries. Building a system for setting long-term priorities for S&T cooperation between BRICS countries should play an important role in accomplishing this objective, as a major aspect of shaping policies to increase competitiveness of the R&D sector, and more efficiently use public resources allocated to support its development, accelerate its modernisation, and promote transformation of the national economies.

Setting up a common system of priorities should involve broad complementarity, which would help to address the existing limitations through closer cooperation of member countries, and application of their best practices.

In the future, shared priorities could provide grounds for stepping up BRICS countries' cooperation with other nations and international organisations. Such priorities should be identified through the application of various quantitative and qualitative techniques, involving top-level experts in priority setting and dealing with numerous other methodological issues emerging in the course of identifying and selecting S&T areas whose development would make the biggest contribution to accomplishing objectives common to BRICS countries.

Approach to and Principles of Setting Priorities for BRICS Countries' S&T Cooperation

In most of the developed and developing economies (such as the UK, Germany, China, the Republic of Korea, Japan, etc.) the system of national science, technology, and innovation (STI) priorities is based on the results of major Foresight studies covering all the most important S&T development areas [Grebenyuk et al., 2016; Gokhberg et al., 2016; Johnston, Sripaipan, 2008; Choi, Choi, 2015; Kuwahara et al., 2008].

Foresight is a systemic process involving numerous participants, which allows the bringing together of their experience to shape common visions of the medium and long-term futures to support current decision making and taking concerted action [Gavigan et al., 2001]. Foresight methodology is typically employed to deal with emerging long-term socio-economic problems, when political decisions must be made to choose strategic alternatives or set development priorities, and build consensus between major stakeholders regarding the means of accomplishing agreed objectives.

Setting international priorities is just that kind of a task: such priorities should identify S&T areas particularly important to a group of countries, whose advancement should be supported by their joint efforts.

The following basic principles of setting common S&T development priorities can be suggested:

– orientation towards accomplishing major socio-economic objectives shared by a group of countries, and joining forces in relevant areas to strengthen their competitive positions and deal with relevant domestic issues;
– taking into account major global STI trends;
– providing member countries of the group with opportunities to implement their competitive advantages (such as S&T capacity, available resources, previously laid groundwork, etc.);
– setting a limited number of particularly important S&T priorities, to concentrate the available resources;
– applying more efficient STI policy tools.

Priorities for BRICS S&T cooperation can be subdivided into thematic and functional categories (Fig. 1).

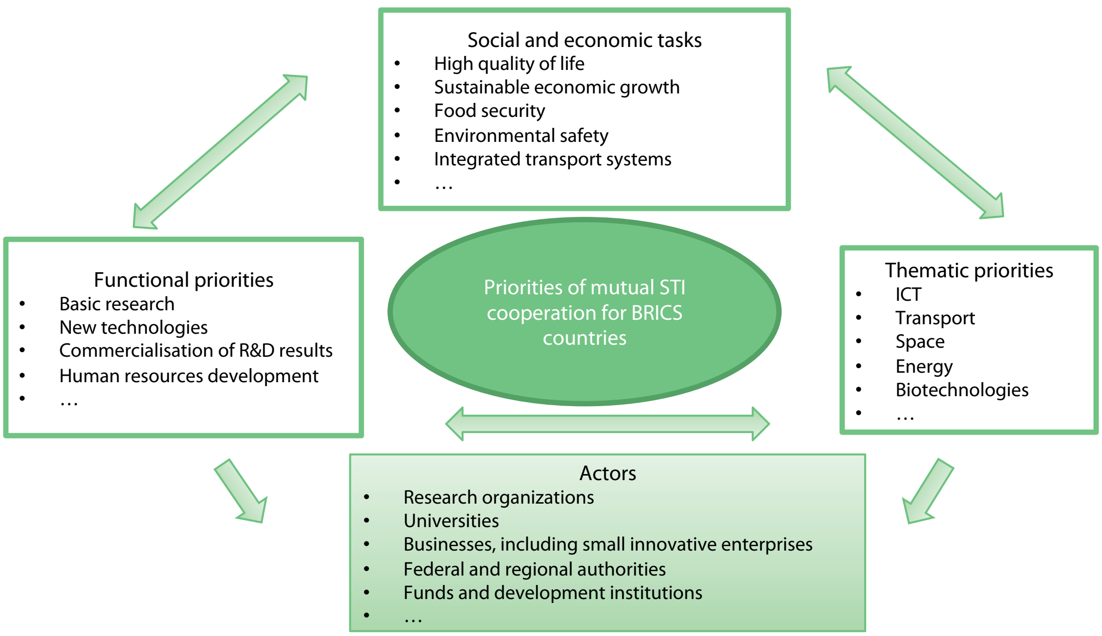

Fig. 1. Structure of system of priorities for BRICS S&T cooperation

Thematic priorities are presented as lists of major R&D areas (such as ICT, space systems, etc.) investing in which could bring significant social and/or economic benefits in the medium to long term: higher economic growth rate, increased competitiveness and accomplishing other key socio-economic and S&T objectives. Functional priorities include objectives aimed at facilitating the development and performance of national research and innovation systems, e.g. accelerated development of human potential, commercialisation of R&D results, etc. Joint implementation of such projects would help accomplish major socio-economic objectives.

Approaches based on Foresight methodology play a major role in setting STI priorities in all BRICS countries [Shashnov, Poznyak, 2011; Chan, Daim, 2012; Sokolov, Chulok, 2012; Cagnin, 2014; Li, 2009; Pouris, Raphasha, 2015]. The selected priorities tend to be oriented towards dealing with strategic socio-economic development issues. To take such issues into account in the course of priority setting, and subsequently facilitate their implementation, relevant stakeholders become involved in the process – public authorities, companies, and members of the academic community, for example. A wide range of experts also take part in priority setting.

Looking at the Russian experience, in the course of updating S&T priorities in 2014-15, particular attention was paid to drafting a list of major socio-economic objectives, which would determine an S&T areas' relevance over the next ten years [Grebenyuk et al., 2016]. For this purpose, a wide range of information sources was analysed, including national-level, industry-specific, and regional strategic documents and forecasts (such as addresses and decrees by the RF President, RF national programmes, industry and regional-level programmes and development concepts). On the basis of this analysis, a list of major socio-economic objectives was drafted, which subsequently served as a key milestone for identifying priority S&T areas and critical technology for the Russian Federation.

The application of the above approaches resulted in drafting lists of priority development areas and critical technology, long-term forecasts of S&T development prospects based on qualitative and quantitative Foresight techniques. Subsequently these results were applied in various strategic documents on the implementation of the identified priorities. In most BRICS countries, such documents comprise STI development strategies, strategic plans, and programmes.

A similar approach was employed to design a system of S&T cooperation priorities for BRICS countries. The application of Foresight methodology implies considering an integrated set of goals and objectives reflected in official international and national documents, taking into account their S&T potential and the opinions of the expert community. The approach was based on the need to advance the BRICS countries' S&T potential and concentrate it on major economic and social development areas, while keeping in mind expected technological breakthroughs. Particular attention was paid to making use of the countries' competitive advantages: only a limited number of especially important S&T priorities were identified for full support for their implementation to be provided.

A wide range of methodologies and techniques were applied in the course of S&T priority setting, including document analysis, bibliometric analysis, and various expert-based procedures (Fig. 2).

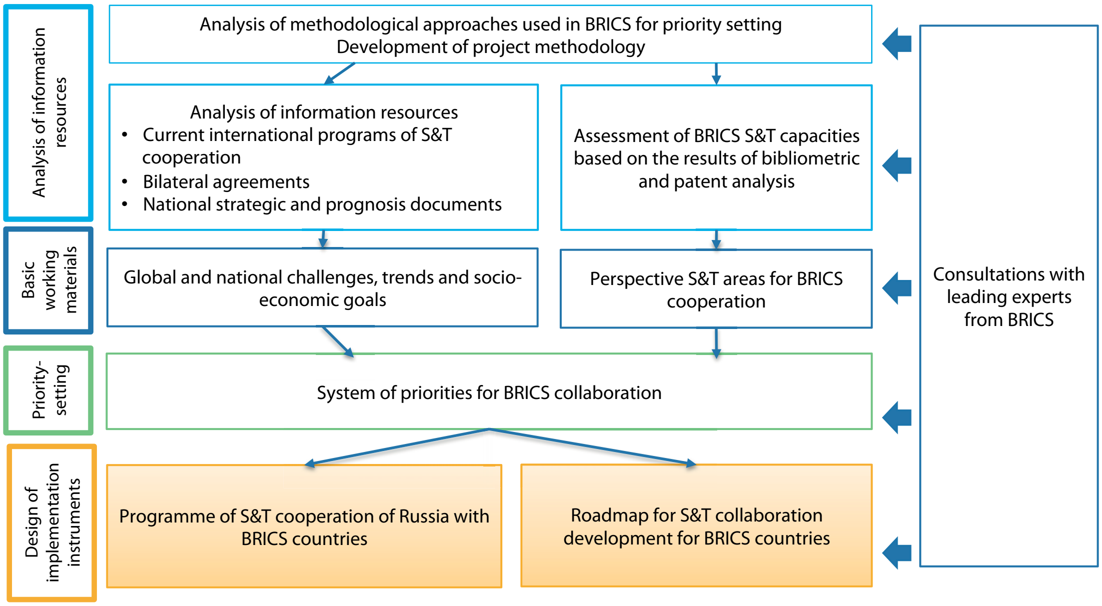

Fig. 2. Scheme of defining priorities for S&T BRICS country cooperation

Analysis of BRICS Countries' International and National Strategic and Forecasting Documents

The information basis for designing a common system of S&T development priorities for BRICS countries comprised the following:

– Each BRICS country's Official documents on S&T cooperation (bilateral and multilateral), approved by the countries' governments or government ministries responsible for shaping and implementing S&T and innovation policies;

– Strategic national documents and Foresight reports from BRICS countries related to STI development.

As was already noted, results of national long-term Foresight studies serve as a basis for designing a system of S&T development priorities. A major objective of such studies is building an information basis for subsequent priority setting exercises, among other things taking into account major global STI development trends. Concerning relevant Russian experience, three rounds of S&T Foresight studies were implemented in the country in recent years [Gokhberg, Sokolov, 2017]. E.g. the results of the Russian S&T Foresight 2025 (2007–2008) were applied to adjust the lists of priority development areas and critical technology. These materials were used to assess global and national-level challenges to socio-economic development; identify prospective innovative product and service markets, and technology that would help Russia progress along the advanced sustainable innovation-based development path.

In 2011–2013, Russian S&T Foresight 2030 was conducted, approved by the RF Prime Minister on 3 January 2014. The goal of this exercise was to identify S&T development areas with the best long-term prospects for Russia, together with appropriate technology and technological solutions that could potentially enable the country to make use of its competitive advantages, taking into account global challenges and windows of opportunity.

The project combined the "technology push" and "market pull" approaches, and covered seven major S&T areas: information and communication technologies; biotechnology; medicine and health; new materials and nanotechnology; efficient environment management; transport and space systems; energy efficiency and energy saving. A wide range of analytical and expert-based techniques were applied in the course of the study, including interviews, expert surveys, and expert panel discussions [Sokolov, Chulok, 2016].

Threats to, and windows of opportunity for, Russia were identified in each of the above seven areas on the basis of: previously identified trends, along with relevant prospective markets, product groups and potential segments of demand for innovative Russian technology and solutions; descriptions of priority S&T subject areas prepared; more than 1,000 priority R&D objectives were formulated. The current state of Russian R&D in these areas was assessed and benchmarked against the world leaders.

The results of this Foresight study (which took into account global S&T development trends) were applied to draft preliminary lists of priority areas and more specific thematic fields for cooperation with BRICS countries.

In line with the suggested principles and methodological approaches to setting priorities for S&T cooperation among BRICS countries, major national-level strategic documents and forecasts were analysed, together with bilateral and multilateral agreements between those nations (Table 1).

The relevant documents were analysed in terms of the thematic or functional priorities they reflect. E.g., the first thematic priorities for international cooperation between BRICS countries were set in documents drafted following the first and second meetings of BRICS education and science ministers [BRICS, 2014, 2015]. These documents stress the need to strengthen STI cooperation to help meet common global and regional socio-economic challenges on the basis of shared experience, complementary efforts, joint creation of new knowledge, the development of innovative products, services and processes using relevant funding mechanisms and investment promotion tools, and encouraging partnership with other strategic players in emerging countries.

The above-mentioned documents identify several particularly important areas for international cooperation (such as food security and sustainable agriculture; managing natural disasters; new and renewable energy sources and energy efficiency; nanotechnology; information and computer technology, etc.).

A number of fundamental documents such as the Moscow Declaration on BRICS Countries' S&T Cooperation, approved by BRICS science, technology and innovation ministers in 2015, and the BRICS Science, Technology and Innovation Work Plan for 2015–2018, play a major role in promoting international activities. Agreeing priority S&T areas is also necessary for implementing the BRICS Multilateral Research Initiative in the scope of the BRICS Framework Programme.

Table 1. Key strategic and forecasting documents in BRICS countries

Countries, groups of countries	Strategic and forecasting documents
BRICS documents on collaboration	Memorandum of Understanding on Cooperation in Science, Technology and Innovation between the Governments of The Federative Republic of Brazil, The Russia Federation, The republic of In-dia. The People's Republic of China and The Republic of South Africa/ Brasilia. 18 March 2015 First BRICS Science, Technology and Innovation Ministerial Meeting (2014) Cape Town Declaration. 10 February 2014 Moscow Declaration of BRICS countries' Science, Technology, and Innovation Ministers of 26 October, 2015
Brazil	National Strategy for ST&I 2016–2019 Growth Acceleration Program The Greater Brazil Plan
Russia	Russian S&T Development Strategy Priority S&T Development Areas for the Russian Federation National Technology Initiative Russian S&T Foresight 2030 Priority S&T Development Areas of the Russian Science Foundation RF National Programme "Development of Science and Technology for 2013–2020
India	Science, Technology and Innovation Policy 2013 Twelfth Five Year Plan Vision 2030; National Action Plan on Climate Change Atal Innovation Mission
China	National Medium and Long-term Plan for the Development of Science and Technology 13th Five-Year Plan for Economic and Social Development Innovation Driven Development Strategy Strategy 2050 20 Strategic Emerging Industries 2010–2020 National Key Technologies R&D Programme
South Africa	Our future – make it work National Development Plan 2030 Innovation Towards A Knowledge-based Economy The Ten-Year Innovation Plan for South Africa 2008–2018 The New Growth Path Strategic Plan 2016–2021

Source: composed (by the authors) on the basis of analysis of BRICS countries' national strategic and forecasting documents (see Appendix 1).

In 2015, BRICS education and science ministers signed the Moscow Declaration on Cooperation, which outlined its major future areas and the support tools to be used, including establishment of work groups on major research infrastructures, funding multilateral research projects, technology commercialisation, and innovation. It paid particular attention to setting up a joint research and innovation platform to coordinate how the national research communities within BRICS countries' approached each of the five agreed (and assigned to specific countries) areas of S&T cooperation:

– Prevention and management of natural disasters (supervised by Brazil);
– Water resources, and prevention of water pollution (supervised by Russia);

– Geospatial technology and its application (supervised by India);
– New and renewable energy; energy efficiency (supervised by China);
– Astronomy (supervised by South Africa).

Along with the above-mentioned, other national and international documents were also analysed (see Appendix 1). The provisions of these documents were summarised in tables reflecting BRICS countries' national and international S&T priorities (Table 2), grouped by major global S&T development areas. It served as the basis for drafting lists of S&T areas (fields) whose advancement would make the biggest contribution to accomplishing socio-economic and STI development objectives common to all BRICS countries.

The draft list of S&T development priorities for BRICS countries assumed they should meet the following requirements:

– the priorities should cover major S&T development areas being advanced by several BRICS countries, and match global S&T trends; these areas should have similar levels of commonality, while the subject fields covered should overlap as little as possible.
– the names (designations) of subject areas should to the maximum possible extent match STI development priorities reflected in national and international strategic documents.

Keeping these requirements in mind, eight areas were initially selected, covering all major avenues of global STI development. Some of them were subsequently broken down into more specific subject fields, e.g. life sciences were divided into two areas: health and medicine and biotechnology; energy – into three areas: energy efficiency and energy saving, nuclear energy and renewable energy. Also, the names of certain areas were changed to more accurately reflect relevant goals and objectives.

To assess the practicality of the second requirement, BRICS countries' S&T development resources were analysed, along with conducting bibliometric and patent analysis of their S&T potential; the results allowed the identification of particular countries' specialisation areas and therefore more promising fields for cooperation.

BRICS Countries' S&T Development Resources

All BRICS countries, except South Africa (SAR), are among the world's largest economies and have significant potential for meeting current global challenges provided that they pool and efficiently apply their resources.

China is the biggest scientific power in the BRICS group (Fig. 3). In terms of gross domestic R&D expenditures (GERD) ($408.8 billion in purchasing power parity (PPP) in 2015) it comes second after the US ($502.9 billion). In 2015, the Chinese GERD exceeded the total GERD of the EU28 countries, and amounted to more than three times the combined GERD of all other BRICS countries.

Table 2. BRICS countries' national S&T and innovation development priorities, and priority cooperation areas

Area	Brazil	Russia	India	China	South Africa	International documents
Information and telecommunication systems	Economics, and digital society; Information and communication technology; Cybersecurity	Information and communication technology; Big Data systems, machine learning, artificial intelligence; Quantum communications; Control and management systems	Information and communication technology; Telecommunication technologies	Information technology Cyberspace, including cybersecurity; Advanced electronics; Telecommunications	Information and communication technology; Digital economy	Information and communication technology; High-performance computing; Photonics
Life sciences	Health; Pharmaceutics; Biomes and bioeconomics; Biotechnology	Personalised medicine, high-tech healthcare, health-improving technology; Medicine and health; Genomics and synthetic biology; Neurotechnology; Biotechnology	Health; Pharmaceutics; Medical equipment; Biotechnology	Health, healthcare; Medicine; Neuroscience; Pharmaceutics, biopharmaceutics; Biotechnology	Health; Biotechnology; Pharmaceutics; Bioeconomy	Medicine and biotechnology; Biomedicine and life sciences (biomedical engineering, bioinformatics, biomaterials); Biotechnology and biomedicine, including health care and neuroscience
Agriculture	Food supply; Agriculture; Biodiversity; Biotechnology	Highly productive green agriculture and aquaculture; efficient chemical and biological crops and farm animals protection systems; efficient storage and processing of agricultural products; production of safe, high-quality foods; Biotechnology; Personal food and water production and delivery systems	Sustainable agriculture; Animal farming; Biotechnology	Agriculture; Agrifood products; Food industry; Biotechnology	Agriculture; Fisheries; Food supply; Biodiversity; Biotechnology	Food security, and sustainable agriculture; Biotechnology
New materials, nanotechnology	Nanotechnology	New materials and design techniques; New materials and nanotechnology	Materials	New materials; Nanotechnology	Nanosystems and materials; Nanotechnology	Nanotechnology; Materials science
Efficient environment management	Environment protection Climate change; Water resources; Ocean, and coastal areas; Hydrocarbon production; Green economy; Preserving biodiversity	Efficient environment management; More efficient production and deep processing of hydrocarbons; Reducing risks, and managing consequences of natural and anthropogenic disasters; Countering anthropogenic and biogenic threats	Climate change; Predicting climate change impact; Environment protection; Water resources; Marine studies; Geosciences, seismology; Himalayan ecosystem; Green technology; Non-fuel mineral resources; Waste management	Water and mineral resources; Ecology; Environment; Deep prospecting and drilling; Deep-water exploration; Water resources; Mineral production; Oceanography; Marine technology	Climate change; Production of mineral resources; Green economy; Water resources; Environment; Waste recycling	Water resources, managing water pollution; marine and polar areas studies; Geospatial technologies and their application; Prevention and management of natural disasters; Marine and polar studies, and relevant technologies; Geospatial technology and its application

Area	Brazil	Russia	India	China	South Africa	International documents
Energy	Energy; Nuclear energy; Renewable energy sources; Biofuel	Environmentally safe, resource-saving energy generation; new energy sources; new energy transmission and storage technology; Energy efficiency and energy saving; Nuclear and thermonuclear energy; New energy sources	Energy; Energy efficiency; Nuclear energy; Solar energy; Renewable energy sources	Energy; Hydroenergy; Energy saving; Next-generation nuclear energy, renewable and non-renewable energy sources	Energy	New and renewable energy sources; Energy efficiency; Clean coal technologies; Natural gas and unconventional gas sources
Transport and space systems	Aerospace technologies; Space; Transport, including high-speed systems	Smart transport and telecommunication systems; transportation and logistics systems; development of airspace and outer space, oceans, Arctic and Antarctic areas; Transport and space systems; Distributed unmanned aerial vehicles systems; Unmanned transportation systems	Space exploration and technology Urban transport	Space exploration; Aerospace equipment; Space technology; Navigation; Transport; High-speed railways; Automobile industry; Aircraft engine production; High-tech vessels Railway equipment	Aerospace technology Astronomy	Space exploration and development, aviation sciences; Astronomy; Earth observation; Geospatial technology and its application
Production	Industry	Advanced digital and smart production technologies; Additive technology; Smart technology for robotic and mechatronic systems; Instruments and devices based on nano- and microsystem technology; Sensory systems; Bionics	Industrial production; Manufacturing	Advanced production technologies; Smart production systems; Robotics; additive production systems	Advanced production technology	
Security	Cybersecurity	Countering anthropogenic, biogenic, sociocultural threats, and cyberthreats		Cyberspace, including cybersecurity	Information security	

Source: prepared by authors on the basis of analysis of strategic documents of STI policy of BRICS countries (see Appendix 1).

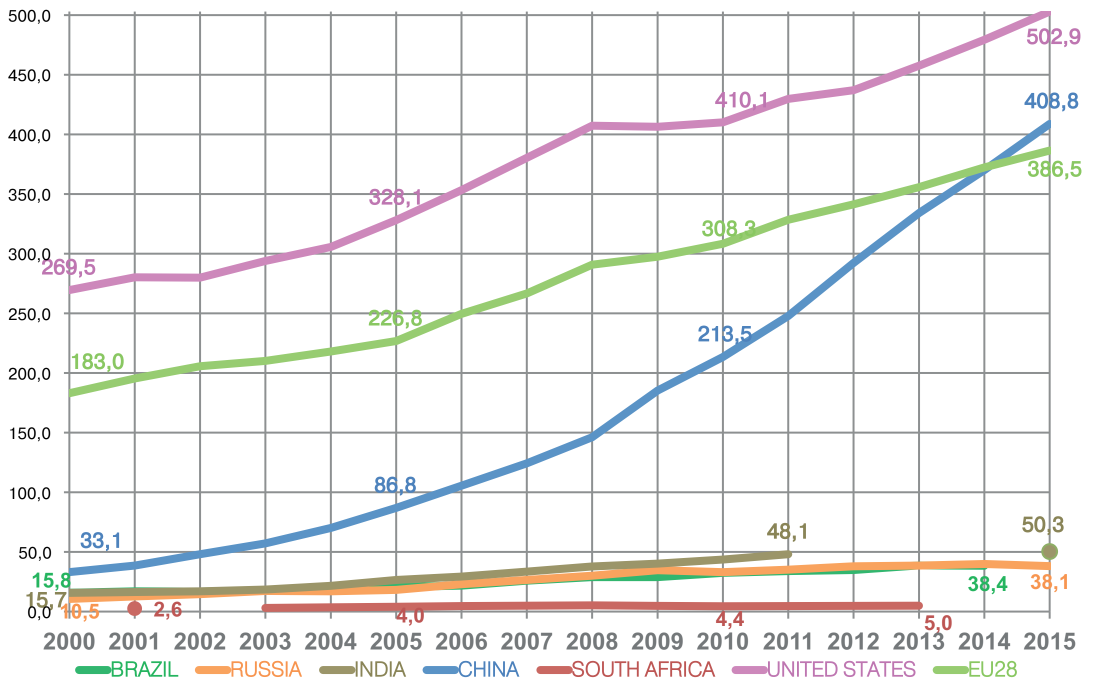

Fig. 3. Dynamics of volumes of gross expenditure on research and development (bln. USD, PPP) in BRICS, EU28 countries, and the USA in 2000–2015

Note. PPP means "purchasing power parity."

Source: USA, EU28, China, Russia, SAR – OECD MSTI (Main Science and Technology Indicators database); Brazil, India – UNESCO Institute of Statistic database (section "Science, technology and innovation"). Data were updated at September 2017.

Russian, Indian, and Brazilian GERD in recent years were comparable, at about \$35–\$50 billion (PPP). South Africa's R&D investments were much smaller, at about \$5 billion (PPP) during the last few years (Table 3).

In China, GERD has increased 11.2 times in the last 15 years; in other BRICS countries the growth has been much lower, from 1.85 times in India to 4.23 times in Russia. It should be noted that in China, annual GERD growth (at about \$30–40 billion) was in recent years comparable with the total annual GERD in Russia, India, and Brazil.

During the last 15 years, R&D intensity steadily grew in China, while in other BRICS countries relevant indicators remained largely unchanged, especially during the last 5 years. E.g. GERD as a percentage of GDP in China has grown from 0.90% in 2000 to 2.07% in 2015, exceeding the relevant figure for the EU28 countries for 2013. In the EU and US, GERD, measured as a share of GDP during the last 15 years, grew insignificantly.

Table 3. Key indicators of BRICS countries' R&D potential

Country	2000	2005	2010	2015
Gross expenditures on research and development (GERD), billion USD (purchasing power parity (PPP)), in current prices				
Brazil	15.8	20.5	32.5	38.4 (2014)
Russia	10.5	18.1	33.1	38.1
India	15.7	26.5	43.7	50.3
China	33.0	86.8	213.5	408.8
South Africa	2.6 (2001)	4.1	4.4	5.0 (2013)
USA	269.5	328.1	410.1	502.9
EU28	183.0	226.8	308.3	386.5
GERD as % of GDP				
Brazil	1.00	1.00	1.16	1.17 (2014)
Russia	0.99	1.00	1.06	1.10
India	0.74	0.81	0.82	0.63
China	0.89	1.31	1.71	2.07
South Africa	0.72 (2001)	0.86	0.74	0.73 (2013)
USA	2.62	2.51	2.74	2.79
EU28	1.67	1.66	1.84	1.96
Number of researchers (full-time equivalents)				
Brazil	73.9	109.4	138.7	…
Russia	506.4	464.6	442.1	449.2
India	115.9	154.8	192.8	283.0
China	695.1*	1 118.7*	1210.8	1619.0
South Africa	14.2 (2001)	17.3	18.7	23.3 (2013)
USA	983.3	1 101.1	1198.8	1380.0
EU28	1 117.8	1 374.8	1601.1	1840.7
GERD per researcher, thousand USD (PPP), in current prices				
Brazil	214.3	187.8	234.5	…
Russia	20.7	39.0	74.9	84.9
India	135.1	171.4	226.5	177.6
China	47.5	77.6	176.3	252.5
South Africa	183.3 (2001)	234.1	236.8	213.1 (2013)
USA	274.1	298.0	342.1	364.4
EU28	163.8	164.9	192.6	210.0

Note. For all countries in the table, the number of researchers is calculated according to the OECD Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development. In China, researcher data has been collected in line with the Frascati Manual definition since 2009 only. Beforehand, this was only the case for independent research institutions, while for the other sectors data collection was in accordance with the UNESCO concept of "scientist and engineer."

Source: USA, EU28, China, Russia, SAR – OECD MSTI (Main Science and Technology Indicators database); Brazil, India – UNECO Institute of Statistic database (section "Science, technology and innovation"). Data were updated at September 2017.

China has the largest number of researchers in the world – 1.62 million in 2015 (in full-time employment equivalents). In the US, the figure (for 2014) is 1.35 million and the EU28 total is 1.81 million. Russia, with 446.2 thousand researchers (in full-time employment equivalents) lags only behind China, the US, and Japan (662.1 thousand). The numbers of researchers in India (192.8 thousand in full-time employment equivalents, 2010) and Brazil (138.7 thousand in full-time employment equivalents, 2010) are comparable. South Africa has much fewer researchers than other BRICS countries – 23.3 thousand in full-time employment equivalents (2013).

In terms of R&D expenditure per researcher (in full-time employment equivalent) Russia has the lowest figure among BRICS countries, at $80– $90 thousand (PPP) over the last 5 years. In other BRICS nations relevant figures in recent years were between $200–$250 thousand, which is comparable with the average for EU28 countries ($200–$210 thousand) but much lower than in the US ($340–$355 thousand).

Analysis of R&D resource availability in BRICS countries revealed that China became a leading global scientific power, dominating the BRICS group both in terms of R&D expenditure and the number of researchers. Regarding GERD, China is gradually getting closer to the US, the world leader and is already ahead of the EU28. In terms of the number of researchers (in full-time employment equivalents) China achieved the leading global position in 2015.

China has the potential to support R&D in a wide range of priority areas; other countries' abilities are much more modest, this implies the need to set a sufficiently limited number of priorities.

Publication Activity in BRICS Countries and Knternational Cooperation

The following analysis of publication activities is based on the 'Scopus' international academic citation database (for details see [Shashnov, Kotsemir, 2015; Kotsemir, Shashnov, 2017]).

The number of publications authored by BRICS country researchers has significantly increased since 2000, along with their proportion of the global research community (Fig. 4).[2] In 2010, the total number of publications by BRICS researchers exceeded that of the US, and in 2014 came very close to the relevant figure for EU28 countries. This was largely due to the exceptionally high growth in Chinese publication activity. In 2000–2015, the number of publications by Chinese authors grew 8.5 times, while the overall growth rate of global publication activity in the last five years has declined. Accordingly, between 2000–2015, China has moved up from 6th to 2nd place in terms of total publications. Due to its relatively high growth in publication activity over recent years, China has managed to come much closer to the US, which has recently displayed a rather low growth in publication numbers.

[2] All calculations are based on Scopus data. Types of publications included: articles, reviews, and conference papers.

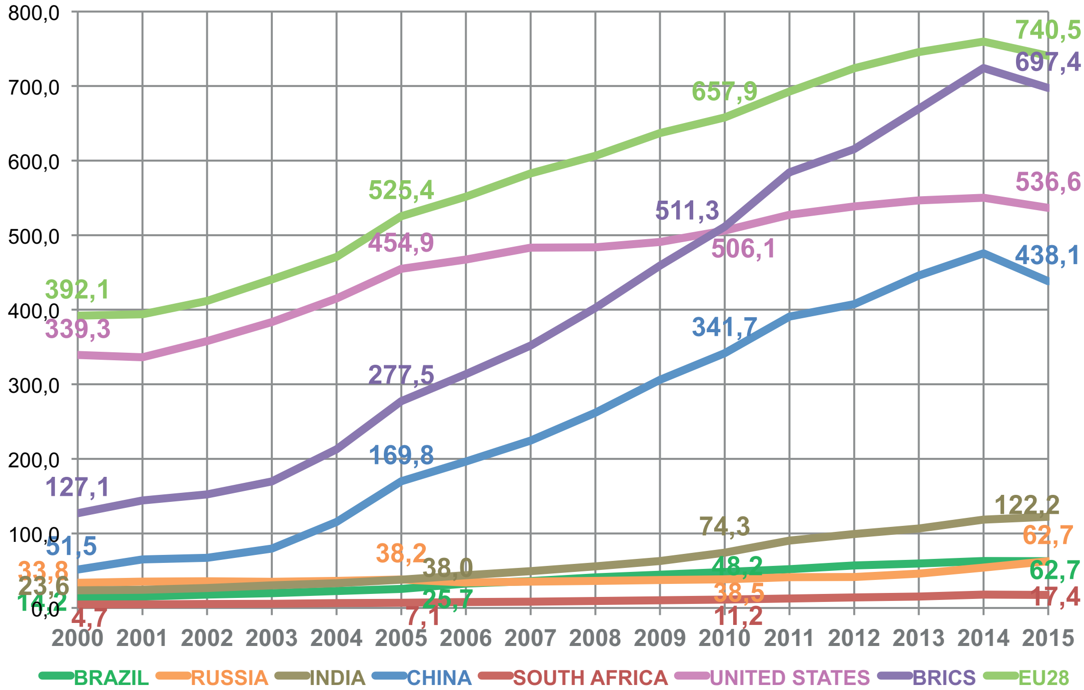

Fig. 4. Growth of the number of publications indexed in Scopus in BRICS, EU28, and US in 2000–2015 (thousands)

Source: authors' calculations based on Scopus SciVal Benchmarking Toolbox. Types of publications included: articles, reviews and conference papers (last update: March 2017).

The number of Russian publications indexed in Scopus grew just 1.86 times in 2001–2015, with the bulk of growth occurring over the last five years. Despite that fact, Russia has moved down in the "Number of publications" rating from 9th to 13th place in the same period. In 2000–2012, the number of publications by Russian researchers remained at about 30–38 thousand a year, and only in recent years has Russian publication activity begun to increase rapidly. India, and to a lesser extent Brazil, along with China displays a high growth rate of publication activity. The number of publications by Brazilian authors indexed in Scopus in 2000–2015 grew from 14.1 thousand to 62.0 thousand. In the global "Number of publications" rating, Brazil moved up from 17th place in 2000 to 14th in 2015. In 2000–2015, the number of Indian Scopus-indexed publications has grown from 23.5 thousand to 122 thousand. South Africa is also showing a rapidly growing rate of publication activity. However, the high growth rate is largely due to the "low start" effect. The number of publications by South African researchers grew 3.75 times from 2000 to 2015, 4.6 thousand to 17.1 thousand. In the overall "Number of publications" rating, South Africa is low in the top 40. Generally, in 2015, BRICS countries produced almost 29% of the world's total number of Scopus-indexed publications; of which; China contributed 18%, India – 5%, Russia and Brazil – 2.6%

each, and South Africa – 0.72% (see table 4). In terms of the total number of Scopus-indexed publications, BRICS countries came very close to the EU28 (30.5% of the world's total in 2015).

Table 4. Share of BRICS, EU-28 and the USA in the globalk volume of publications in Scopus in 2000 – 2015

Country/Country group	2000, %	2005, %	2010, %	2015, %
Brazil	1,2	1,6	2,3	2,6
Russia	2,8	2,3	1,8	2,6
India	2,0	2,3	3,5	5,0
China	4,3	10,3	16,0	18,0
South Africa	0,39	0,43	0,53	0,72
BRICS	10,7	16,8	24,0	28,7
United States	28,5	27,5	23,8	22,1
EU28	33,0	31,8	30,9	30,5
World	**100,0**	**100,0**	**100,0**	**100,0**

Source: authors' calculations based on Scopus database. Types of publications included: articles, reviews and conference papers (last update: March 2017).

South Africa shows the most active involvement in international research cooperation among all BRICS countries (Table 5). Since 2005, more than 40% of the nation's Scopus-indexed publications were co-authored with scientists from other countries. Note that the share of internationally co-authored publications in South Africa has been growing over the last five years.

Table 5. Share of publications n international collaboration in total number of publications in Scopus in BRICS countries in 2000–2015

Country	2000	2005	2010	2015
Brazil	29,5	27,6	23,9	30,1
Russia	25,9	33,6	28,3	25,5
India	15,3	18,5	17,8	16,6
China	15,2	13,6	14,6	20,2
South Africa	29,8	40,5	42,2	47,4

Source: authors' calculations based on Scopus database. Types of publications included: articles, reviews and conference papers (last update: September 2016).

In Russia, the share of internationally co-authored publications for the last 15 years has remained at 25–35%. Note that in Russia, unlike South Africa, China, and Brazil, this figure has been steadily decreasing in recent years – from 33.6% in 2005 to 25.5% in 2015. The level of participation by Brazilian scientists in international research cooperation was somewhat lower than in Russia (25–20% during the last 15 years). As in South Africa, the share of internationally co-authored publications by Brazilian researchers has grown in the last 5 years (from 23.9 to 30.1%). In India and China, scientists are integrated into international research cooperation to a lesser extent than in other BRICS countries (the relevant figure is about 15–20% for the last 15 years). In the last 5 years, China has managed to increase its share of internationally co-authored publications from 14.6% in 2010 to 20.2% in 2015. In India, the relevant figure has slightly dropped during the same period, from 18.5% in 2005 to 16.6% in 2015. At the same time, Asian countries with advanced research systems tend to display rather low participation in international scientific cooperation, for example, in 2015 only 20.9% of Scopus-indexed publications by Iranian authors were internationally co-authored; for Turkey the figure was 21.1%, for Japan – 26.6%, for the Republic of Korea – 26.5% [HSE, 2017].

The involvement of BRICS countries in international research cooperation (except South Africa) is much lower than that of European countries'. E.g. in France in 2015, 51.8% of all Scopus-indexed publications were internationally co-authored; for the UK the relevant figure was 50.0%, for Germany – 48.5%, and for Italy – 43.9%. In Scandinavia the relevant values are even higher: 59,1% in Sweden, 58.5% in Denmark, 57.1% in Norway, and 56.0% in Finland. In the US the share of internationally co-authored publications in 2015 was 32.8% [HSE, 2017].

BRICS countries do not yet constitute key research partners for each other (Fig. 5).

The main partner for all BRICS countries in 2015 was the US (as in all other years). E.g. 44.6% of all internationally co-authored Chinese publications were written jointly with American scientists, while the share of China's second biggest partner (the UK) was just 9.9%. No BRICS country was among China's ten biggest research partners. Russia's structure of research partners is different from China's, Brazil's, and India's. It has two key research partners – the US and Germany, with 25.4% and 23.7% internationally co-authored publications in 2015, respectively. Then, in descending order: France (14.1%), the UK (13.2%), Italy (9.6%), and China (8.4%). Other BRICS countries play much smaller roles in Russia's international cooperation. The share of internationally co-authored Russian publications written jointly with Brazilian scientists is 3.9%; the relevant figure for India is 3.8%, and for South Africa – 2.1%.

As the above data shows, an explosive growth in both R&D expenditure and publication activity allowed China to become a new scientific superpower on a par with the US. If the current publication activity growth rate remains, in the next 3–5 years, China may well get ahead of the US by total number of publications indexed in the Scopus database. No other BRICS country has demonstrated such a high growth in

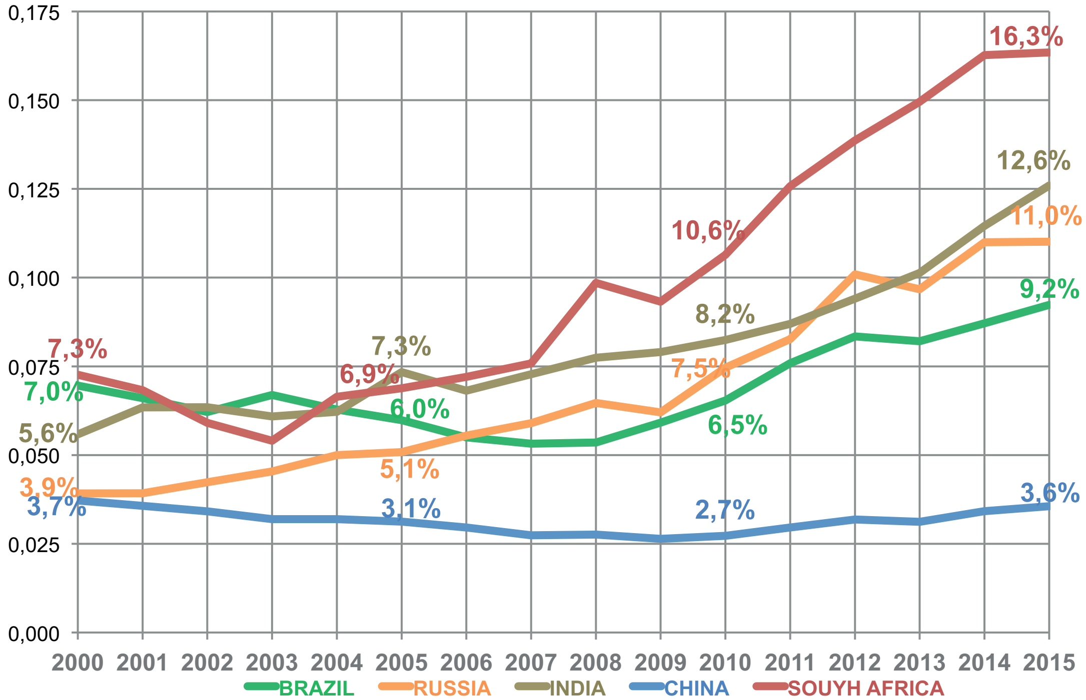

Fig. 5. Share of publications in collaboration with other BRICS countries in the total number of internationally collaborated publications of BRICS countries in Scopus in 2000–2015

Source: authors' calculations based on Scopus database. Types of publications included: articles, reviews and conference papers (last update: March 2017).

publication activity. Still, all of them became more "visible and important" within the international academic community. They have managed to increase both the number of scientific publications indexed in Scopus, and their citation indices. Unlike other BRICS countries whose publication numbers steadily grew throughout the period in question, Russia was only able to radically increase its presence in the Scopus database over the last three years. This implies a significant accumulated growth in the BRICS countries' S&T potential, which can be applied more productively if members of the group coordinate their efforts.

Thematic structure of BRICS countries' publications

Structures of publications by BRICS country scientists were assessed using 27 major subject areas of the Scopus database, and compared with the global publication structure to calculate each country's Index of Scientific Specialisation or Revealed Comparative Advantages Index (RCA index) (see table 6). The RCA index of country 'j' in scientific field 'I', is calculated as the relationship between the share of its publications in scientific field 'i', the total number of publications by country 'j' and the equiva-

Table 6. Thematic structure of publications and Revealed comparative index values in BRICS countries in 2011–2015

Subject area		World Struct.	Brazil		Russia		India		China		South Africa	
			Struct.	RCA	Struct.	RCA	Struct.	RCA	Struct.	RCA	Struct.	RCA
Agricultural and Biological Sciences		7,9%	***20,3%***	***2,57***	5,7%	0,72	8,7%	***1,09***	6,4%	0,81	***16,4%***	***2,07***
Arts and Humanities		3,7%	1,9%	0,51	2,1%	0,57	0,6%	0,16	0,5%	0,14	8,7%	***2,31***
Biochemistry, Genetics and Molecular Biology	*	***12,0%***	***11,2%***	0,93	9,3%	0,77	12,9%	***1,07***	11,1%	0,93	9,8%	0,82
Business, Management and Accounting		2,2%	1,6%	0,72	0,9%	0,41	1,7%	0,80	1,2%	0,55	3,2%	***1,49***
Chemical Engineering		4,5%	3,5%	0,78	5,1%	***1,12***	6,8%	***1,51***	6,7%	***1,48***	3,0%	0,66
Chemistry	*	8,9%	7,2%	0,82	***15,0%***	***1,69***	***14,2%***	***1,60***	12,6%	***1,42***	7,6%	0,86
Computer Science	*	***12,4%***	8,9%	0,72	6,9%	0,56	***15,4%***	***1,24***	***15,5%***	***1,25***	6,8%	0,55
Decision Sciences		1,0%	1,3%	***1,29***	0,5%	0,48	0,9%	0,89	0,9%	0,96	0,8%	0,81
Dentistry	*	0,5%	2,8%	***5,50***	0,0%	0,02	1,0%	***1,90***	0,1%	0,28	0,2%	0,32
Earth and Planetary Sciences	*	4,4%	3,7%	0,84	10,0%	***2,25***	3,7%	0,83	5,6%	***1,27***	7,5%	***1,68***
Economics, Econometrics and Finance		1,5%	0,8%	0,53	1,3%	0,88	0,9%	0,62	0,5%	0,31	4,1%	***2,68***
Energy	*	3,3%	2,3%	0,70	4,2%	***1,29***	3,5%	***1,08***	4,9%	***1,49***	2,6%	0,81
Engineering	*	***21,3%***	***11,7%***	0,55	***18,5%***	0,87	***21,8%***	***1,03***	***38,4%***	***1,80***	***10,1%***	0,48
Environmental Science	*	5,0%	5,8%	***1,17***	3,2%	0,64	5,8%	***1,17***	5,1%	***1,03***	7,3%	***1,46***
Health Professions		1,1%	1,7%	***1,49***	0,7%	0,66	0,4%	0,39	0,3%	0,29	1,0%	0,93
Immunology and Microbiology	*	2,8%	4,3%	***1,54***	1,6%	0,58	2,6%	0,94	2,1%	0,76	4,6%	***1,65***
Materials Science	*	10,3%	6,3%	0,61	***18,1%***	***1,77***	12,4%	***1,20***	***15,8%***	***1,54***	6,2%	0,60
Mathematics	*	6,9%	5,3%	0,78	***10,5%***	***1,54***	6,2%	0,90	8,1%	***1,18***	5,1%	0,74

Subject area		World Struct.	Brazil		Russia		India		China		South Africa	
			Struct.	RCA	Struct.	RCA	Struct.	RCA	Struct.	RCA	Struct.	RCA
Medicine	*	***28,1%***	***29,5%***	***1,05***	8,5%	0,30	***19,8%***	0,70	***14,8%***	0,53	***25,6%***	0,91
Multidisciplinary		1,0%	0,7%	0,72	1,2%	***1,26***	1,6%	***1,58***	1,4%	***1,42***	0,5%	0,53
Neuroscience		2,4%	2,7%	***1,15***	0,9%	0,39	0,9%	0,36	1,2%	0,51	1,0%	0,43
Nursing		1,5%	2,5%	***1,64***	0,3%	0,19	0,3%	0,22	0,3%	0,17	1,2%	0,82
Pharmacology, Toxicology and Pharmaceutics	*	3,3%	3,8%	***1,13***	1,6%	0,47	9,8%	***2,93***	3,1%	0,92	2,8%	0,84
Physics and Astronomy	*	***12,3%***	***10,0%***	0,82	***33,4%***	***2,72***	***13,8%***	***1,13***	***15,5%***	***1,26***	***10,0%***	0,82
Psychology		2,2%	1,9%	0,86	0,4%	0,20	0,4%	0,16	0,3%	0,12	2,7%	***1,25***
Social Sciences		7,5%	6,0%	0,79	4,1%	0,54	3,3%	0,43	2,3%	0,30	***16,6%***	***2,20***
Veterinary	*	0,8%	3,7%	***4,42***	0,1%	0,06	1,2%	***1,44***	0,3%	0,34	1,4%	***1,74***
Total number of papers for 2011–2015		**11 668 705**	**285 454**		**2 092 672**		**239 799**		**525 853**		**75 234**	

Note. In this table we present the shares of different subject areas in the total number of publications by a given BRICS country. The sum of the shares of 27 subject areas exceeds 100% because some publications relate to several different subject areas.

Source: authors' calculations based on Scopus. Types of publications included: articles, reviews and conference papers (last update: September 2016).

lent global figure. Those fields where the RCA value is greater than 1 are classified as areas of the country's scientific specialization. Subject areas where RCA index is significantly greater than 1 (e.g. more than 1.5. or 2) may be called key areas of scientific specialisation.

The Russian research sector has a predominantly "physics and technology" profile whose origins go back to the Soviet era. The subject area with the highest presence of Russian researchers (Scopus-indexed publications in 2011–2015) was Physics and Astronomy – 33.4% of all Russian publications. Other major subject areas being researched in Russia include Engineering (18.5% of all Russian publications in 2011–2015), Materials Science (18.1%), and Chemistry (15%). Such fields as Neuroscience, Business, Management, and Accounting, Health, Decision Making, Psychology, Nursing, Veterinary, and Dentistry are represented very poorly in the structure of Russian publications (less than 1% of the total number of published works). The share of Physics and Astronomy publications by Russian researchers in all Scopus-indexed publications (33.4%) is much higher than the relevant world's average figure (12.3%).

Russia's Scientific Specialisation Index (SSI) within the Physics and Astronomy subject area was 2.72. It is the highest specialisation level in this area among all BRICS countries. To compare, China's SSI for this area is 1.26, India's – 1.13, and in South Africa and Brazil the figure is 0.82. A high SSI in the structure of Russian Scopus-indexed scientific publications was noted for Earth and Planetary Sciences – 2.25 in 2011–2015. Again, it is the highest value among all BRICS countries. SSI ranging between 1.5 and 2.0 were noted in subject areas such as Material Science (1.77), Chemistry (1.69), and Mathematics (1.54). At the same time, very low SSI values were noted in Psychology (0.20), Nursing (0.19), Veterinary (0.06), and Dentistry (0.02).

China's status as the "global manufacturer" is supported by its Scopus thematic profile. The main area of Chinese research is Engineering (38.4% of all publications). Other prominent areas in the structure of publications by Chinese authors include Material Science (15.8%); Computer Science (15.5%), Physics and Astronomy (15.5%); Medicine and Health (14.8); Chemistry (12.6); Biochemistry, Genetics, and Molecular Biology (11.1%). At the same time, numerous subject areas are very poorly represented in the structure of Chinese publications (less than 1% of the total number in 2011–2015): Decision Making; Humanities; Economics, Econometrics, and Finance; Health; Veterinary; Psychology; Nursing; Dentistry.

China's main specialisation areas include Engineering (SSI of 1.80 in 2011–2015, the highest value among all BRICS countries), Material Sciences (1.54), Chemical Technologies (1.48), and Chemistry (1.42). Less important subject areas include Earth and Planetary Sciences (1.27), Physics and Astronomy (1.26), and Computer Sciences (1.25). The largest subject area (Engineering) accounts for 21.8% of all Scopus-indexed publications in 2011–2015. Other major areas of Indian research include Medicine (19.8%), Computer Science (15.4%), Chemistry (14.2%), Physics and Astronomy (13.8%); Biochemistry, Genetics, and Molecular Biology (12.9%); and Material Science (12.4%). Analysis of the country's Scientific Specialisation Indices for the 27 top-level subject areas clearly reveals an Indian profile shift towards pharmaceutics and chemical sciences. The country's main specialisation area (in terms of Scopus-indexed publications by local researchers) is Pharmacology and Pharmaceutics. India's SSI in this area in 2011–2015 was 2.93 (the highest among all BRICS countries; to compare, the relevant figure for Brazil was 1.13, and in other BRICS nations is below 1). Other areas of specialism for Indian scientists include Dentistry (1.90); Chemistry (1.60); Interdisciplinary Studies (1.58); Chemical Technologies (1.51); and Veterinary (1.44).

Brazil's and South Africa's publication structures are quite different from other BRICS countries. Brazil gravitates towards medical and biological research, with major Scopus-indexed areas being Medicine (29.5% of all publications by Brazilian researchers in 2011–2015) and Agricultural and Biological Sciences (20.3%). Other important fields include Engineering (11.7%), Biochemistry, Genetics, and Molecular Biology (11.2%), and Physics and Astronomy (10.0%).

Brazilian publications stand out with extremely high SSI values in Dentistry (5.50 in 2011–2015) and Veterinary (4.42). These are the highest figures among BRICS countries and among the highest in the world (for countries with a significant number of publications). Other Brazilian specialisation areas include Agricultural and Biological Sciences (2.57), Nursing (1.64 – the highest SSI in this area among BRICS countries), Microbiology and Immunology (1.54), and Health (1.49).

In South Africa, the main research area, as in Brazil, is Medicine (25.6% of all Scopus-indexed publications by South African scientists in 2011–2015). Other important research areas include Social Sciences (16.6%), Agricultural and Biological Sciences (16.4%), Engineering (10.1%), Physics and Astronomy (10.0%).

South Africa, unlike other BRICS countries, specialises in social sciences and humanities. Its SSI in these areas exceeded 2.00 in 2011–2015: Economics, Econometrics, and Finance (2.68), Humanities (2.31), and Social Sciences (2.20). These are the highest SSI values among all BRICS countries: their relevant figures in the above areas remain below 1. South Africa also has relatively high SSI in the following areas: Veterinary (1.74), Microbiology and Immunology (1.65), Management Technology (1.49), and Environmental Sciences (1.46). Brazil and South Africa also display high SSI values in Immunology and Microbiology.

The thematic structure of intra-BRICS publications strongly gravitates towards Physics and Astronomy (Table 5). This area's share in the total number of intra-BRICS publications in 2011–2015 amounted to 35.8%. It remains the biggest field in all possible pairs of BRICS countries, and in many cases dominates their S&T cooperation. The importance of Physics and Astronomy is particularly evident in the structure of Russia's cooperation with BRICS countries – the overall share of relevant publications is 55.9%, while in the total number of joint Russian-Brazilian publications, the share of this subject area is 75.6%; for joint Russian-Indian publications it is 72.3%.

Another major area of BRICS country research cooperation is Medicine: it accounts for 18.9% of intra-BRICS publications in 2011–2015. Medicine is particularly important for joint Brazilian – South African publications (33.1%), and least important for joint publications by Russian and Chinese researchers (8.3%). The share of medical publications co-authored by Russian and BRICS countries' scientists (10.3%) is much lower than the relevant figures for other BRICS nations: 17.1% for China, 21.5% for India, and 24.1% for Brazil. The thematic structure of Russia's research cooperation with BRICS countries matches both the overall structure of Russian Scopus-indexed publications, and the structure of internationally co-authored publications by Russian scientists. As for other BRICS countries (especially Brazil and China), there is a certain mismatch between the thematic structures of intra-BRICS collaboration and the overall structure of internationally co-authored publications by those countries' researchers.

Our analysis revealed 15 S&T areas where BRICS countries have the highest relative shares or specialisation indices (marked with * in Tables 6 and 7). These are among the top-priority areas for R&D cooperation, since BRICS countries have already laid the groundwork. In some of these areas (first of all Physics and Astronomy, and to a lesser extent Engineering), BRICS countries are already collaborating quite actively; in others (Biochemistry, Genetics and Molecular Biology, Material Science, Agricultural and Biological Sciences), cooperation between BRICS countries is less active, though they maintain good contacts with other nations. Comparing subject areas selected at this stage with those specified in BRICS countries' strategic documents (see Table 2) allowed to draft a list of priorities for group members' S&T cooperation.

Priorities for S&T Cooperation between BRICS Countries

On the basis of analysing BRICS countries' strategic documents and assessing their S&T potential, 14 subject areas were selected for inclusion in the list of those countries' priorities for S&T cooperation:

– Information and telecommunication technology;
– Nanotechnology and next-generation materials;
– Advanced production technology and robotics;
– Space systems and astronomic observations;
– Transport systems;
– Energy efficiency and energy saving;
– Nuclear energy;
– Renewable energy sources;
– Search, exploration, production and mining of mineral resources;
– Climate change, environment protection, natural disaster management;
– Water resources and their management;
– Food security and sustainable agriculture;
– Health and medicine;
– Biotechnology.

The above subject areas are considered priorities by all (or almost all) BRICS countries, as confirmed by their national strategic documents (development strategies, strategic plans, five-year plans, initiatives, mission statements, etc.). These areas are also included in most of bilateral agreements signed by BRICS countries. These areas have a wide scope for practical application, and open opportunities for making use of national comparative advantages (such as territory, available resources, S&T potential, etc.). In the framework of overall priority systems, the issue of wide complementarity can also be considered, which would help tackle existing S&T problems and limitations through increased cooperation and exchanges between participating countries, and the sharing of best practice. Furthermore, in most of these areas, BRICS countries have a significant S&T potential – evidenced by their science specialisation and citation indices calculated on the basis of Scopus data. All calculations were made using the following conversion table (from Scopus subject areas and subject categories to the 14 priority areas; see conversion table in Appendix 2).

The number of publications, specialisation and citation indices for the summary list of national S&T areas are presented in Table 9. In one of the above subject areas (Search, Exploration, Development and Mining of Minerals) four BRICS countries have RCA values in excess of 1; in seven other areas, there are three such countries; and only in four subject areas – one or two such countries.

In only three areas (Transport Systems, Health and Medicine, Biotechnology) does a single BRICS country have SSI above 1, while for all others that value is below 1. At the same time, these areas were still included in the list of priorities, since they of great importance to all BRICS countries – which is reflected in relevant national and international strategic documents adopted by them.

Citation impact figures in the selected subject areas in most cases are below the global averages. Only in two areas (Energy Efficiency and Energy Saving, and Renewable Energy Sources), do four BRICS countries have citation impact figures higher than world average values; in two other areas, two or three countries have relevant values higher than 1; in the remaining areas either a single country has a citation impact in excess of 1, or all of them are below global averages. In most of the selected areas, BRICS country researchers display significant publication activity, though their citation levels remain relatively low. Note that SAR and China have the highest citation figures. Analysis of SSI and citation values allowed assessing the scope for stepping up BRICS countries' cooperation in implementing S&T priorities.

All BRICS countries are active in areas where Russia could organise cooperation on a parity basis, or act as either a "leader" or a "catch up" country. E.g., Russia conducts active research in energy efficiency and energy saving areas, but citation of relevant Russian publications is lower than of those published by scientists from four other BRICS countries. Russia could significantly increase the number of, and demand for publications in this field by establishing close cooperation with BRICS countries. To increase productivity of Russian research and development, stepping up cooperation with China as the principle partner would seem a wise course. A positive effect could also be achieved by collaborating with India, Brazil, and in certain areas, with SAR.

Table 7. Thematic structure of joint publications of BRICS countries in Scopus in 2011–2015

Subject Areas		World structure	BRICS countries	IntraBRICS collaboration	Structure of internationally collaborated publications									
					Brazil		Russia		India		China		South Africa	
					All collab	BRICS collab	All collab	BRICS collab	All collab	BRICS collab	All collab	BRICS collab	All collab	BRICS collab
Agricultural and Biological Sciences	*	7,9%	8,1%	10,5%	***17,2%***	***9,2%***	7,5%	7,6%	8,7%	9,0%	9,5%	***10,9%***	***19,7%***	***14,2%***
Arts and Humanities		3,7%	1,0%	0,6%	1,2%	0,5%	1,0%	0,3%	0,7%	0,6%	0,8%	0,7%	3,8%	0,8%
Biochemistry, Genetics and Molecular Biology	*	***12,0%***	11,2%	***11,4%***	***14,5%***	***10,5%***	9,9%	8,0%	14,2%	12,0%	***15,8%***	***11,3%***	***12,7%***	10,6%
Business, Management and Accounting		2,2%	1,3%	0,9%	1,2%	0,9%	0,5%	0,3%	1,5%	1,0%	1,7%	1,0%	1,9%	1,1%
Chemical Engineering		4,5%	6,2%	4,1%	3,6%	2,0%	3,7%	2,5%	7,4%	5,2%	6,5%	3,7%	3,1%	4,7%
Chemistry	*	8,9%	12,4%	11,3%	***7,6%***	***5,0%***	***13,1%***	9,0%	***17,4%***	***12,8%***	13,0%	10,6%	8,1%	10,5%
Computer Science	*	***12,4%***	***14,3%***	5,8%	***9,6%***	***4,7%***	6,3%	3,3%	11,4%	6,3%	***16,7%***	6,2%	4,9%	4,4%
Decision Sciences		1,0%	0,9%	0,6%	1,2%	0,4%	0,6%	0,3%	1,1%	0,6%	1,5%	0,7%	0,6%	0,7%
Dentistry	*	0,5%	0,5%	0,5%	2,3%	1,1%	0,0%	0,0%	0,4%	0,2%	0,3%	0,6%	0,1%	0,4%
Earth and Planetary Sciences	*	4,4%	5,5%	10,7%	6,1%	***8,0%***	11,0%	***12,3%***	5,9%	9,1%	6,9%	9,2%	***10,2%***	***13,1%***
Economics, Econometrics and Finance		1,5%	0,7%	0,6%	0,8%	0,5%	0,6%	0,2%	1,1%	0,7%	1,2%	0,7%	1,7%	0,8%
Energy	*	3,3%	4,4%	2,7%	2,4%	1,7%	2,9%	2,2%	3,1%	2,4%	4,1%	2,9%	2,0%	2,6%
Engineering	*	***21,3%***	***31,3%***	***13,4%***	***12,5%***	***10,4%***	***15,3%***	***12,8%***	***17,5%***	***12,8%***	***25,4%***	***14,5%***	8,6%	***12,5%***
Environmental Science	*	5,0%	5,2%	4,9%	***6,4%***	3,9%	3,4%	2,6%	6,1%	5,6%	6,5%	5,2%	7,8%	5,9%

Subject Areas		World structure	BRICS countries	IntraBRICS collaboration	Structure of internationally collaborated publications									
					Brazil		Russia		India		China		South Africa	
					All collab	BRICS collab	All collab	BRICS collab	All collab	BRICS collab	All collab	BRICS collab	All collab	BRICS collab
Health Professions		1,1%	0,5%	0,4%	1,6%	0,7%	0,3%	0,2%	0,5%	0,4%	0,5%	0,4%	1,1%	0,6%
Immunology and Microbiology	*	2,8%	2,4%	3,2%	5,1%	3,7%	2,2%	1,7%	3,5%	3,2%	3,0%	3,0%	6,1%	5,0%
Materials Science	*	10,3%	***14,4%***	***11,9%***	***7,9%***	***7,3%***	***18,5%***	***11,5%***	***16,6%***	***12,8%***	15,1%	***10,9%***	5,8%	8,5%
Mathematics	*	6,9%	7,7%	7,9%	***7,6%***	***6,9%***	9,9%	6,6%	8,4%	7,2%	9,5%	8,4%	5,8%	6,6%
Medicine	*	***28,1%***	***17,4%***	***18,9%***	***31,2%***	***24,1%***	***11,3%***	***10,3%***	***22,1%***	***21,5%***	***20,0%***	***17,1%***	***33,0%***	***22,0%***
Multidisciplinary		1,0%	1,3%	1,5%	0,9%	1,5%	1,1%	1,3%	1,2%	1,3%	1,7%	1,8%	1,1%	1,5%
Neuroscience		2,4%	1,3%	1,1%	3,3%	1,6%	1,2%	0,6%	1,3%	0,9%	2,2%	1,3%	1,5%	1,1%
Nursing		1,5%	0,5%	0,5%	1,3%	0,7%	0,1%	0,1%	0,7%	0,8%	0,5%	0,5%	1,3%	0,9%
Pharmacology, Toxicology and Pharmaceutics	*	3,3%	4,2%	2,6%	3,4%	2,5%	1,6%	1,0%	5,3%	3,3%	2,9%	2,3%	3,2%	3,0%
Physics and Astronomy	*	***12,3%***	***15,7%***	***35,8%***	***16,4%***	***42,6%***	***45,0%***	***55,9%***	***22,0%***	***33,8%***	***16,9%***	***36,2%***	***13,9%***	***26,5%***
Psychology		2,2%	0,5%	0,7%	1,6%	1,1%	0,6%	0,5%	0,7%	0,6%	0,9%	0,7%	2,6%	1,0%
Social Sciences		7,5%	3,3%	2,0%	3,6%	2,1%	2,1%	1,0%	3,1%	2,2%	3,1%	1,9%	9,5%	3,0%
Veterinary	*	0,8%	0,8%	0,5%	1,8%	0,7%	0,1%	0,1%	0,5%	0,5%	0,3%	0,5%	1,8%	0,9%

Note. In this table we present the shares of different subject areas in total number of publications of a given BRICS country. Sum of shares of 27 subject areas is more than 100% since some publications are attached to several subject areas.

Source: authors' calculations based on Scopus. Types of publications included: articles, reviews and conference papers (last update: September 2016).

Fourteen top-level priority areas have been selected so far. Subsequently they will be broken down into smaller categories/groups: about 70 major subject fields (on average, five subject fields per subject area). E.g., the following fields are suggested for consideration in the Information and Communication Technologies subject area:

– high-performance computing architectures and systems;
– technology and communication infrastructure for high-speed data transfer;
– data analysis and processing technology, artificial intelligence;
– human-machine interfaces, neural and cognitive technology;
– smart control systems, smart infrastructures, machine-to-machine interaction, the internet of things;
– new component bases, electronic devices, quantum technology;
– information security technology.

Information about the importance of these subject fields and the potential for their implementation will be collected by polling experts in all BRICS countries. Similar subject fields will be identified for all other priority areas. Their names will be formulated using, to the maximum possible extent, the names of relevant subject fields specified in national and international strategic documents adopted by BRICS countries. Depending on the readiness of most of the technology required for the implementation of these priority areas, specific STI policy tools will be chosen.

Priorities can also be structured on the basis of potentially interested participants and technology readiness level: e.g. cooperation between R&D organisations and universities to develop technology, which requires public support; public-private partnerships at pre-competitive stages; the participation of businesses, including small innovation companies, in developing prototypes and applying advance technological solutions, etc. Shared S&T development priorities create a basis for mutually beneficial cooperation, in the framework of which scientists from different countries would be able to extend the scope of their research, step up collaboration, share experience, and ultimately strengthen Russia's S&T cooperation with other countries. The list of priorities for BRICS country S&T cooperation may be useful for drafting inter-agency agreements with BRICS countries on conducting R&D, preparing work plans (roadmaps) for stepping up S&T cooperation, and applying other relevant tools and mechanisms.

Based on the results of assessing BRICS countries' potential, calls for joint R&D project proposals can be arranged (aimed at developing innovative technology, promoting S&T-based entrepreneurship, and the application of R&D results with high commercialisation potential). The results of such projects could subsequently be integrated into a database to be used by various participants in national innovation systems, which would help them quickly identify suitable areas for further S&T cooperation with BRICS countries, find partners (including R&D organisations, universities, companies operating in various industries), and identify more efficient and productive cooperation mechanisms and formats.

Table 9. Number of publications in Scopus, Relative comparative advantages index values and field-weighted citation impact values for priority areas in BRICS countries for 2011–2015

Priority areas	Brazil	Russia	India	China	SAR	Brazil	Russia	India	China	SAR	Number of subj. Areas with RCA=>1	Brazil	Russia	India	China	SAR
	Number of publications in Scopus					Revealed comparative advantage index (RCA)						Filed-weighted citation impact				
1. Information and communication technologies	26 091	17 366	83 235	331 226	5 399	0.72	0.56	1.24	1.25	0.56	2	0.82	0.93	0.75	0.77	0.81
2. Nanotechnology and new materi-als	18 163	44 339	65 799	335 146	4 711	0.61	1.77	1.20	1.55	0.60	3	0.84	0.65	0.97	1.05	0.91
3. Advanced manufacturing and robotics	24 937	33 356	76 608	417 316	5 520	0.69	1.00	1.05	1.69	0.55	3	0.89	0.68	0.97	0.86	1.27
4. Space systems and astronomical observations	3 075	7 334	5 771	38 976	1 795	0.64	1.91	0.66	1.29	1.35	3	0.98	0.72	0.99	0.71	1.35
5. Transport systems (including aerospace)	1 022	395	3 004	18 763	214	0.49	0.25	0.76	1.43	0.44	1	0.86	1.03	0.87	0.77	0.92
6. Energy efficiency and energy saving	4 243	7 721	9 155	66 191	1 254	0.74	2.11	0.95	1.66	1.08	3	1.22	0.34	1.05	1.02	1.30
7. Nuclear energy	858	2 678	2 604	15 375	230	0.53	1.95	0.87	1.30	0.54	2	0.99	0.65	1.15	0.99	1.42
8. Renewable energy resources	2 007	836	7 405	26 125	894	0.70	0.34	1.39	1.24	1.17	3	1.22	1.10	0.97	1.86	1.19
9. Search, exploration, development and mining of minerals	4 189	11 137	7 496	70 183	2 411	1.03	2.33	0.61	1.60	1.45	4	0.70	0.69	0.90	0.92	1.26
10. Climate change, environmental protection and disaster management	18 462	10 524	33 668	120 599	6 191	1.16	0.73	0.73	0.88	1.73	2	1.09	0.87	0.87	1.19	1.24
11. Water resources	7 222	5 708	9 856	36 244	2 432	1.27	1.34	0.94	0.87	1.48	3	0.75	0.59	0.71	0.92	1.30
12. Food security and sustainable agriculture	31 091	3 337	31 104	55 194	4 970	3.34	0.32	1.65	0.73	1.78	3	0.73	0.80	0.62	0.99	1.07
13. Healthcare and medicine	87 882	22 636	108 790	321 297	20 375	1.27	0.49	0.54	0.41	0.92	1	0.86	0.66	0.82	0.87	1.45
14. Biotechnology	18 634	12 313	42 775	138 343	3 930	0.88	0.83	1.39	0.98	0.80	1	0.87	0.71	0.76	1.04	1.10

Note. According to Scopus SciVal analytical toolbox Field-weighted Citation Impact (FWCI) is "the ratio of citations received relative to the expected world average for the subject field, publication type and publication year". Averaging is carried out for all publications of the same type, year and field of science. This measure is convenient because its values can be compared both across the different disciplines, and time for individual countries/organisations/authors. See more in SciVal metrics Guide book https://www.elsevier.com/__data/assets/pdf_file/0020/53327/scival-metrics-guidebook-v1_01-february2014.pdf

Source: authors' calculations based on Scopus. Types of publications included: articles, reviews and conference papers (last update: December 2016).

Conclusion

As the experience of BRICS countries shows, S&T priorities are usually set in the context of designing long-term sustainable development strategies, to support the accomplishment of key national and global socio-economic objectives. The results of our analysis allowed a number of prospective S&T areas to be identified in which BRICS countries may be interested in stepping up bilateral and multilateral cooperation and thus more efficiently implement their own national priorities. The similarity of S&T and innovation development priorities within BRICS countries is a major factor in promoting the establishment of sustainable long-term partnerships between them. Furthermore, recent cooperative practice shows that such partnerships tend to strengthen the participants, specifically in the scope of projects implemented in priority subject areas, with the potential to produce significant economic and social effects. Cooperation between BRICS countries becomes more efficient and productive the more it covers all stages of the innovation cycle – from creating new basic knowledge to its practical application – new technology, products, and services. This implies that such stages may be "distributed" between BRICS countries, in line not only with their respective S&T priorities but also their production potential. Subsequently, an information database could be created on the basis of the obtained results to support the various participants in national innovation systems, so that they would quickly be able to identify suitable subject areas for S&T cooperation with other BRICS countries, find partners (including R&D organisations, universities, industrial enterprises specialising in various sectors of the economy, etc.), and identify the best formats and mechanism for cooperation. Acting in the international arena as a single group, BRICS countries could become a global node of advanced STI development.

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Appendix 1. List of Strategic Documents on BRICS Countries' S&T Policy Analysed in the Course of the Study

Brazil

Government of Brazil (2008) National Plan on Climate Change.

MINISTÉRIO DA SAÚDE (2011) Plano Nacional de Saúde – 2012-2015.

MCTI (2016) "Estratégia Nacional de Ciência, Tecnologia e Inovação 2016-2019", Brasilia.

Russia

RF National Programme "Development of Science and Technology for 2013-202",

S&T Development Strategy of the Russian Federation (approved by the RF Presidential Dcree on 1 December, 2016 N 642). [in Russian]

Foresight of Science and Technology Development in the Russian Federation: 2030 (aproved by the RF Prime Minister's order № DM-P8-5 of 3 January, 2014). [in Russian]

State Programme of the Russian Federation "Development of Science and Technology in 2013-2020" (approved by the RF Government Regulation of 15 April, 2014 № 301). [in Russian]

Federal Targeted Programme "Research and Development in Priority Areas for the Russian S&T Complex in 2014-2020". Approved by the RF Government Regulation of 21 May, 2013 № 426. [in Russian]

Lists of priority S&T areas for the Russian Federation. Approved by the RF Presidential Decree of 07.07.2011 № 899. [in Russian]

Lists of critical technologies for the Russian Federation. Approved by the RF Presidential Decree of 07.07.2011 № 899. [in Russian]

Agency for Strategic Initiatives (2016). National Technology Initiative. [in Russian]

India

Department of Science and Technology (2007) Information and Communication Technology. Research & Development and Innovation Strategy, South Africa.

Ministry of Environment, Forest and Climate Change (2008) National Action Plan on Climate Change, India.

Department of minerals and energy (2009) National Energy Efficiency Strategy of the Republic of South Africa.

Government of India, Ministry of Water Resources, River Development and Ganga Rejuvenation (2010) National Water Mission.

Ministry of Agriculture and Farmers Welfare (2010) "National Mission for Sustainable Agriculture", India.

Government of India (2012) Twelfth Five Year Plan (2012-17).

Government of India (2013) Science, Technology and Innovation Policy. New Delhi.

Government of India, National Institution for Transforming India (2016) Atal Innovaton Mission, India.

Department of Water Affairs (2013) National Water Resource Strategy, South Africa.

Department of Agriculture, Forestry and Fisheries (2015). Strategic Plan for the Department of Agriculture, Forestry and Fisheries 2015/16 to 2019/20, South Africa.

Department of Industrial Research and Promotion (2015) Make in India, India.

Department of Science and Technology (2015) National Biotechnology Development Strategy 2015-2020, India.

Ministry of Earth Sciences (2016) Vision for 2030, India.

China

Ministry of Science and Technology (2006) Implementation of the "National Medium and Long Term Science and Technology Development Plan (2006–2020)" a number of supporting policies, China.

Chinese Academy of Sciences (2009) Innovation 2050: Science and Technology and China's Future "Chinese Academy of Sciences Strategic Research Series released, China.

State Council, CPC Central Committee (2010). Decision of the State Council on Accelerating the Cultivation and Development of Strategic Emerging Industries, China.

State Council, CPC Central Committee (2014). Energy Development Strategy Action Plan (2014-2020), China.

National Development and Reform Commission (2015). "Silk Road Economic Zone", China, Kazakhstan.

State Council, CPC Central Committee (2016) THE 13TH FIVE-YEAR PLAN FOR ECONOMIC AND SOCIAL DEVELOPMENT OF THE PEOPLE'S REPUBLIC OF CHINA (2016–2020), China.

Science and Technology Department of the People's Republic of China (2016) National Innovation-Driven Development Strategy Outline "Three-step to build the world's science and technology innovation in 2050" China.

State Council, CPC Central Committee (2016) "Healthy China 2030" Plan, China.

South Africa

Department of Science and Technology (2008) The Ten-Year Innovation Plan for South Africa 2008–2018, South Africa.

South Africa Government (2010) The New Growth Path.

National Planning Commission. Republic of South Africa (2011) Our Future-make it work. National Development Plan 2030.

Department of Science and Technology (2016) SOUTH AFRICAN RESEARCH INFRAESTRUCTURE ROADMAP: First Edition.

Intergovernmental BRICS documents

Moscow Declaration of BRICS countries' Science, Technology, and Innovation Ministers of 26 October, 2015.

Working Plan on Science, Technology and Innovation for BRICS countries 2015–2018, (2015).

BRICS, 2014. First BRICS Science, Technology and Innovation Ministerial Meeting (2014) Cape Town Declaration. 10 February 2014. Cape Town, South Africa.

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BRICS, 2016. BRICS STI Framework Programme Coordinated call for BRICS multilat-eral projects – Pilot call.

BRICS, 2017. BRICS STI Framework Programme Coordinated call for BRICS multilat-eral projects.

Appendix 2. Conversion Kable from Scopus Subject Areas and Subject Categories to 14 Priority Areas

Priority areas	Scopus subject areas and subject categories
1. Information and communication technologies	All subject categories of subject area "Computer Science"
2. Nanotechnology and new materials	All subject categories of subject area "Material Science"
3. Advanced manufacturing and robotics	Subject categories "Control and Systems Engineering"; "Electrical and Electronic Engineering"; "Industrial and Manufacturing Engineering"; "Mechanical Engineering"; "Mechanics of Materials"
4. Space systems and astronomical observations	Subject categories "Space and Planetary Science"; "Aerospace Engineering"
5. Transport systems (including aerospace)	Subject categories "Automotive Engineering"; "Transportation"
6. Energy efficiency and energy saving	Subject categories "Energy Engineering and Power Technology"; "Fuel Technology"
7. Nuclear energy	Subject categories "Nuclear Energy and Engineering"
8. Renewable energy resources	Subject categories "Renewable Energy, Sustainability and the Environment"
9. Search, exploration, development and mining of minerals	Subject categories "Economic Geology"; "Geochemistry and Petrology"; "Geology" "Geophysics"; "Geotechnical Engineering and Engineering Geology"
10. Climate change, environmental protection and disaster management	Subject categories "Ecological Modelling"; "Ecology"; "Environmental Engineering"; "Global and Planetary Change"; "Management, Monitoring, Policy and Law"; "Nature and Landscape Conservation"; "Pollution" "Atmospheric Science"; "Earth-Surface Processes"
11. Water resources	Subject categories "Aquatic Science"; "Oceanography"; "Ocean Engineering"; "Water Science and Technology"
12. Food security and sustainable agriculture	Subject categories "Agronomy and Crop Science"; "Food Science"; "Plant Science"; "Veterinary"
13. Healthcare and medicine	«Medicine» и «Health Professions»
14. Biotechnology	Subject categories "Biochemistry"; "Biophysics"; "Biotechnology"; "Cell Biology"; "Molecular Biology"; "Molecular Medicine"; "Structural Biology"; "Applied Microbiology and Biotechnology"

Since no research areas and categories in the Scopus classification exactly match the identified 14 priority S&T cooperation areas, a conversion table was designed to provide an adequate basis for calculations. Each priority area for cooperation was treated as a set of Scopus areas (categories) reflected in the table. It was used to calculate indicator values for priority S&T cooperation areas.

Определение приоритетов научно-технологического сотрудничества стран БРИКС[1]

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В статье представлены методические подходы к выбору приоритетов научно-технологического сотрудничества стран БРИКС на основе анализа международных и национальных стратегических документов стран БРИКС и тематики наиболее значимых публикаций ученых из этих стран, отраженных в базе данных Scopus. Систематизированы национальные научно-технологические приоритеты стран БРИКС и произведена сравнительная оценка их ресурсов научно-технологического развития.

Проанализированы показатели публикационной активности стран БРИКС, существенно активизировавшейся с 2000 г. и расширяющейся в межнациональных масштабах при доминировании Китая. Показана особая значимость развития сотрудничества с Китаем, уверенно выдвигающимся на позиции одного из мировых научно-технических лидеров, выделены перспективные области исследований для кооперации с Индией, Бразилией и ЮАР.

Сформирован перечень из 14 тематических приоритетов научно-технологического сотрудничества стран БРИКС (на основе анализа их национальных, двусторонних и многосторонних стратегических и прогнозных документов). Выделенные приоритеты научно-технологического развития создают основу для взаимовыгодного и эффективного сотрудничества стран БРИКС, в рамках которого ученые разных стран могут расширять диапазон исследований, развивать существующие и внедрять новые инструменты научно-технологического сотрудничества и обмениваться лучшим опытом.

Ключевые слова: научно-технологическое сотрудничество; международное партнерство; приоритеты сотрудничества; библиометрический анализ; страны БРИКС

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