

INTERNATIONAL SCIENTIFIC MIGRATION: PROGRESS OR A THREAT TO RUSSIA'S SCIENTIFIC AND TECHNOLOGICAL SECURITY

The authors focus on the issues of scientific migration. This trend is relevant from both an academic perspective – studying the individual's economic behaviour, as well as practical one, because competition for talent has a significant impact on innovation policy initiatives around the world. Most Russian and foreign researchers are unanimous about the main complication for these studies: the lack of reliable information about scientific researchers' migration. To search for these data, we have developed a methodology implemented in software based on the big data technology. This software allows analysing data sets from leading scientific citation bases. The information on scientific migration has resulted from the analysis of changes in affiliation. We have collected the data on the scientific migration of researchers employed by the Ural Federal University from the Scopus database. The verification of the obtained data showed their high reliability. Most researchers move to Western European countries and the United States (up to 72 %). The main areas of emigrating researchers' scientific interests are natural and technical sciences. The optimal approach to minimizing the negative impact of scientific migration on Russia's scientific and technological security is the practical application of the theory of brain sharing. According to this theory, a large scientific diaspora abroad is an essential resource for the development of science and innovation.

Keywords: international scientific migration, economic and mathematical modelling, behavioural economy, brain drain, brain sharing

Introduction

The most successful and dynamic modern models of economic and social development are based on the progress of knowledge-intensive industries. Therefore, countries and corporations invest huge amounts of money in the development of fundamental and applied scientific research. It is evident that despite the high cost of research infrastructure, human capital is the scarcest resource for accelerating the development of science. In these conditions, the issue of scientific migration cannot be considered in isolation from global competition for researchers—both for recognized “stars” and for young researchers. Competition for talent influences innovation policy initiatives around the world [1]. In the case of Russian science, which has rather limited resources in global terms, it is essential to develop a strategy for responding to the emerging challenges. In our opinion, this is not only of practical interest, but also of scientific interest for such a rapidly developing research area as behavioral economics. The huge amount of information about scientific publications in databases of abstracts makes it possible to use the most advanced tools, in particular, big data, for researching the problem.

Literature review

The attention to studying scientific migration was fuelled by the phenomenon of ‘brain drain’, the term coined by the Royal Society of London for Improving Natural Knowledge to refer to engineers' and researchers' migration from the UK to the USA and Canada during and after the Second World War [2].

The interest to the issue of scientific migration was further stimulated by the increased role of knowledge-intensive industries in economic development. Thus, the broad opportunities for attracting scientists by means of return immigration are recognized as a competitive advantage of China's high-tech industries [3]. When considering the characteristic features of modern globalization and technocapitalism, researchers [4] note that technological creativity, corporate research, and talent flows are increasing in importance more than ever before. They are becoming the contextual central features of the 21st century macro-social dynamics globalization. Scientific migration cannot be considered in isolation from the issues of technology transfer. In this respect, the obtained results when researching scientific mobility are noteworthy. They show that organizations, whose employees are involved in the circulation of intelligence between countries, are the most productive in the creation of new technologies [5].

New theoretical approaches and concepts, many of which are controversial, are being developed to evaluate the processes of scientific migration. For example, according to a number of experts [6],

the current model of researchers' migration is characterized by a transition from the model of brain drain from one country and the growth of intellectual potential in another (brain gain) to the model of brain sharing. One of the conclusions about the transition to the model of brain sharing is as follows: international mobility benefits all parties, including the countries that are merely exporting researchers.

Despite this theory, preventing technology drain and stimulating return emigration are the most important areas of research that are of practical importance for donor countries in researchers' migration [7]. One example is a migration study based on 83 in-depth interviews with Italian researchers working in Europe (mainly mathematicians, engineers and physicists) and on the results of a survey using electronic questionnaires (528 respondents). The authors identify the common reasons that motivate researchers to move abroad, their professional and academic ties with Italy and their inclination to return.

For countries with weaker scientific and technological systems, it is essential to consider the "return dilemma" [8] in terms of scientists' mobility and its consequences. The conditions stimulating return emigration, such as the influence of a diaspora and the role of policies in minimizing the impacts of unbalanced flows, are considered. It is emphasized that developing a method for identifying and locating key expatriate scientists is extremely important for the study of scientific migration.

The hunt for talent stimulated the development of scientific research into the factors contributing to the attraction and retention of scientists. A number of researchers believe [9] that the major motive for scientific migration is the search for the most favourable environment in terms of productivity, with environmental factors, individual indicators of scientific effectiveness, and family factors considered as important determinants affecting the scientist's mobility. The role of cultural policy in attracting researchers has also been examined [10]. From the authors' viewpoint, the policy of multiculturalism helps attract the human resources essential for the country's development. The immigrants who remain in touch with their countries of origin can contribute to the "reverse brain flow".

Considerable attention has been given to identifying the aspects of the researchers' personality, scientific research activity and behaviour patterns that influence their attitude to migration. Many researchers refer to research interests as a key factor that stimulates or, on the contrary, inhibits a scientist's migration. In particular, considering the migration of Austrian and Hungarian scientists, the authors of the paper [11] note the high rate of mathematicians' international mobility. They attribute this to the fact that mathematics carries qualification regardless of cultural contexts and has a certain terminology that can easily be used in different languages.

Many researchers have focused on the factors that determine the researchers' adaptability to a new environment. For example, the role of the dual identity of immigrant scientists and the importance of developing networks of immigrant researchers are examined using Chinese scholars in Australia as a case study [12].

The specifics of women's scientific mobility have also been studied [13], taking into account the type of marriage (one-career or two-career marriage), the presence of children and other factors. A lot of controversies are caused by the age threshold for scientific migration. A number of researchers believe that young age is one of the most important factors determining the potential willingness to migrate, whereas others question this statement [14].

The methods used to study scientific migration are also noteworthy. For example, using mathematical modeling, the authors identify the factors that determine young scientists' immigration plans. The application of social inequality theories and decision making in the field of education and migration from a life course perspective is analyzed [15]. Along with the obvious conclusions about the role of a high social status in increasing mobility and the importance of gender for determining attitude to migration only for patriarchal societies, the crucial role of immersion in the internationalized academic environment is noted.

Russian researchers suggested an interesting method for studying the mobility of computer scientists [16]. The authors of the article compare the scientists' publication activity and their activity on the Internet on the sites related to the development of applications.

The study of scientific migration is of vital importance for Russia. The studies conducted by Russian Presidential Academy of National Economy and Public Administration (RANEPA) conclude that, on the whole, migration processes lead to a decrease in the educational level of the Russian

population¹. In the 2010s, from 30 to 70 % (depending on the country) of the emigrants from Russia are those with university degrees. Only 13–17 % of more than 9.1 million migrants who moved to Russia in 1992–2016 have a university degree or incomplete university course certificates (for Russians the percentage is 28 %). It does not seem possible to obtain government statistics on the immigration of highly qualified scientists. The issues of quantitative assessment of migration are reflected in a number of studies by Russian researchers [17]. Moreover, researchers express serious doubts about the reliability of statistics on emigration from Russia². The studies carried out by the Innovation Bureau “Expert” [18] and the Russian International Affairs Council [19] substantiate the fact that emigration of scientists from Russia is significant, and they have already formed diasporas abroad.

Researchers recognize that the lack of information on the rate of scientists’ emigration on a national scale complicates the analysis and understanding of the issue. Data is available only from selective surveys and studies of a local nature. The authors justifiably note that the long-term drain of Russian researchers abroad is not only a problem, but at a certain stage, it also becomes a resource for the innovative development of the Russian economy.

Actions are currently being taken to activate this resource: for example, when implementing the Russian Federation Government Decree No. 220 of April 9, 2010 “On measures to attract leading scientists to Russian institutions of higher education”, a competition was held to head research projects funded from the federal budget. Among the winning applicants, more than a third of applicants are Russian-speaking scientists working abroad (35.6 %) [19, p. 30]. An international Russian-speaking Academic Science Association (RASA) was created. Its goal is to preserve, strengthen and improve the common intellectual and cultural space of the Russian-speaking academic community³.

Methodology

The analysis of scientific mobility was carried out using the developed software for searching and processing data based on the original algorithms proposed by the authors.

The initial data array for articles is presented in the form of a column-matrix $X_{s1} = (a_{s1})_{r \times 1}$, $s = \overline{1, r}$, where the column is the organization under consideration, s is the line with the article title, r is the total number of articles with the analyzed organization affiliation. These matrix arrays are collected automatically for each year $k = \overline{2011, 2017}$.

At the second stage, the X_{s1} matrix is expanded by adding new columns of characteristics to the analyzed data set: author ID, name, country of affiliation, additional affiliations, and the number of citations for the article under analysis. As a result, 7 data sets on these indicators were obtained, reflecting Ural Federal University’s academic mobility dynamics from 2011 to 2017.

To identify migrant scientists, a new matrix is formed, reflecting the information on how many papers the authors have published with external organizations by year. For this, we introduce i —the parameter which determines the author’s ID. Then, when the author search algorithm is launched in the assembled data array (determining if the ID matches the target value), the A^k matrix will be formed in which the a_{ij}^k element is obtained by accumulating values in case the authors’ identification numbers in the array coincide with the authors’ target numbers.

As a result of the transformations, the $A^k = (a_{ij}^k)_{m \times 1}$ matrix is obtained, with the matrix lines representing all the authors of research papers, and the matrix columns ($i = 1, \dots, m$)—all the academic organizations identified. This matrix is compiled for each analyzed year, so each article has 3 main indexes that determine its position in the analyzed data array a_{ij}^k . It should be noted that the resulting matrix A^k is a sparse matrix with elements reflecting information on the number of articles a_{ij}^k of author i from organization j for selected year k .

In the compiled matrix, the academic organization being analyzed is represented by the first column. Thus, if the affiliation of the main organization is identified, element a_{ij}^k is fixed in the first column specifying the number of articles. When a change in the author’s affiliation is detected, element a_{ij}^k is assigned the value of the articles, then it is written in column j , where j is the ordinal number of the column denoting the organization the author moved to. To output data on brain drain based on

¹ Gordeev, A. (2015, January 23). “Utechka mozgov” iz Rossii usililas [“Brain Drain” from Russia has increased]. Vedomosti. (In Russ.)

² Mukhametshina, E. (2016, October 6). Iz Rossii uezhayut v razy bolshe lyudet, chem uchityvaet statistika [Many more people move from Russia than statistics account for]. Vedomosti. (In Russ.)

³ See: <https://www.dumaem-po-ruski.org/> (date of access: 15.12.2017).

the obtained data array, the elements of matrix A^k need to be checked for compliance with a number of conditions for time interval $k = \overline{2011, 2017} = 1, N$.

In general, the solution of the problem can be represented by a conditional breakdown of the total time into two parts: $k = 1, \frac{N}{2}$ and $k = \frac{N}{2} + 1, N$, and by putting the data on affiliation with the Russian university under consideration in the first column $j = 1$. As a result, the problem is reduced to the compilation of a final matrix $B = (b_{ij})_{c \times d}$ reflecting the number of publications attributed to the academic organizations identified without any reference to the time criterion. The search and accumulation of the array of articles attributed to authors i and academic organizations j on time length $k = 1, \frac{N}{2}$, are performed as follows: $\sum_{k=1}^{\frac{N}{2}} a_{ij}^k = b_{ij}$, if $b_{ij} > 3$, then author i is affiliated with organization j . The search on time length $k = \frac{N}{2} + 1, N$ is performed in a similar way.

For each particular case, checking is performed using the following algorithm:

– if condition $\sum_{k=1}^{\frac{N}{2}} a_{ij}^k > 3, j = 1$ is fulfilled on time length $k = 1, \frac{N}{2}$, the author is considered to be working in the main organization under consideration (UrFU);

– if condition $\sum_{k=\frac{N}{2}+1}^N a_{ij}^k = 0, j = 1$ is fulfilled on time length $k = \frac{N}{2} + 1, N$, the author is considered to have left the main organization under consideration (UFU);

– if condition $\sum_{k=\frac{N}{2}+1}^N a_{ij}^k > 3, j \neq 1$ is fulfilled on time length $k = \frac{N}{2} + 1, N$, the author is considered to be working for a foreign organization;

As a result, the final matrix $B = (b_{ij})_{c \times d}$ reflects the number of articles written by author i from academic organization j . The information presented in this matrix can be represented by the example of Table 1.

Table 1

Data array on researchers' publications taking into account their affiliation

	UrFU	Universiteit Gent	Universitat Lausanne Schweiz	Riga Technical University	Universitetet i Tromso	Guangdong Ocean University	National Institute for Materials Science Tsukuba	Radboud University Nijmegen	Max Planck Institut fur Astronomie	International Institute for Applied Systems Analysis, Laxenburg	Facebook, Inc.	CNRS Centre National de la Recherche Scientifique	Universidade de Aveiro	Nova School of Business and Economics, Universidade Nova de Lisboa	University of Alaska Fairbanks	⋮	Belarusian State University
Author 1 (ID)	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	⋮	0
Author 2 (ID)	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	⋮	0
Author 3 (ID)	1	0	0	0	6	0	0	0	0	0	0	0	0	0	0	⋮	0
Author 4 (ID)	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	⋮	0
Author 5 (ID)	2	1	0	0	0	3	0	0	0	1	0	0	0	0	0	⋮	0
Author 6 (ID)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	⋮	0
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
Author c (ID)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	⋮	0

To obtain the array of data on researchers who have moved to foreign universities, the first column in matrix $B = (b_{ij})_{c \times d}$, responsible for affiliation with the main organization under analysis, is crossed out. The resulting sparse matrix $C = (c_{ig})_{(c-1) \times d} = (b_{ij})_{c \times d} - (b_{i1})_{c \times 1}$ lists all the authors who published papers with UrFU and then moved to foreign organizations.

Results

The developed model and software were applied to analyze data on migration of researchers employed by the Ural Federal University. As a result of data collection and processing, a sample was obtained comprising 8986 researchers who published papers with the Ural Federal University affiliation. A total of 367 scientists were identified, whose affiliation changed: they started publishing papers affiliated with foreign universities. After that, the data were further processed, expert evaluation was carried out, and data on researchers whose change in affiliation might not be related to emigration or another form of long-term cooperation with a foreign university or scientific centre were deleted from the sample. The information was selectively verified according to the details the researchers provided in social networks. The analysis of the revealed tendencies, in our opinion, is of interest for the research into the human potential of Russian science and education.

A wide geography of Russian researchers' is noteworthy, with the United States, Germany, Great Britain and France leading as host countries (Fig.1). It should be noted that, contrary to many researchers' opinion, the share of scientists leaving for China and other Asian countries with a fast-growing economy remains insignificant: the leadership belongs to European countries and the United States.

The research interests of migrant scientists are mainly natural and applied sciences (Fig. 2), with physics, engineering, and materials science holding the leading positions. In fact, the percentage of researchers studying social sciences among those who have chosen an academic career abroad is even lower. This is due to the fact that the analysis of changes in affiliations was carried out using Scopus database, where data on publications in social sciences are more widely represented than in Web of Science, which mostly features data on natural sciences.

The analysis of the structure of research interests of scientists leaving Russia demonstrates that not only their departure poses threat to Russia's economic development. A large percentage of researchers moving abroad are engaged in research areas of direct practical value, where research results are quickly put into practice, such as engineering, computer technology, materials science. The demand for Russian researchers in the fields of science that provide rapid economic growth is evidenced by the fact that some scientists, without stopping their publication activity, continued their academic and practical activities not in universities, but in innovative companies, including such recognized world leaders of innovation economy as Facebook and Google.

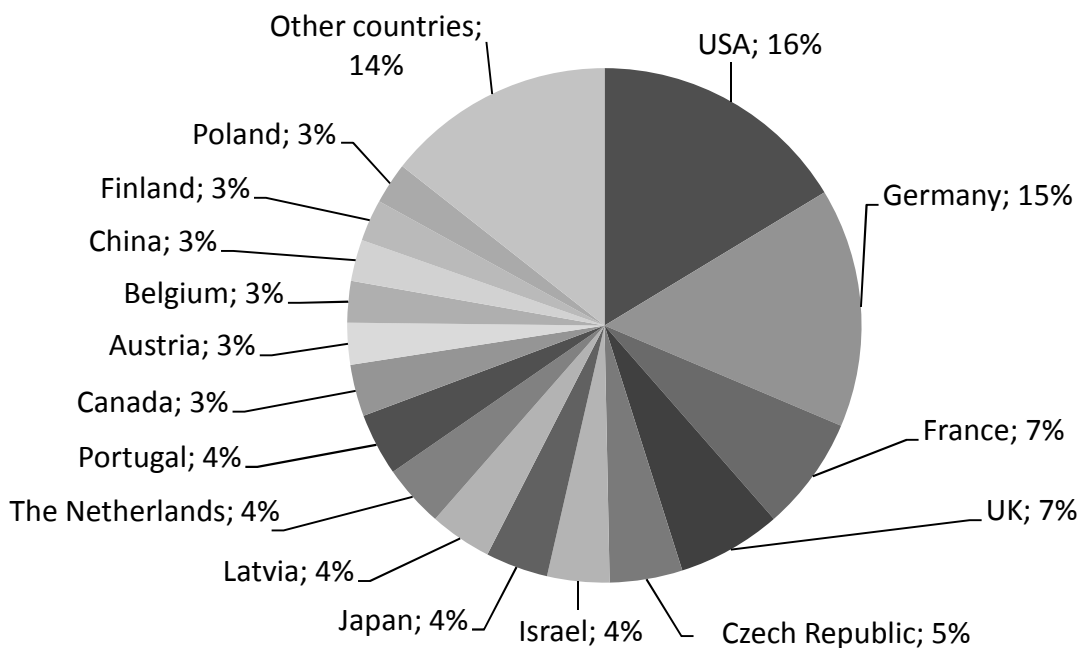


Fig. 1. Countries hosting Russian researchers

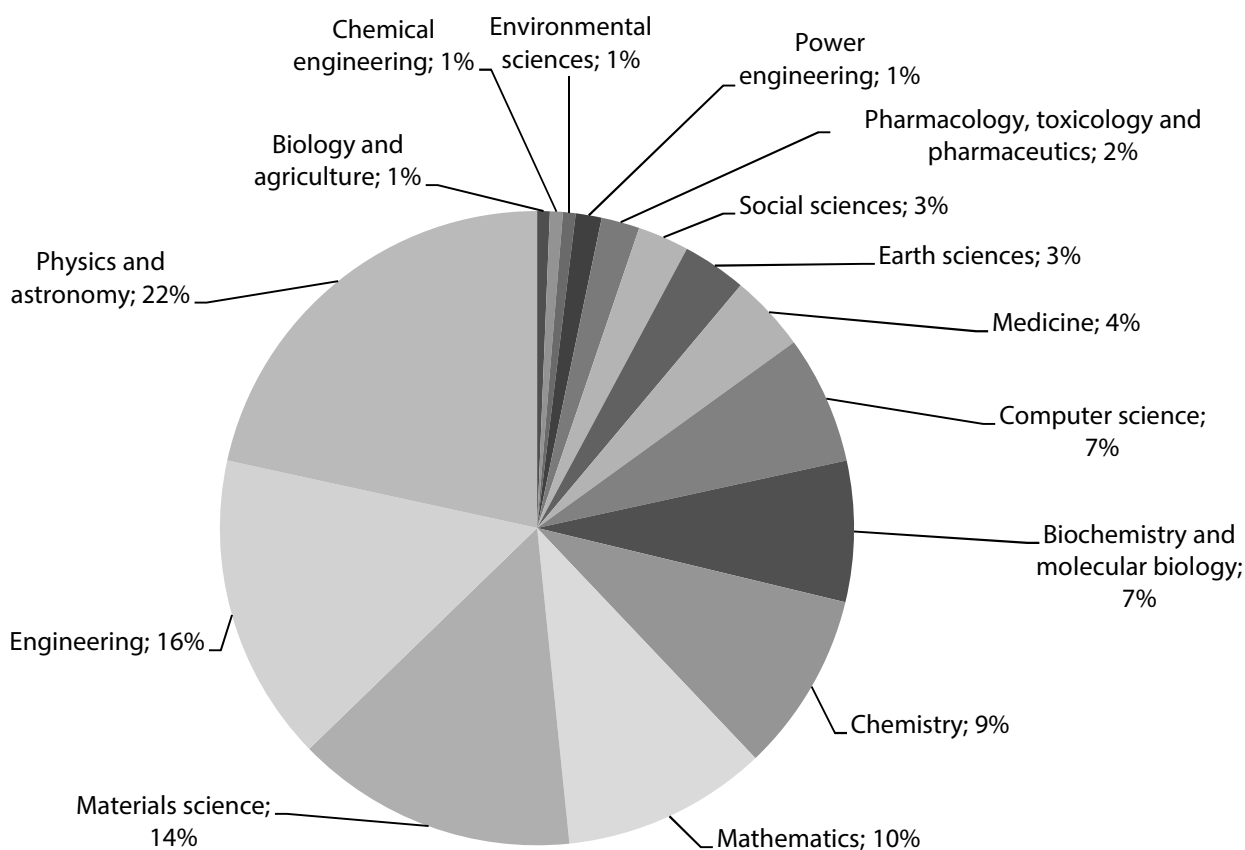


Fig. 2. Research interests of Russian researchers making an academic career abroad

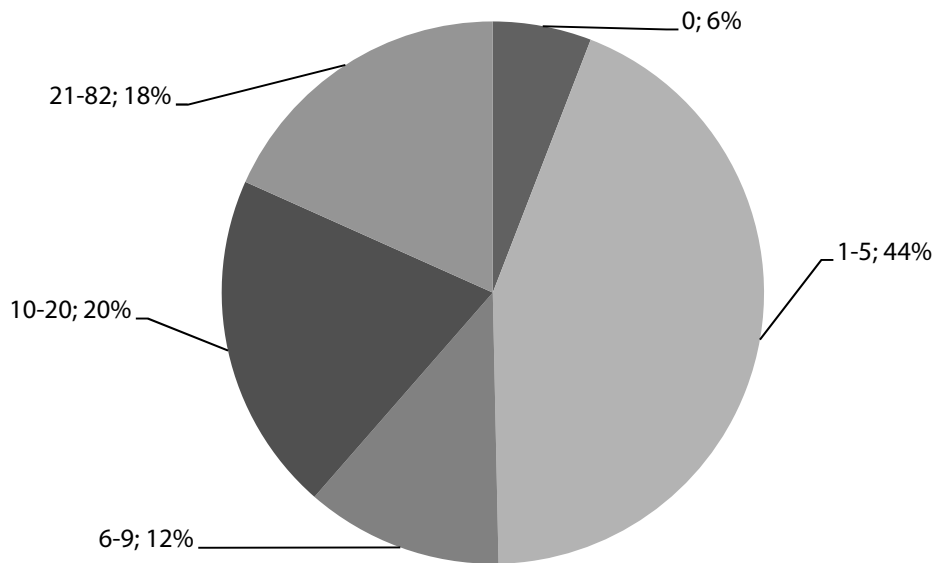


Fig. 3. The Hirsch index of Russian researchers making an academic career abroad

Places of work like these show the researchers' high status no less than their Hirsch index, which for scientists leaving Russia varies from 0 to 82 (Figure 3).

As a detailed analysis shows, there is a direct correlation between the academic positions held and the field of research interests: practice-oriented researchers have fewer publications and their h-index is lower. A significant proportion of scientists with a low Hirsch index shows that foreign universities and companies are willingly attracting young scientists who have not yet made a name in science, and evidences the outflow of young researchers motivated for academic activity.

To obtain a basis for comparing the intensity of internal and external scientific mobility using the described algorithm, we identified the researchers who have scientific publications in journals indexed in the Scopus database, and who have moved from Ural Federal University to other Russian universities. Their number is six times lower than the number of those who have chosen an international career.

In our opinion, the development of intra-Russian academic mobility could become a partial alternative to the departure of scientists abroad. The creation of the conditions for the realization of scientific interests within Russia is largely impeded by conservatism in the academic staff formation by universities and, in general, all-Russian barriers to labour migration that exist regardless of profession.

It is obvious that the current situation with the migration of Russian scientists is inseparable from the general economic situation that generates the lack of demand for researchers due to the slow development of knowledge-intensive industries. However, this does not eliminate the need for targeted measures to develop the academic human capital by reducing the researchers' emigration and encouraging return migration. In our opinion, this can be implemented according to one of the three scenarios: inertial, the scenario of leading scientists' retention, integration into world science.

1. The inertial scenario implies the preservation of the current policy regarding international scientific migration: maintenance of the current system of grants for young scientists and research projects aimed at attracting leading scientists, developing the programme of enhancing Russian universities' international competitiveness⁴, and promoting existing programmes of interaction with the Russian-speaking diaspora. The inertial scenario is low-risk, but the preservation of current trends does not provide for breakthrough achievements in the development of science and education human capital.

2. The scenario of retaining leading scientists. As the name implies, the scenario is based on creating conditions for preventing the leading scientists' migration from Russia by creating a favourable working environment: providing special grants, funding the research infrastructure of their laboratories. This would also involve offering grants to young talented scientists, the government drawing up, implementing and funding long-term contracts with young scientists, including, for example, providing housing for those employed by the university, creating, as an alternative to international mobility, conditions for internal academic mobility in Russia, the development of programmes to support the labour migration of talented young scientists and their families to work in leading Russian academic centres.

Obviously, the main risk of this scenario, besides increased costs, is the artificial isolation of Russian science from the world science, weaker competition among scientists and an almost inevitable lag behind the world's leading trends.

3. The scenario of integration into the world science aims to apply in practice the theory of brain sharing, according to which a large scientific diaspora abroad is an essential resource for the development of science and innovations. Efforts are channeled not into regulating researchers' migration, but into creating centres integrated into world science.

Academic centres that have world-level competencies and the necessary infrastructure should attract both Russian and foreign researchers. Various incentives and financial support for short-term academic mobility will increase their involvement in global scientific research trends. Centres like this will help preserve and multiply the human resources potential while concentrating research on breakthrough directions.

The interaction with the Russian-speaking academic diaspora should not be reduced to attempts to return scientists to Russia. The network forms of interaction need to be developed: foreign researchers' participation in co-authored publications, academic supervision, evaluating and auditing research and business projects, joint applications for research projects funding, supporting the work of graduates' associations at the international level.

The main risk for the implementation of this scenario is the difficulty of addressing at the government level the issues related to reducing bureaucratic barriers for scientists' interaction and to recognizing new forms of network cross-border interaction: prompt provision of visas, fixing formats for remote work of foreign scientists in Russia and options for funding them, expediting customs procedures to supply research centres with externally produced equipment and materials. Settling these issues of

⁴ О мерах государственной поддержки ведущих университетов Российской Федерации в целях повышения их конкурентоспособности среди ведущих мировых научно-образовательных центров. Постановление Правительства РФ от 16.03.2013 № 211. Red. of 15.11.2017 [On measures of government support for leading Russian universities to increase their competitiveness among the world's leading research and education centres. Russian Federation Government Decree No. 211 of 16.03.2013. Ed. of 15.11.2017]. *Sobranie zakonodatelstva RF*. 2013. № 12 (25.03). St. 1314 [Russian Federation Legislation. 2013. № 12 (25.03). Article 1314]. Retrieved from: <http://www.pravo.gov.ru> (date of access: 15.12.2017). (In Russ.)

organizing international academic cooperation is essential: there is virtually no alternative, in terms of cost-effectiveness, to the scenario of integration into world science.

Conclusion

The study of Russian researchers' scientific migration using the methodology developed by the authors to analyze international databases of scientific publications confirms the significant impact of researchers' international migration on Russian science.

Emigration involves both young scientists and researchers recognized by the scientific community. 18 % of the researchers who emigrated have the Hirsch-index from 21 to 82. Russian scientists' migration is directed mainly to Western European countries and the USA (up to 72 %). The main areas of interest for emigrating researchers are natural sciences and engineering (physics and astronomy—22 %, engineering—16 %, materials science—14 %, mathematics—10 %).

Numerous publications by Russian and foreign scientists evidence the relevance of research into the issues of scientific migration. In many ways, they are aimed at addressing practical issues of hunting for talent: searching for factors that help attract and retain researchers, interacting with the academic diaspora abroad, developing incentives for researchers' return emigration.

The key challenge for migration research is the collection of data on scientists' migration. Our research shows the prospects for the development of methods for analyzing databases of scientific publications using big data in order to obtain the required data.

The results obtained can be used when making decisions on enhancing the human resources potential of Russian science. According to our estimates, it is possible to create a partial alternative to international migration by stimulating intra-Russian mobility. At present, the rate of intra-national mobility of researchers with publications indexed in international databases is six times lower than their international mobility rate. The Russian-language scientific diaspora formed as a result of emigration is a resource for the development of Russian science and innovations according to the theory of brain sharing.

The prospects for research into scientific migration through analysing data in reference databases of scientific publications are related to increasing the volume of data arrays processed, for example, for all the participants in the project of enhancing Russian universities' competitiveness.

Online surveys of scientists making an academic career abroad will make it possible to significantly expand the understanding of scientific migration. Their high information value will be due to the selection of a sample of respondents based on the data from reference databases. It will ensure the representation of scientists from various fields of knowledge, with various citation rate and publication activity.

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