Identifying Directions for the Russia's Science and Technology Cooperation

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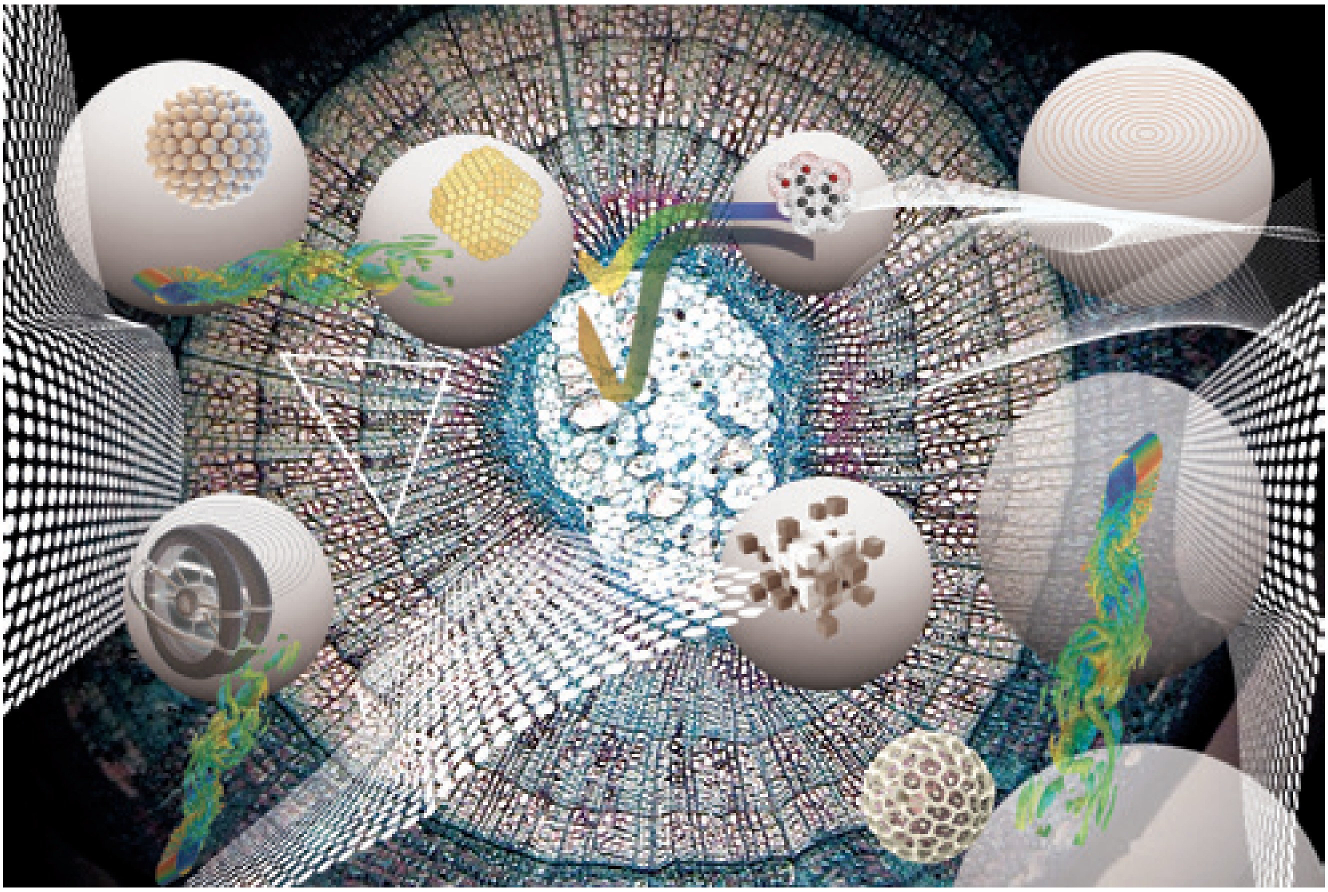

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Abstract

Strong international partnerships are a key vehicle for building an efficient national innovation system. Successful global cooperation needs comprehensive knowledge of the features of the science and technology (S&T) sphere in a changing environment of global division of labour, competition, and political climates. New realities and trends emerge, changing the established 'rules of the game' and calling for immediate actions from politicians, experts, and various economic actors.

The authors propose an analytical approach to build and examine an empirical database. Drawing on bibliometric analysis and expert survey tools, such an approach helps allows identifying the most promising areas for Russia's international S&T cooperation. The authors assess the scope for applying the proposed methodology. Based on the latest available data in Web of Science, the international scientific citation indexing service (2014 and early 2015), they compare the structure and variation over time of scientific specializations in Russia, leading S&T countries, and several rapidly growing global economies.

The cooperation priorities that were identified via matrix analysis were complemented with data from expert surveys. The surveys highlighted the partner organizations, thematic areas, and instruments of S&T cooperation, which indicate some of the future possibilities for Russia's international S&T cooperation.

Keywords: science and technology cooperation; international partnerships; priorities for STI cooperation; bibliometric analysis; expert interviews

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One of the most important factors underpinning the effective development of the national science, technology, and innovation system is its global integration, based on balanced partnerships with other countries. Strengthening international science and technology cooperation (ISTC) helps to stabilize the national economy and promote growth in its scientific potential. Up-to-date notions of the nature of S&T development against the backdrop of large-scale changes in the international division of labour and intensifying global competition determine the outlined cooperation strategies. The most successful of these strategies are summarized, improved, and circulated on international and national levels. Both traditional, well-established approaches and entirely new, pilot initiatives are introduced. Although the actual forms of partnership and corresponding policy measures are disseminated relatively intensively, certain problems that are not always easy to overcome still persist. The continuing emergence of new challenges and trends is forcing a change in the established rules and has prompted a need for a swift response by policy makers, politicians, experts, and economic players [OECD, 1988, 1988, 2015; European Commission, 2011, 2012].

In the context of developing Russia's ISTC, the following issues demand particular attention:

- The global economy and society are facing a growing number of global problems and solutions, which can only be resolved on an international level. Climate change, shortage of water resources, epidemics, and other global challenges all require a united effort to retain multilateral S&T collaboration independent of national agendas or the political environment. Searching for responses to these challenges shapes government policy around large-scale, complex, and long-term issues on a global and national level.
- Growing budgetary restrictions in many countries, including Russia, are increasing the demands on scientific facilities and the structure and effectiveness of funding for the sciences, and are broadening the range of problems encountered in government-supported scientific research. Against this backdrop, long-term guidelines (priorities) defined using forecasts, Foresight studies, and other analytical methods have become key when drafting S&T policy and policy instruments.
- The increasing complexity of the foreign political situation (in particular, the introduction of political and economic sanctions against Russia, and response measures by the Russian government) poses real threats to the national economy and scientific sphere. The negative effects are evident, and will continue to intensify if Russia does not succeed in embarking upon an innovative developmental model, raising the efficiency of all spheres and sectors of the economy, achieving high growth rates and quality, and making active use of scientific results and new technologies.

ISTC has been examined in many countries around the world and many studies have been devoted to the subject, focusing, in particular, on questions such as science, technology and innovation policy in Russia [*Gokhberg et al.*, 2009; *Gokhberg, Kuznetsova,* 2011; *Gokhberg, Zaichenko et al.*, 2011] and selected foreign countries [*Xiwei, Xiangdong*, 2007]. These also study priority areas and mechanisms for cooperation, including regulatory and legal frameworks, joint collaboration bodies, and financial instruments that support cooperation [*Gutnikova et al.*, 2014]. In several works, specific recommendations have been drafted to strengthen ties in science, technology and innovation between certain countries and regions, together with ways to achieve these aims through working with stakeholders [*Arzumanyan et al.*, 2012; *Balashova et al.*, 2013; European Commission, 2013; *Sokolov et al.*, 2014]. In works devoted to Russia's collaboration with leading countries abroad, special attention has been paid to expanding Russia's involvement (including in the geographical sense) in international S&T collaboration and analysing the restrictions impeding these efforts. Some studies devoted to collaboration prospects in the framework of BRICS offer a comparative analysis of the national innovation systems of the countries in this group [*Cassiolato, Vitorino*, 2009; *Gokhberg et al.*, 2012; *Arroio, Scerri*, 2013; *Cassiolato et al.*, 2013; *Kahn et al.*, 2013; *Scerri, Lastres*, 2013].

The Organization for Economic Cooperation and Development (OECD) actively engages in studying international cooperation by developing effective management decisions taking into account the specifics of innovation processes using an open innovation model. The interdisciplinarity and hyper-connectedness of certain segments of scientific systems are an important factor, and at the same time a condition, of the emergence of network collaboration on various levels, the consolidation of the ramified international research infrastructure and other elements of the system to support science, technology and innovation. Analytical and practice-oriented efforts are focused on deepening the internationalization of research in the public and private sectors, intensifying academic mobility and professional contacts, supporting project-specific and institutional cooperation between national research institutes and companies, and increasing the effectiveness of collaboration and broadening collaboration horizons [OECD, 2012a, 2012b, 2014].

From an objective standpoint, it is beneficial for Russia to look for joint collaboration objectives and priorities with other countries and set up a dialogue for ISTC. Some of these are not difficult to identify and are simply a continuation of policy from previous periods, while others still need to be found and added to the agenda of possible future partnerships. In the current economic and foreign political situation, streamlining bilateral collaboration[1] is a top priority for taking advantage of Russia's competitive advantages. The particular importance of this form of ISTC stems from its ability to directly influence the effectiveness of involvement in the international division of labour and output of domestic scientific achievements and high-tech products in traditional and emerging markets. In this regard, there needs to be some differentiation between approaches to developing ISTC with a focus on the specifics of different groups of states (Table 1). The implementation of a complex array of measures to develop ISTC needs to take account of the state of Russian research and development (R&D), and if Russian R&D fits into both national S&T priorities and the global standard. However, the data presented in Table 1, although incomplete, show that in every case there needs to be a detailed analysis of areas of mutually beneficial relations and the scientific, technological and economic profiles and needs of current and potential partners.

This paper proposes an approach to form a database to justify prospective areas of international S&T collaboration for Russia using bibliometric and expert analysis.

Methodology

In order to research ISTC priority areas, we tested a complex approach combining a bibliometric analysis of S&T specialisations in Russia and other countries and areas of joint publication activity with an expert assessment of collaboration priorities broken down thematically and by country.

Studies of publication activity are often used to compare the effectiveness of the scientific systems in developed countries [*Wagner*, 1995; *Tijsen et al.*, 2002; *Klitkou et al.*, 2005; *Gokhberg, Sagieva*, 2007; *Jarneving*, 2009; *Arencibia-Jorge, de Moya-Anegón*, 2010; *Peclin, Juznic*, 2012; *Gokhberg, Kuznetsova*, 2012] and the power dynamics in the research environment [*Barré*, 1987; *Grupp*, 1995; *Schneider*, 2010; *Kotsemir*, 2012; *Confraria, Godinho*, 2014; *Zacca-Gonzalez et al.*, 2014]. Aside from serving particularly scientific objectives, this makes it possible to establish an information resource, which may be used to increase the adaptiveness and effectiveness of state policy and to identify the most promising areas for international collaboration. The largest international database of publication activity and scientific citations is the Web of Science (WoS), which, as of the start of 2015, had indexed roughly 58.3 million records, classified under 151 research areas or 263 research areas for scientific journals.[2]

[1] Russia has signed bilateral S&T collaboration agreements with more than 70 countries.

[2] For more on international scientific citation databases see [*Brusoni et al.*, 2005; *Brusoni, Genua*, 2005; *Yang, Meho*, 2006; *Fingerman*, 2006; *Falagas et al.*, 2008; *Archambault et al.*, 2009].

Table 1. **Trajectories of bilateral S&T collaboration between Russia and foreign countries**

Groups of countries	Positive and negative factors when selecting ISTC areas	Possible ISTC areas for Russia
Developed countries	Strong economic and technological potential Potential interest in exporting technology from the previous technological wave to Russia, contacts in specific R&D fields, importing ideas and 'minds' Traditional restrictions on exporting advanced technologies (especially dual purpose) Involvement in economic sanctions	Maintaining (searching for) mutually beneficial, sustainable areas for cooperation Carrying out joint projects and programmes, including megascience Involvement in the activities of international organizations, global initiatives Growth in academic mobility
BRICS countries	Maintaining positive growth dynamics in a number of countries Production of 'cheap' and 'reverse' innovations Ambitions in science and technology, high interest in developing collaboration with Russia Pressure of explicit and implicit restrictions in technological exchanges with the West	Updating the general framework for ISTC priority areas Commercialization of R&D results Signing additional agreements with clear and well thought-out benefits for Russia Serving as platforms to expand Russia's communication with other states and international organizations Signing in 2015 of a memorandum of cooperation in science, technology and innovation (medicine, biotechnology, food safety, nanotechnology, high-power computing, support for technology and innovation infrastructure transfers) Creation of the BRICS Development Bank
Other countries with fast-growing economies	High economic growth in the long-term Own ambitions in science and technology, high interest in developing ISTC Opportunities for mutually beneficial technology exchange	Joint development of advanced technologies Localization of Russian high-tech manufacturing, S&T centres Exchange of best practices Expanding Russian high-tech exports
Other developing countries	Demand for 'simple' and cheap technological solutions, products, etc.	Implementation of more general programmes through assistance in international development

Source: compiled by the authors.

The scientific specialisation of countries is determined by comparing the thematic structure of its publications, while the scientific specialisation index (SSI) of country *j* in scientific field *i*, calculated as the relationship between the share of its publications in scientific field *i* in the total number of publications of country *j* and the equivalent global figure [*Gokhberg*, 2003; *Gokhberg, Sagieva*, 2007]. Those fields where the SSI value is higher than 1 are classified as areas of scientific specialisation. It is important to bear in mind the following characteristics of the SSI for analytical purposes and to justify administrative decisions. First, the index value is highly dependent on the thematic structure of journals in a particular country. The largest scientific citation databases traditionally are geared towards the natural and medical sciences to the detriment of a wide range of humanities and social disciplines. Second, it is important to bear in mind national specifics, which can manifest themselves in surges of joint publications by academics from developed and developing countries in extremely narrow disciplines (for example, parasitology and tropical medicine in some of the poorest countries in Africa). Third, the scale of publication activity is important. The structure of publications among the traditional leaders is, as a rule, more thematically balanced and growth is not sporadic or uneven in nature. Where publication figures are low overall, there are strong imbalances in certain scientific fields. Thus, this figure is effective when comparing the structure of scientific publications in different regions or groups of countries, evaluating the publication activity of a particular country, or identifying potential scientific partners in a specific research field [*Pianta, Archibugi*, 1991; *Barré*, 1991; *Nagpaul*, 1993;

Guena, 2001; *Tuzi,* 2005; *Laursen, Salter,* 2005; *Murmann,* 2012; *Bongioanni et al.,* 2013, 2014; *Abramo et al.,* 2014; *Acosta et al.,* 2014; *Askens et al.,* 2014].

The analysis of joint publications offers valuable research information, which may be useful in political decision making [*Luukkonen et al.,* 1993; *Katz, Martin,* 1997; *Dumont, Meeusen,* 2000; *Grupp et al.,* 2001]. It allows us to study key partners, promising areas for collaboration, broken down by country, and the characteristics of forming co-authorship networks, on both organizational and personal levels [*Gomez et al.,* 1995; *Glänzel,* 2001; *Wang et al.,* 2005; *Zhou, He,* 2009; *Hoekman et al.,* 2010]. Supplementing a bibliometric analysis with a network analysis allows the density of the observed ties to be evaluated [*El Alami et al.,* 1992; *Basu, Kumar,* 2000; *Chinchilla-Rodríguez et al.,* 2010; *Ding,* 2011; *Perc,* 2010]. Joint publication figures, however, only give a general overview of the level of cooperation. It is important to bear other aspects in mind too, for example, the existence of common research interests, modern equipment for joint experiments, international laboratories, strong skill sets in a particular area, personal contacts, youth exchange and academic cooperation programmes, new scientific journals, joint monographs and reports, and regular communication events such as conferences.

When identifying ISTC prospects, the global challenges facing humanity should not be ignored — joint efforts are needed on both a regional and international level. Global challenges in many ways format the multipolar scientific world and determine S&T development priorities as reflected in part in national industry development strategies. To identify and analyze these priorities, a range of expert surveys are widely used alongside other methods [European Commission, 2011; ICSU, 2011; *Silberglitt et al.,* 2006; UNIDO, TUBITAK, 2003]. Currently, distance personalized questionnaires and working face-to-face and online conferences are the most widespread tools [NISTEP, 2010, p. 28; *Sokolov et al.,* 2014; *Syrjänen et al.,* 2009].

In line with the methodical approaches outlined above, our study involved:

- identifying the scientific specialisation of Russia and 25 other countries according to five major and 39 detailed scientific areas (Table 2). The search used all current Web of Science databases. For each country, we looked at figures such as publication numbers; position in the overall publications ranking; proportion of specific industries as a percentage of all publications in the country; and countries' specialisation index in specific scientific fields;
- evaluating the scale and structure of joint publications by Russian researchers with colleagues from 25 countries (the number of joint publications, their proportion as a percentage of total internationally co-authored publications by Russian academics (broken down by country), and joint publication activity dynamics in 2003–2014);
- expert surveys and interviews with the scientific advisors of 15 foreign embassies in Russia, representatives of 38 leading Russian universities and research institutions involved in international programmes, and 530 foreign experts (online). Individual expert assessments were summarized and analyzed to obtain additional information on the current state and development prospects of Russian ISTC, partner countries, and the forms and thematic fields of collaboration with these countries. Respondents were given a list of prospective technologies and thematic R&D areas (in line with the Russian S&T Development Forecast for the period up to 2030, as approved by the Chairman of the Government of the Russian Federation on January 3, 2014) [*Gokhberg,* 2014].

Bibliometric analysis results

Scientific specialisation

The analysis allowed the following conclusions to be drawn. The scientific profile of virtually all of the countries included in the study shifts immediately after new technology trends emerge (Table 2). New industrial and rapidly developing countries are shown to be most efficient in this regard.[3] Over the last ten

[3] The attribution is conditional and serves only for ease of interpretation.

years, industrial biotechnology has been the specialist scientific field of countries such as Singapore (SSI 2.98), Malaysia (1.34), China (1.44), Brazil (1.14), and India (1.11), and nanotechnology in Singapore (3.22) and Taiwan (2.12). At the same time, these countries maintain their specialisation in traditional fields such as agriculture, forestry and fisheries (Brazil — 3.59, Argentina — 2.16), chemical engineering (Iran — 2.55) and materials engineering (China — 2.24). The majority of 'old' leaders of the global economy as a general rule support a broad profile of areas of specialisation and close SSI values between traditional (physics, chemistry, medicine) and relatively new scientific fields (biotechnology, ICT, and others).

The absolute leader in the majority of scientific fields is still the US, losing its position only in a few areas. China overtook the US in the number of publications in materials engineering in 2006, computer technology, ICT and chemistry in 2007, and new chemical technologies, civil engineering in 2008. Some growing economies are now likely going through the stage that the leading global economies went through 30–40 years ago, when areas of scientific specialisation were less clearly classified, and attention was paid to many scientific fields at once.

Table 2. **Scientific specialisation index of countries in 2003–2013**

Scientific field	Austria	UK	Germany	Spain	Italy	Netherlands	Finland	France	Argentina	Mexico	Brazil	India	China	South Africa	Israel	Iran	Canada	USA	Turkey	Switzerland	South Korea	Malaysia	Singapore	Taiwan	Japan
Industrial biotechnology							1.2				1.1	1.1	1.4						1.1	1.2	**1.9**	1.3	**3.0**	1.4	**1.7**
Physical sciences	1.1		1.4	1.0	1.2			1.4	1.1	1.4		1.2	1.2		1.2					1.2	1.4		1.4	1.3	**1.5**
Materials engineering												1.4	**2.2**			1.2				0.6	**1.9**	1.5	**1.6**	1.4	1.3
Chemical sciences			1.0	1.2				1.0	1.1			**2.0**	1.6			**1.7**				0.9	1.4	1.4	1.2	1.0	1.3
Environmental biotechnology				1.1			1.1		1.3	1.3	1.1	**1.7**	1.0	1.3					1.0	0.9	**1.6**	**1.6**	1.1		1.3
Nanotechnology			1.0									1.4	**1.6**			1.3				1.0	**2.4**	1.8	**3.2**	**2.1**	1.2
Basic medicine	1.0	1.1	1.1		1.3	1.3	1.0		1.1		1.2				1.1		1.2	1.3		1.2					1.2
Other agricultural sciences				**2.1**	1.2		1.2		**2.3**	**1.6**	**1.9**	1.5		1.2		1.3			**1.9**	0.6	1.5	**2.3**		1.1	1.2
Biological sciences	1.2	1.1	1.1	1.2	1.0	1.1	1.2	1.1	**2.0**	1.5	1.4			1.6	1.1		1.2	1.2		1.2					1.1
Mechanical engineering					1.0			1.1				1.0	1.5			**1.8**				0.8	1.3	1.2	1.0	1.1	1.1
Clinical medicine	1.4	1.2	1.2		1.4	**1.6**	1.2	1.0							1.3		1.2	1.3	1.8	1.3					1.1
Electrical engineering, electronic engineering, information engineering													**1.5**			1.3				0.6	1.5	1.8	**2.2**	**2.1**	1.0
Other engineering and technologies												1.1	**1.9**			1.3				0.7	1.3	1.4	1.2	1.5	1.0
Medical engineering	1.1				1.1	1.1											1.1	1.2		1.1	1.2	1.2	**1.9**	1.3	1.0
Agricultural sciences				**1.6**	1.0		1.2		**2.1**	**2.0**	**3.1**	**1.6**		**1.6**		**1.5**	1.1		**1.8**	0.8		1.3			0.9
Agriculture, forestry and fisheries				**1.6**	1.0		**1.6**		**2.2**	**2.3**	**3.6**	**1.6**		**1.6**		**1.5**	1.3		1.3	0.7		1.2			0.9
Environmental engineering												1.1	**1.7**	1.1		1.4	1.0		1.3	0.7	1.0	**1.7**		1.1	0.8
Other natural sciences (multidisciplinary)	1.2	1.4	1.1		1.1	1.3	1.1	1.1	1.1			1.5	1.1	**1.9**	1.3		1.1	1.4		**1.5**		**1.8**			0.8
Chemical engineering				1.3					**1.7**	1.5	1.1	**1.7**	1.4	1.2		**2.6**			1.8	0.5	1.4	**2.2**	1.4	1.1	0.8
Computer and information sciences	1.0			1.0									**1.6**			1.1				0.7	1.2	**1.7**	**1.7**	**1.7**	0.8
Earth and related environmental sciences	1.2	1.2	1.0	1.2	1.2	1.2	1.3	1.2	**1.7**	1.4		1.1	1.0	**1.8**			**1.4**	1.0	1.1	**1.3**					0.7
Veterinary science	**1.4**	1.1			1.2	1.0			1.7	1.4	**3.6**			**1.9**		1.4			**2.8**	**1.4**					0.7
Mathematics	1.2		1.0	1.3	**1.3**			**1.5**	1.0	1.3			1.3		**1.9**	**1.5**			1.0	0.7					0.7
Animal Science				1.3	**1.4**	1.2			1.6	2.2	**3.4**	**2.6**		**2.0**		**1.7**	1.3		1.3	0.7					0.7
Civil engineering													**2.0**			**1.7**	1.0		1.3	0.6	1.3	1.2	1.4	1.3	0.6
Health sciences		**1.5**				**1.6**	**1.4**				1.9			**1.8**			**1.5**	**1.5**		1.2					0.5
Media and communications		1.2		1.3		1.1	**1.6**							**1.9**				1.2		0.5		**2.1**	**1.6**	1.3	0.2
Social sciences		**1.7**				1.3								**1.8**	**1.6**		1.3	**1.5**		0.6		1.2			0.2

Notes. This table takes into account the following types of documents in all languages and all scientific fields indexed on Web of Science: articles, reviews, and conference proceedings papers. The search was carried out on all current Web of Science databases. This data is current as of the first half of September 2014.

Source: authors' calculations.

Table 3. **Key characteristics of publication activity among Russian academics (according to Web of Science data for 2003–2013)***

Years	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Key Russian publication activity figures											
Total publications	28 707	28 876	28 422	27 508	28 997	30 825	31 201	29 627	31 135	31 044	31 911
Position in global publications ranking	11	12	13	15	15	16	16	16	17	17	17
Share of global flow of publications (%)	2.74	2.64	2.45	2.24	2.16	2.16	2.08	2.01	2.01	1.88	1.93
Fields where Russian science occupies a leading position**											
Physical sciences	6	7	7	8	7	7	7	8	7	8	8
Mathematics	10	9	9	11	11	11	11	11	11	11	11
History and archaeology	11	11	10	10	10	12	10	9	9	9	11
Chemical sciences	7	8	8	10	10	9	11	11	11	12	12
Mechanical engineering	8	9	11	11	11	12	11	13	12	13	12
Materials engineering	9	9	10	10	11	10	10	13	11	12	12
Fields where Russian science is lagging critically behind**											
Civil engineering	40	18	42	36	40	38	52	52	60	56	47
Health sciences	39	39	41	40	42	48	50	49	53	51	54
Other agricultural sciences	46	46	52	60	46	57	53	66	57	58	57
Media and communications	10	30	32	36	40	47	38	40	38	42	57
Animal and dairy science	70	73	71	57	67	64	76	68	91	79	68
Veterinary science	58	68	80	62	70	67	67	69	73	67	69
Key thematic areas in Russian sciences on the Web of Science database ***											
Physical sciences	38.0	37.7	37.2	37.1	36.4	35.8	35.1	34.6	34.8	35.2	34.0
Chemical sciences	20.9	21.6	20.9	20.2	20.5	19.6	19.3	19.4	19.8	18.1	18.8
Biological sciences	10.7	11.1	10.4	10.9	10.9	10.6	10.4	11.3	11.0	11.1	10.9
Materials engineering	9.3	9.8	8.5	9.3	8.7	8.8	8.4	7.9	8.8	8.9	9.1
Earth and related environmental sciences	8.6	8.6	8.1	8.7	7.9	8.5	8.6	8.2	7.9	7.6	7.9
Mathematics	6.8	7.1	7.9	7.8	7.1	8.1	8.1	8.4	8.0	8.1	7.3

Notes.

* This table and subsequent tables take into account the following types of documents in all languages and all scientific fields: articles, reviews, conference proceedings papers. We used the tool to go between Web of Science categories and the scientific field classification system developed by the OECD (OECD fields of science classification: http://incites.isiknowledge.com/common/help/h_field_category_oecd_wos.html).

** Russia's position in the global ranking by the number of publications in respective fields of science.

*** Share of respective fields of science in the total number of Russia's publications (%).

Source: authors' calculations.

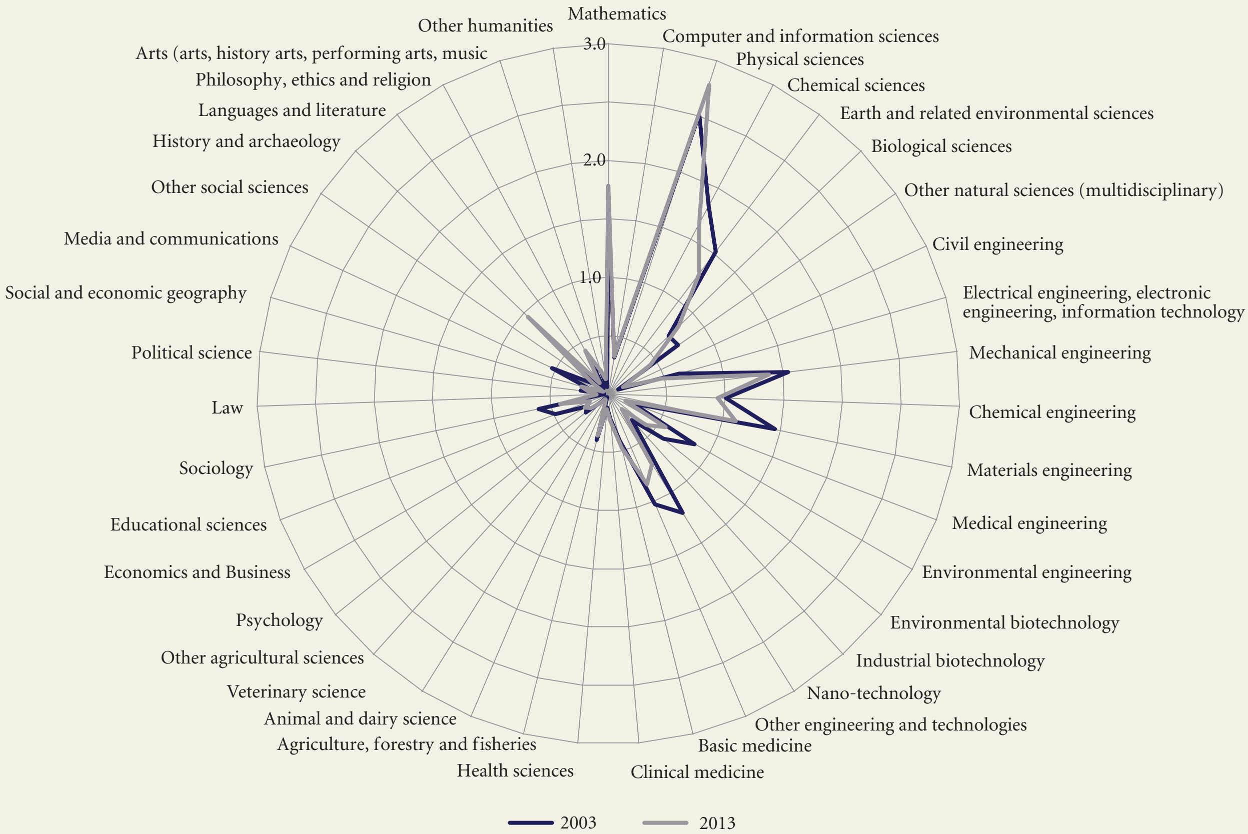
According to Web of Science data, the publication activity of Russian academics in 2003–2013 grew slowly and the country's position in the global rankings fell (Table 3). Russia only managed to secure a position among the top 20 leaders in certain natural science fields: 6th–7th place for physics and 7th–12th place for chemistry. The SSI value for physics is 2.78 and for mathematics and chemistry 1.78. The prevalence of publications in natural and exact sciences has led to them playing a decisive role in shaping Russia's scientific specialism. In the context of technological modernization, it is telling that the SSI for technical sciences is close to one, while for medical and agricultural sciences the figure is no higher than 0.4.

The structure of Russia's scientific specialisation is visualized by scientific field in Figure 1. The disparity between the relatively high indices of traditional fields (physical sciences, materials engineering, mechanical engineering) and the lower figures for social sciences, humanities, computer sciences, chemical sciences and nanotechnologies, and in prospective fields such as industrial biotechnology, is clear to see. Even the preliminary analysis of the bibliometric data clearly shows that the problem in Russian sciences lies not so much in it falling behind technologically developed countries, but rather in the far-from-optimal concentration of research efforts, both in terms of scale and structure. The poor choice of priorities is linked to the specific nature of Russia's economic development in recent times and the legacy of the Soviet era (Box 1).

Joint publications

As shown in Figure 2, the dynamics of joint Russian publications with other countries fluctuate, having grown by little more than 1% over the last decade.

Fig. 1. **Russia's scientific specialisation index by publications indexed on Web of Science, in 2003 and 2013**



Source: authors' calculations.

Box 1. **Russia's publication activity thrust: historical circumstances**

The dynamics of Russian publications on Web of Science are to a large degree shaped by trends, which took hold in Soviet times. In 1975, there were 28,900 of all types of publications by USSR academics on this database. By 1990, this figure reached 42,600, where it stayed until this bar was raised again in 2007. In 2014, the total number of former Soviet countries' publications was 53,600. For comparison, in China the number of publications increased from 62 in 1975 to 8,152 in 1981, and by 2014 had already reached 319,600.

The prevalence of physics and chemistry in the structure of Russian publications is a long-standing, historical phenomenon. In 1975–1992, the USSR's proportion of physics in total publications increased from 19.9% to 28.2%, while chemistry reduced from 30.9% to 24%.

The fact that the USSR was closed off from the rest of the world also had an impact on the intensity of Soviet researchers' collaboration with foreign colleagues, which continued to be relatively low: the proportion of joint publications in 1973 was only 1.25% (315 publications) and reached 5.03% (2,100) in 1990. In the early 1990s, cooperation between researchers in the former Soviet Union and foreign academics started to grow rapidly. By 1992, the proportion of joint publications for all former Soviet states reached 10.6% (3,900) and in 1994 16.7% (6,300). In 1999, this figure rose to 26.4% (10,900) and by 2014 to 32.3% (17,600 publications).

Russia's key channels for scientific collaboration existed back in Soviet times and have not changed significantly since. The USSR's main scientific partners were Germany (primarily East Germany) and to a lesser degree the US. In 1973–1990, Germany accounted for 27% of the total number of joint publications by the USSR with other countries, while the US accounted for 14%. Since 1992, the share of these two countries in total publications by former Soviet academics has remained virtually unchanged, fluctuating between 23% and 27%.

Some similarity can also be seen in thematic terms. In 1973–1990, the main areas of foreign scientific collaboration for the USSR, as indexed on Web of Science, were interdisciplinary studies in physics (10.4%), condensed matter physics (9.6%), biochemistry and molecular biology (7%), interdisciplinary studies in chemistry (5.9%) and physical chemistry (5.6%).

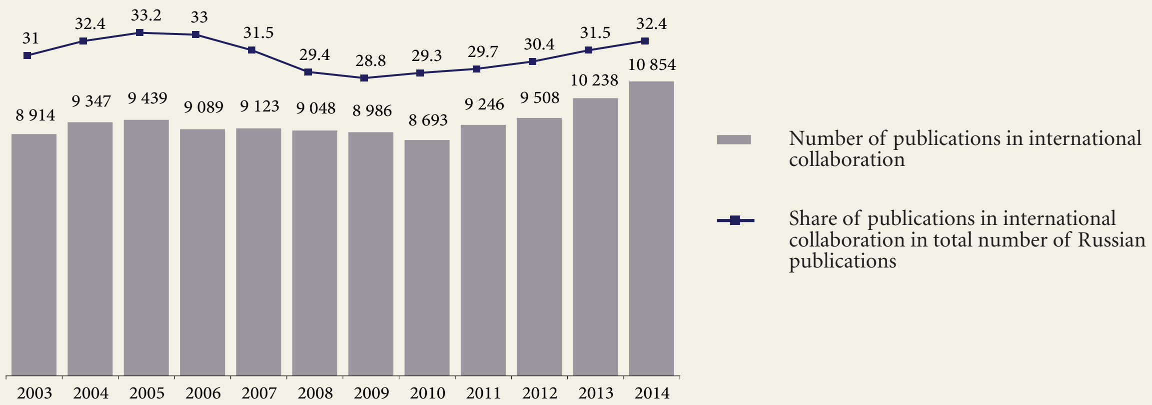
Source: authors' calculations.

Table 4. **Basic characteristics of joint publications by Russian academics with foreign colleagues in 2003–2014**

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Number of permanent partners (100 or more publications between 2003-2014)	31	32	33	33	32	35	34	38	49	54	56	58
Number of partner countries for Russia in terms of international co-authorship	99	107	113	124	109	120	117	114	119	130	131	154
Average number of partner countries in joint publications	1.66	1.78	1.86	1.89	1.94	2.00	2.03	2.25	2.59	3.10	2.85	2.85

Source: authors' calculations based on the data of the Web of Science (data is current as of April 2015).

Fig. 2. **Dynamics of joint publications by Russian academics with foreign colleagues (according to Web of Science data for 2003–2014)**



Source: authors' calculations.

However, a stable trend of intensifying international collaboration has started to establish itself: the group of partner countries is expanding (including permanent partners) and the average number of authors in a single joint publication is growing (Table 4). Today, as in Soviet times, the key partners of Russian researchers are colleagues from Germany and the US (roughly 26% each of the total number of joint publications). France, the UK and Italy are also among this group of important partners, which can be explained both by traditional scientific ties and the emigration of Soviet academics after the collapse of the USSR.

Table 5 shows data for several countries with the best figures for international co-authorship with Russian academics in absolute terms or in growth terms over the period 2003–2014. Out of all countries with which Russian academics had joint publications, three countries stand out: China, with three-fold growth; Australia, with four-fold growth; and Turkey, with seven-fold growth. The observed trend can be explained not only by mutual interests, but also by the active involvement of Russian and foreign researchers in large-scale collaborative Megascience projects (such as the Large Hadron Collider at CERN, among others).

Table 6 shows the distribution of joint publications by Russian and foreign academics according to the thematic areas with the highest figures (total over 2003–2014) or highest rates of growth. As expected, in absolute terms traditional physical sciences and mathematics, materials engineering, and certain other engineering sciences are the leading fields. The most intensive growth in publication activity was recorded in interdisciplinary studies, nanotechnology, applied mathematics, metallurgy, and certain medical fields. However, negative dynamics were seen in Russian priority areas such as electronics, aerospace engineering, nuclear physics, nuclear science and technology, and modern areas in chemistry.

Table 5. **Russia's key partner countries in terms of joint scientific publications**

Country	Share of publications as a percentage of total Russian co-authored publications (%)		Number of joint publications (units)		Growth in joint publications over 2003-2014 (%)
	2003	2014	2003	2014	
USA	25.3	27.3	2 257	2 965	31.4
Germany	26.9	26.7	2 400	2 895	20.6
France	12.3	15.7	1 096	1 699	55.0
UK	9.1	14.5	815	1 571	92.8
China	2.9	9.7	262	1 049	**300.4**
Switzerland	4.4	7.2	394	779	97.7
Finland	3.1	5.6	276	604	118.8
Czech Republic	2.2	5.4	192	589	**206.8**
Brazil	1.7	5.0	154	542	**251.9**
Australia	1.5	4.9	133	535	**302.3**
India	1.2	4.8	110	522	**374.5**
South Korea	2.9	4.6	257	503	95.7
Austria	1.8	4.1	164	447	**172.6**
Turkey	0.6	3.8	51	408	**700.0**
Taiwan	1.3	3.5	113	379	**235.4**

Source: authors' calculations based on the data of the Web of Science (data is current as of April 2015).

Table 6. **Leading thematic areas of Russia's S&T collaboration with foreign countries**

Scientific field (Web of Science categories)	Number of joint publications (units)			Percentage of Russia's joint publications in the period 2003-2014 (%)	Growth in joint publications over 2003–2014 (%)
	2003	2014	2003–2014 — total		
Physics Condensed Matter	1 046	689	10 065	8.9	–34.1
Physics Multidisciplinary	859	787	9 910	8.8	–8.4
Astronomy Astrophysics	604	858	8 588	7.6	42.1
Physics Applied	709	758	8 317	7.4	6.9
Physics Particles Fields	558	739	7 929	7.0	32.4
Materials Science Multidisciplinary	574	799	7 485	6.7	39.2
Chemistry Physical	552	694	6 834	6.1	25.7
Optics	363	483	4 957	4.4	33.1
Physics Atomic Molecular Chemical	430	382	4 703	4.2	–11.2
Biochemistry Molecular Biology	421	365	4 611	4.1	–13.3
Physics Nuclear	420	319	4 418	3.9	–24.0
Geosciences Multidisciplinary	247	329	3 468	3.1	33.2
Chemistry Multidisciplinary	341	199	3 244	2.9	–41.6
Mathematics	266	244	2 808	2.5	–8.3
Nuclear Science Technology	180	290	2 736	2.4	61.1
Physics Mathematical	229	179	2 344	2.1	–21.8
Physics Fluids Plasmas	101	268	2 158	1.9	165.3
Instruments Instrumentation	127	202	1 823	1.6	59.1
Mathematics Applied	64	343	1 578	1.4	435.9
Chemistry Inorganic Nuclear	153	81	1 371	1.2	–47.1
Spectroscopy	28	87	653	0.6	210.7
Geochemistry Geophysics	26	101	625	0.6	288.5
Chemistry Organic	84	20	569	0.5	–76.2
Engineering Electrical Electronic	13	45	315	0.3	246.2

Source: authors' calculations based on the data of the Web of Science (data is current as of April 2015).

Table 7. **Russia's potential partner countries for collaborative projects in certain scientific fields**

Country	Scientific field								
	Clinical medicine	Industrial biotechnology	Computer and information sciences	Civil Engineering	Electronics and electrical engineering	Environmental biotechnology	Health sciences	Veterinary science	Agricultural sciences
Austria	X		X					X	
UK	X						X	X	
Germany	X								
Spain			X			X			X
Italy	X							X	X
Netherlands	X						X	X	
Finland	X	X				X	X		X
France	X								
Canada	X			X			X		X
USA	X						X		
Switzerland	X	X					X	X	
Japan	X	X			X	X			
Argentina						X		X	X
Mexico						X		X	X
Brazil		X				X	X	X	X
India		X				X			X
China		X	X	X	X	X			
South Africa						X	X	X	X
Iran			X	X	X			X	X
Turkey	X	X		X		X		X	X
Israel	X								
South Korea		X	X	X	X	X			
Malaysia		X	X	X	X	X			X
Singapore		X	X	X	X	X			
Taiwan		X	X	X	X				

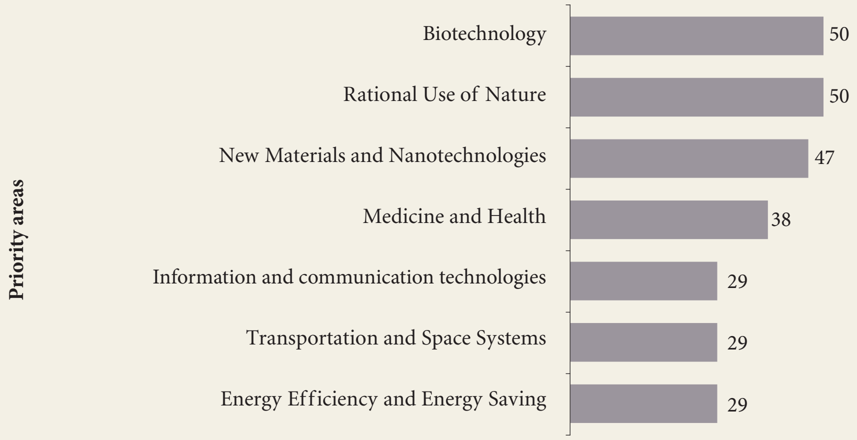
Source: compiled by the authors.

The results of bibliometric analyses of scientific specialisation and joint publications of Russian and foreign academics were used to compile a matrix of likely areas of long-term stable research cooperation according to scientific field and country, a fragment of which is given in Table 7. Notwithstanding the unfavorable foreign political conditions, collaboration with global leaders, BRICS nations, and some new developed economies demonstrating high growth in publication activity in certain scientific fields shows promise and is desirable for Russia. The analysis of bibliometric data reveals Russia's gaping holes in fields such as cell and tissue engineering, neuroimaging, robotics, and medical informatics. Generally, these fields are some of the most advanced, which creates some objective barriers when seeking partners for specialist projects. Evidently, special measures are needed to support Russian developments and guarantee access to foreign achievements.

Results of the expert survey

The expert survey of those involved in international programmes with a Russian party, conducted to supplement the bibliometric analysis, allowed us to identify partner countries and organizations and collaboration fields and instruments, as well as obtain individual assessments from qualified experts regarding the prospects of developing ISTC.

Fig. 3. **Priority S&T areas in the Russian Federation** (proportion of respondents selecting the corresponding response, %)



Note: The total exceeds 100% as respondents could select several responses.

Source: results of the survey carried out by ISSEK, NRU HSE.

Biologists, physicists, mathematicians, chemists, geologists, representatives of the medical and engineering sciences, and employees from large multidisciplinary organizations took part in the survey (Skolkovo Institute of Science and Technology, National Research Nuclear University 'MEPhI', Tomsk Polytechnic University, Russian Academy of Sciences Institute of Oceanography, MISiS National University of Science and Technology, Southern Federal University, Immanuel Kant Baltic Federal University, and Voronezh State University). The activities of each of these are linked to one or more of the current priority areas for development in science and technology (Figure 3).

The geography of the respondents' international collaboration in the S&T sphere was extremely vast and covered dozens of countries (Figure 4). The global leaders — Germany, US, China, UK and Japan — are still the main partners of the surveyed organizations, which is in line with the bibliometric data.

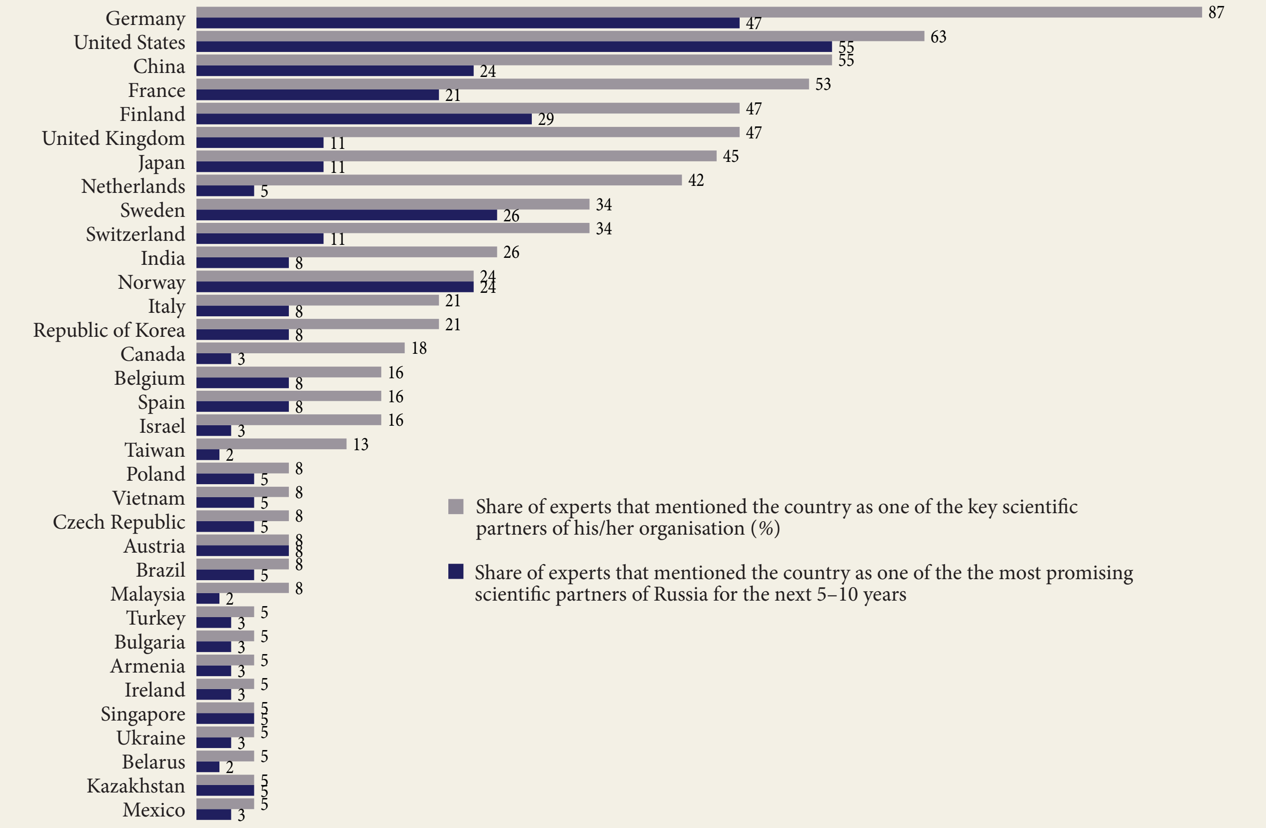
In the next 5–10 years, according to experts, the leading countries will probably continue to be Russia's main partners in the S&T sphere. These may be joined by Sweden, Netherlands, Finland, Spain, Norway, Austria, Singapore, Switzerland, Czech Republic, Brazil, Kazakhstan, and others.

As for ISTC development conditions, the respondents indicate that many of the barriers in this sphere are caused by internal circumstances linked to the complex economic situation in the country: depreciation of the rouble, budget deficit, and the inert nature of Russian bureaucracy. However, almost 45% of those surveyed reported that they had already experienced some negative impact of foreign political conditions.

Among the barriers and restrictions on developing ISTC are:

- a fall in the intensity of collaboration, including the reduction in the number of contracts signed; restrictions on access to funding through the European Union framework programmes; the suspension of a number of international projects due to a significant proportion of electronic components for R&D and modern equipment and technology falling under the sanctions; and the decrease in opportunities for Russian academics to work in international laboratories;
- general increase in the complexity of relations with partners, even as far as a reduction in business correspondence;
- costs and other problems in purchasing and supplying equipment and consumables;
- a fall in collaboration with foreign state institutions (for example, joint programmes with Russia were curtailed by the US Geological Survey, the leader in environmental monitoring);

Fig. 4. **Countries with which respondent organizations already collaborate in the S&T sphere and the most promising for collaboration in the next 5-10 years**



Source: results of the survey carried out by ISSEK, NRU HSE.

- refusal to publish articles by international journals which were previously happy to collaborate with Russian authors;
- limited grants handed out to Russian participants at international conferences;
- growing cost of scientific work following the depreciation of the rouble;
- difficulties in obtaining visas for scientific workers;
- difficulty in attracting foreign professors;
- the outflow of foreign specialists.

Many respondents pointed to guarded attitudes towards Russian academics among foreign colleagues, even those with experience of long-term collaboration. Foreigners fear that the involvement of an organization from Russia could have a negative impact on the fate of a project and jeopardize funding from national or international structures. In several cases, this trend has been successfully overcome through negotiations. Long-term contact partially offsets the negative impact of foreign political conditions. At the same time, experts remarked upon the comparatively high stability of ties with universities and foreign companies. There were even instances of scientific collaboration that were comparable with circumstances during the Cold War, for example in optics and laser technologies.

One of the consequences of the current foreign political climate, according to experts, is the geographical expansion of Russia's international collaboration in the S&T sphere, where partners from BRICS, ASEAN, and APEC countries are playing an ever-increasing role.[4] Table 8 lists Russia's ISTC priorities as a summary of the bibliometric analysis and expert survey results.

[4] However, the bibliometric analysis confirmed the existence of potential for cooperation only with certain countries in these groups and in certain scientific areas.

Table 8. **Priorities for Russia's S&T collaboration with foreign countries**

No.	Area of S&T collaboration	Countries	Type of research		
			Theoretical	Applied	Theoretical and applied
	Information and communication technologies				
1.	Computer architecture and systems	Germany, Israel	x	x	x
2.	Telecommunication technologies	Germany, Israel	x	x	x
3.	Data processing and analysis technologies	Germany, US, India	x	x	
		Germany			x
4.	Hardware components, electronic devices, and robotics	Germany			x
5.	Predictive modelling and simulation	France	x		
		EU countries			x
6.	Information security				
7.	Algorithms and software	Israel, Germany, Italy	x	x	x
	Biotechnology				
8.	Development of the scientific and methodological basis for biotechnology research	Spain, Japan, Sweden, France, Germany	x	x	x
		UK, Israel, US, Belgium	x		
		UK, Israel		x	
9.	Industrial biotechnology	China, France, Germany	x	x	x
10.	Agricultural biotechnology	US, Germany, UK, Japan, France	x	x	x
		Netherlands	x	x	
		Poland		x	
11.	Environmental biotechnology	Netherlands, Brazil	x	x	
		UK, Italy, France, Germany	x	x	x
12.	Food biotechnology	Netherlands	x	x	
		Italy, Spain, France, Germany	x	x	x
13.	Forestry biotechnology	Finland	x	x	
		France, Germany	x	x	x
14.	Aquabioculture	France, Germany, Norway	x	x	x
	Medicine and health care				
15.	Discovery of drug candidates	US, Germany, India	x	x	x
		UK, France		x	
		Sweden, China	x		
16.	Molecular diagnostics	US, Singapore, Taiwan, Japan, Portugal, China, Germany, Armenia, UK, Finland	x	x	x
		Italy, France	x		x
		Sweden, Norway	x		
17.	Molecular profiling and identification of molecular and cellular pathogenesis mechanisms	US, Germany, Sweden	x	x	x
		Japan, UK		x	
		France, China, Italy	x		
18.	Biomedical cell technologies	Japan		x	
		Portugal	x		
		Sweden, US, UK	x	x	x
		Germany, Italy	x		x
19.	Biocomposite materials for medical application	Germany, Israel, Switzerland	x	x	x
		France		x	
20.	Bio-electrodynamics and radiation medicine	US, Israel	x	x	
		China, Finland, Germany	x	x	x
		France		x	
21.	Genomic passportisation of humans	US, UK, Singapore, Japan, Sweden	x	x	x
	New materials and nanotechnologies				
22.	Structural and functional materials	US, Germany, Japan, Italy	x	x	x
		Finland		x	
		France, Israel	x	x	
23.	Hybrid materials, converging technologies, bio-mimetic materials and medical supplies	France, Czech Republic	x	x	x
		USA	x		
		China, Spain			
		Germany, Finland		x	
24.	Computer simulation of materials and processes	US, Germany, Japan, Finland, Israel, UK	x	x	x
		China	x		

Table 8 (continued)

25.	Diagnostics of materials	US, Germany, Japan, Italy	x	x	x
		Finland		x	
	Rational use of natural resources				
26.	Environmental protection and safety technologies	Germany, Sweden, US, China	x		
		EU countries, Japan, South Korea, Hungary	x	x	x
		Kazakhstan, Saudi Arabia, Germany, US		x	
27.	Monitoring of environment, assessment and forecasting of natural and technogenic emergencies	Norway, US, France, Japan, member states of the UN WMO, EU countries, South Korea, Italy, Germany	x	x	x
		UK	x	x	x
		Finland, Saudi Arabia		x	
		Finland, Sweden	x		
28.	Exploration of subsoil assets, mineral prospecting and integrated development of mineral and hydrocarbon resources	Saudi Arabia, Germany, US		x	
29.	Exploration and utilization of oceanic resources, the Arctic and Antarctic	US, Germany, Norway, France, Finland	x	x	x
				x	
	Transport and space systems				
30.	Development of an integrated transport space	Finland, Brazil		x	
		Canada, US, Germany, France, Italy	x	x	x
31.	Increasing safety and environmental neutrality of transport systems	Sweden, US	x		
		Germany, France, Brazil	x	x	x
		Netherlands	x	x	
32.	Prospective transport and space systems	US, Germany	x		
		France, China	x	x	x
		Netherlands	x	x	
	Energy efficiency and energy saving				
33.	Efficient exploration and mining of fossil fuels	Saudi Arabia, Germany, US	x	x	x
34.	Efficient and environmentally clean heat and power engineering	Germany, US	x		
		Saudi Arabia		x	
		France			
35.	Safe nuclear power engineering	Saudi Arabia		x	
		Germany, US	x		
36.	Efficient use of renewable energy sources	Czech Republic	x		
		Saudi Arabia		x	
		Germany, UK, Brazil	x	x	x
37.	Prospective bioenergy	Saudi Arabia		x	
38.	Deep processing of organic fuels	Saudi Arabia		x	
39.	Efficient storage of electric and thermal energy	Saudi Arabia		x	
40.	Hydrogen power	Saudi Arabia, Germany, US		x	
41.	Efficient transportation of fuel and energy	Saudi Arabia		x	
42.	Smart power generation systems of the future	Germany, US, Canada	x	x	x
		Saudi Arabia		x	
43.	Efficient energy consumption	Saudi Arabia, Germany, US		x	
44.	Modelling prospective power generation technologies and systems	USA	x		
		Saudi Arabia		x	
		EU countries, Germany, France	x	x	x
45.	Development of an advanced electronic component base for power engineering	Saudi Arabia		x	
		Germany, China, US	x	x	x
46.	New materials and catalysts for power engineering of the future	US, UK, BRICS countries, Germany, Netherlands, France	x	x	x
		Saudi Arabia		x	
		Australia	x	x	

Note. The list of areas in the second stage of the itemization was compiled in accordance with the Russian S&T Development Forecast for the period up to 2030 [*Gokhberg*, 2014].

Source: compiled by the authors.

Conclusion

The proposed approach to selecting ISTC priorities is not without its limitations, of course, as noted in the description of the research method. However, the authors did not set out to identify specific partners for cooperation, and, as international practice shows, such an aim is not what is called for. A more pressing task is to summarize the analytical data and evaluations, which will be beneficial to those making the decisions based on the available information and negotiations with partners. Using data that are more diverse will ultimately better satisfy Russia's national interests, in terms of overcoming the after-effects of economic and political crises, implementing national modernization objectives, and guaranteeing scientific achievement on a global level. The intensifying and increasing scales of international cooperation are key factors behind the achievement of Russian S&T complex development targets.

The current model of ISTC needs to be improved radically in the interest of intensifying the country's role as an equal participant in international S&T relations. Among the real and potential advantages derived by Russia from collaboration with foreign states in science, technology, and innovation, long-term ties with leading research centres and academics are of the greatest value. This would increase and transfer knowledge as well as thematic and geographical distribution of a range of ISTC areas; improve forms and mechanisms of integration in the global context; and increase Russia's involvement in solving global problems which would also positively impact the domestic condition, among others. From a strategic perspective, we can count on the intensification of partnerships with all states in future.

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