Artículo de investigación

Assessing the impact of regional scientific environment on the performance of scientific organizations: the example of Russia

Оценка влияния региональной научной среды на результативность научных организаций: на примере России

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Abstract

The goal of the study is to determine the impact of the regional scientific environment on the performance of scientific organizations. The indicators of a regional scientific environment, which were used as predictors in a regression model built to assess the dependence of the effectiveness of scientific organizations has been identified during the study. In the model, the

Аннотация

Целью исследования является определение влияния региональной научной среды на результативность научных организаций. В ходе исследования были выявлены показатели региональной научной среды, которые использовались в качестве предикторов в регрессионной модели, построенной для оценки зависимости

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category of scientific organizations was assigned as a dependent variable, according to the results of the federal monitoring conducted in 2016 for 541 scientific organizations located in 65 Russian regions. The study showed that there were no significant differences between regions when comparing factors determining the regional scientific environment and the performance of scientific organizations.

Keywords: Regional scientific environment, scientific organizations, performance, regression analysis

эффективности деятельности научных организаций. В модели категория научных организаций была взята в качестве зависимой переменной, согласно результатам федерального мониторинга, проведенного в 2016 году для 541 научной организации, расположенной в 65 регионах России. Результаты исследования показали отсутствие выраженных различий между регионами в степени влияния региональной научной среды на деятельность научных организаций.

Ключевые слова: региональная научная среда, научные организации, результативность, регрессионный анализ

Introduction

Under the unstable economic conditions in Russia caused by the global financial and economic situation in the hydrocarbon market, trade wars of the main economies of the USA and China, sanctions pressure and other factors, the development of new technologies can ensure sustainable development and competitiveness of the Russian economy in the long term. Considering the importance of solving this task, the National Technology Initiative was launched in 2016. It is the state program supporting the development of promising industries in Russia, that over the next 20 years could become the basis of the global economy.

In addition, the Decree of the President of the Russian Federation No. 204 of 07.05.2018 sets the task to ensure the presence of the Russian Federation among the five leading countries of the world that conduct research and development in areas defined by the priorities of scientific and technological development.

At the same time, the state continues to be the largest source of support for Russian science: by the end of 2017 its funds as part of domestic expenditures on R&D are more than twice as large as those in the business sector.

However, the analysis of Russian science's state shows that the organizations' scientific productivity does not allow them to reach a level that provides it with competitive advantages compared with leading economies. Moreover, a decrease in patent activity in areas such as information technology in management; fine and organic chemistry; the chemistry of high-molecular compounds and other directions (Streltsova, 2018) characterizing the 6th technological mode, testifies to the significant lag of Russia in the development of this important technological specialization.

By the number of scientific publications on technical specialties indexed in the Web of Science database for 2015–2017, Russia ranked 12th in the HSE rating (Dyachenko & Fursov, 2018).

Meanwhile, the research results indicate the growing interaction of the processes of knowledge generation and the creation of innovations at the regional level and the challenges of global science (Fritsch & Wyrwich, 2018; Oinas et al., 2018; Hazelkorn & Gibson, 2017).

In this regard, the presence of incentives for the growth of the scientific productivity of research institutions at the regional level is a factor that ensures the generation of new knowledge and enhances the country's competitiveness in the global market for new technologies.

The concept of a scientific organization and assessment of its performance

The object of this study is a scientific organization. At the same time, the authors proceed from the understanding of a scientific institution, which is enshrined in Russian legislation. According to Federal law No. 127-FZ of August 23, 1996 "On Science and the State Scientific and Technical Policy", the scientific organization is a legal entity, regardless of its organizational and legal form and form of ownership, which carrying out scientific and / or scientific technical activities. Thus, despite the fact that in a number of countries, universities, hospitals, museums, libraries and other institutions in the health and cultural sphere (OECD, 2011) are included in the category of organizations engaged in research and development, the research activities aimed at generating and disseminating knowledge for them is not included in the list of priority areas of work.

Analysis of the world practice of evaluating the activities of scientific organizations shows different approaches to the ranking of scientific institutions, depending on their performance (Maltseva et al., 2017). In particular, in scientometric method of evaluating research organizations, the creation of which is obliged to the works (Garfield, 1979; Price, 1976) and others, the main criteria for evaluating institutions are publishing and patent activity, citation indicators of the scientific institution's works and other measurable indicators. The introduction of this system allowed us to formalize the approach to the evaluation of scientific organizations, and provided an opportunity for officials responsible for the financing of scientific organizations to highlight priorities and support those research directions that demonstrate high performance. The scientometric approach underlies the SCImago Institutions Rankings, which is made annually by the research team of the University of Granada (Spain) based on a multi-factor model for evaluating scientific organizations in three indices — research, innovation, and social.

Another approach to analyzing the performance of scientific organizations is the qualitative examination of the institution’s main activities. As a rule, the experts from the field of knowledge in which the scientific organization specializes are involved to this work. The advantage of this approach is that it allows for a comprehensive assessment of the institution based on such criteria as novelty and originality of the research results, their global significance, the management system of the scientific organization, etc. The advantage of this approach is in the conducting a comprehensive diagnosis of the scientific institution aimed at development of recommendations to improve the efficiency of its work. However, unlike the scientometric approach, expertise requires additional time and human resources.

In addition, in evaluating the activities of scientific organizations, it is customary to highlight an assessment of performance and efficiency. If performance refers to the ability to receive results on specific research and development projects and programs, the degree of achievement of the goals set for the organization, then efficiency is the assessment of the costs of obtaining specific results (Kulagin, 2011; Kulagin, 2018; Fedotov, 2012).

In this regard, according to this criterion, it is possible to distinguish country characteristics in the system of evaluation of scientific institutions. For example, in the United States, the object of evaluation is not the scientific organizations, but federal programs, which that are implemented by federal agencies and departments that receive budget funds (federal research laboratories and research centers). Under current legislation state auditing services (The Office of Management and Administration of the Executive Office of the President of the United States, the United States Audit Office, and others) evaluate the strategic plans of a research institution, including the availability of the necessary resources, i.e. the human, information, capital costs, skills and technologies which are needed to achieve goals and objectives specified in the plans. Thus, officials determine the effectiveness of the implementation of programs in order to determine the amount of their further financial support, including their elimination if the goals are not achieved within three years.

An integrated approach is used in Russia to assess the performance of scientific organizations. According to Decree of the Government of the Russian Federation No. 312 of April 8, 2009, the assessment of the performance of scientific organizations is based on the scientometric approach, as well as expert assessment of the main results of the activities of scientific organizations. At the same time, an analysis is made of scientific organization’s dynamics of activities results in relation to the dynamics of the performance of organizations in the reference group. Scientific organizations are ranked according to the following scale based on the results of the assessment:

– First category - leading research organizations;
– Second category - scientific organizations that have reached stable pattern in their development goals and provide a satisfactory level of outcomes;
– Third category - scientific establishments that cannot be attributed to the research organizations due the lack of R&D activities and have no prospects for development.

The results of the evaluation are used to make management decisions in the field of science, including the development of programs for the development of leading scientific organizations, determining the amount of financial support for activities and development, optimization and development of a network of scientific organizations including the elimination of scientific establishments that cannot be attributed to the research organizations.

In this regard, the viability of a scientific organization depends on the effectiveness of its work. Accordingly, the analysis of factors that has a direct impact on the ability of a scientific organization to generate knowledge and get concrete results on the results of R&D projects, allows to use this information in management activities for the internal organization of a scientific institution’s work, as well as the development of relationships with partners and stakeholders, including public sector of science financing.

Literature review

An analysis of the scientific literature on the stated research topic showed a wide range of papers on the study of individual performance factors of scientific institutions. For example, in the framework of the concept of Creative Knowledge Environments, factors of the meso and macro levels are considered that has a positive impact on employees engaged in R&D both individually and as part of research teams of research organizations in their activities aimed at generating of new knowledge and creating innovation. At the same time, the authors of the concept include the scope of research, human capital, physical infrastructure of research, management system, as well as the external environment, including regional, national and cultural characteristics, as the main characteristics of the knowledge environment (Hemlin et al., 2008).

Certain characteristics of the creative knowledge environment were studied in more detail in the works of a number of authors. In particular, it was found that the individual components of the employee’s physical environment, for example, the nature of lighting, acoustics, the layout of the room, the use of natural materials in its decoration (Organizational behaviour and the physical environment, 2020), and other components that characterize the workplace, must meet the social and psychological preferences of workers to unleash their creative potential (Bryant, 2012). In addition, among the important parameters affecting the process of generating knowledge and creativity, there are nature of the problem being solved (routine, complex, simple, with uncertain goals, etc.), parameters of the scientific team, including conflicts, as well as temporary expenses (Girdauskiene & Savaneviciene, 2015).

A separate study was devoted to investigating the influence of the researcher's experience, expressed in the number of published publications, as well as the academic environment, that is, the researcher’s belonging to a scientific institution, on the research quality, which was measured by the number of citations. The authors concluded that both factors - the researcher’s experience and their affiliation affect the citation rates. At the same time, the researcher’s experience is crucial (Hanssen et al., 2018).

Scientific productivity, measured by such a scientometric indicator as the Hirsch index, also depends on the involvement of a particular researcher and his position in research collaborations. In this case, the citation indicators of works of a particular researcher are the higher, the more interdisciplinary the academic network will be (Contandriopoulos et al., 2018).

As shown by the results of research conducted based on an analysis of the publication rate of researchers at Norwegian universities, scientific performance depends on the academic position. At the same time, no statistically significant correlations were found between the number of publications, as well as the age and sex of the researcher (Rørstad & Aksnes, 2015).

During studying the issue of academic research efficiency, the DEA (Data Envelopment Analysis) method is used. The method allows, based on data set on the activities of organizations, to construct the boundaries of its production capabilities and assess the technical effectiveness of the activities of Decision Making Units (DMU) (Agile approaches for successfully managing and executing projects in the fourth industrial revolution, 2019). As a result, the assessment of an organization effectiveness is the relative distance in the cost space of resources or production output from the point characterizing the results achieved by the organization to the corresponding part of the graph of the piecewise linear function that displays the limits of production capabilities.

Thus, using the DEA method in analyzing technical efficiency of 102 articles, the authors concluded that the number of indicators that has a positive correlation with academic research efficiency should include the work experience and composition of employees of a research organization, institutional factors, size of organization, financial structure and scientific meritocracy (Rhaiem, 2017).

Thus, the main part of research is devoted to the study of human capital factors, the influence of microenvironment on the performance and effectiveness of scientific organizations. At the same time, there is a lack of research on the problems of the influence of meso-level factors, that is, the regional scientific environment on scientific productivity.

Despite the fact that in recent years the number of publications related to the use of the concept "research environment" has demonstrated the steady growth, the term "regional scientific environment" has not been reflected yet in the scientific literature (figure 1).

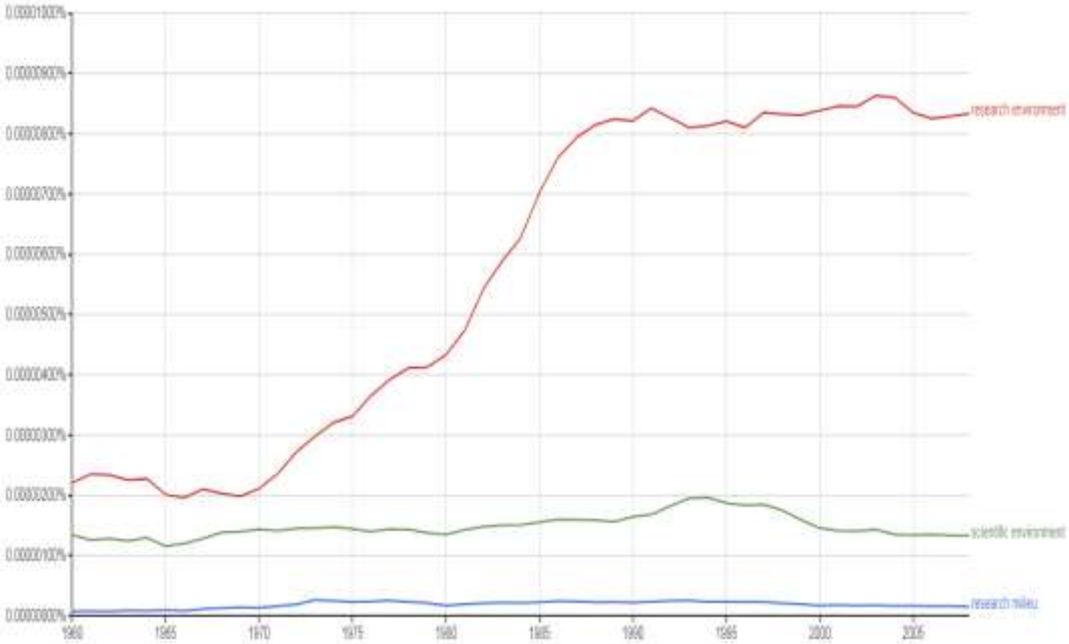

Figure 1. Graph of the frequency of language units - research milieu, research environment, scientific environment, built by the google books Ngram viewer online service for the period from 1960 to 2008.

Thus, the present study is intended to fill this gap in scientific research.

Methodology

As part of the study, the authors identified 47 analytical indicators that characterized the availability and level of development of a research support system in the region, including infrastructure, financial support for science, human capital, research management, etc.

The indicators used to assess the regional environment were divided into groups: "Conditions for involving young people in science and popularizing a research career" (Akhilesh, 2014; Leonidova et al., 2016), "The set of material, technical and financial conditions for the development of scientific activity" (Leonidova et al., 2016; Dranev et al, 2018; Best Practices in Assessment of Research and Development Organizations, 2012), "Conditions for communication and collaboration between researchers, commercialization of research and development" (Roesler & Broekel, 2017; Martinez-Noya & Rajneesh, 2018), "Effective system of management and coordination of scientific activities in the region" (OECD, 2011; Zhang et al., 2016) and "Conditions for the integration of Russian science into international space" (Lewandowska & Stopa, 2018;Fitjar & Rodríguez-Pose, 2015), and are listed in the table l.

The dependent variable was a category to which a scientific organization is assigned in accordance with the results of monitoring the performance of scientific organizations performing research, development and technological works for civil purposes in accordance with the data of the Federal Monitoring System of Scientific Organizations (FMSSO). The sample includes 541 organizations that have been assessed by the FMSSO. The number of regions in which scientific organizations are geographically located has been rated as 65.

For the convenience of interpreting the results, the categories of organizations were inverted (3 - the highest category, 1 - the lowest one). The calculation of the average category of organizations by region was made using the following formula:

$$x_{reg} = \frac{\sum_{reg}(x_i \cdot s_i)}{s_{reg}},$$

where x_i - the category of the i-th organization in the region, s_i - the number of employees of the i-th organization, s_{reg} - the total number of employees for all scientific organizations in the region, x_{reg} - the average category of scientific organizations in the region, summation was performed for all scientific organizations in the region.

The weighted average indicator provides comparability of data regarding the number of their staff (Table 1).

Table 1. Indicators of the regional scientific environment

Indicator	Identification
Conditions for promoting the involvement of young people in science and raising awareness of science careers	
Number of created children's technoparks Kvantorium	x1
Number of established Centers for Youth Innovation Creativity	x2
Number of types of regional awards in science	x3
Number of types of individual scholarships for regional researchers	x4
Number of types of regional scholarships and competitions for young scientists	x5
Grade point average of Unified State Exam passed by school leavers who are accepted to state-funded places in regional higher educational establishments	x6
Average annual number of winners of the all-Russian schoolchildren's competition per 1000 high school grads	x7
Number of grantees and holders of the scholarships of the President of the Russian Federation for young scientists per 100 researchers with an academic degree	x8
Number of graduate students and doctoral candidates per 10,000 persons of the population	x9
A set of logistical, technical and financial resources to promote knowledge generation	
Number of established engineering centers per 1,000 research and development organizations	x10
Number of established centers for collective use of scientific equipment per 1, 000 research and development organizations	x11
Number of unique scientific installations per 10,000 researchers	x12
Availability of project competition in the field of basic scientific research administered by Russian Foundation for Basic Research (RFBR) in conjunction with the authorities of the entities of the Russian Federation	x13
Availability of regional funds to support research activities	x14
Amount of regional funds budgeted for fundamental and applied research per one researcher, thousand rubles	x15
The proportion of the region’s budget, provided for supporting of program activities for the development of scientific activity and the conducting of basic and applied scientific research, %	x16
The proportion of the budget of the Russian Federation’s subject and local budgets in financing domestic expenditures on R&D, %	x17
The number of winners of the competitions of the Russian Science Foundation per 100 organizations engaged in R&D	x18

The number of winners of the Federal Targeted Program "Research and Development" per 100 organizations engaged in R&D	x19
Internal costs of research and development on average per 1000 organizations, thousand rubles	x20
Number of advanced production technologies created (developed) by subjects of the Russian Federation per 100 organizations engaged in R&D	x21
Conditions for communications and collaborations between researchers, commercialization of research and development	
Number of created clusters per 1000 organizations engaged in R&D	x22
Number of created technology parks per 10,000 researchers	x23
Innovative activity of organizations	x24
Number of created small innovative enterprises per 100 organizations engaged in R&D	x25
Number of winners of the mega-grants program per 1000 organizations engaged in R&D	x26
The number of winners of the competition for the development of cooperation of Russian universities, research institutions and manufacturing enterprises, per 1000 organizations engaged in R&D	x27
Indicator of the number of potentially commercialized patents per 1000 researchers	x28
Effective management and coordination system of scientific activities in the region	
The presence of subdivision responsible for scientific activities in the structure of the region executive authorities	x29
The presence of a coordinating structure (council) for scientific activities	x30
The presence of the actual regulatory legal act on scientific activities	x31
The number of state programs in the region, including the main activities to support scientific research	x32
The presence of the vector of scientific and technological development for the purposes and objectives of the strategy of socio-economic development	x33
Participation in the development and testing of the regional model of the National Technology Initiative	x34
The number of personnel engaged in R&D per 10,000 population	x35
Average salary in the research and development sector, thousand rubles	x36
The number of high-performance jobs created in the research and development sector, in the total number of high-performance jobs in the region, %	x37
Conditions for the integration of Russian science into the international space	
The number of foreign scientists working in scientific organizations and universities of the region per 100 organizations engaged in R&D	x38
The number of regional universities, participants of "5-100" project	x39
The number of researchers assigned to work in leading Russian and international scientific and scientific-educational organizations per 100 researchers	x40
The number of created results of intellectual activity having legal protection outside the Russian Federation for 10,000 researchers	x41
Cumulative number of publications in the Scopus database per 100 people engaged in R&D	x42
Cumulative number of publications in the Web of Science database per 100 people engaged in R&D	x43
Cumulative citation of publications in the Web of Science database per 1 organization engaged in R&D	x44
Cumulative citation of publications in the Scopus database per 1 organization engaged in R&D	x45
The number of articles prepared jointly with foreign organizations, per 1 organization engaged in R&D	x46
The number of agreements on the export of technology and technical services per 100 organization engaged in R&D	x47
Dependent variable	
Category of scientific organizations in the region	y

As part of the study it was hypothesized that there are statistically significant associations between factors determining the regional scientific environment and the performance of scientific organizations in each individual region.

Multicollinear variables from the original regression model were excluded based on calculating the factors of inflation variance (VIF) and removing the variables with a high degree of correlation. The final variables of their VIF are shown in Table 2.

Table 2. Variables of the final model

Indicator	VIF	Indicator	VIF	Indicator	VIF
x1	1,95	x15	4,85	x30	1,93
x3	1,50	x16	3,54	x31	2,62
x4	2,35	x17	4,71	x32	3,28
x5	3,35	x20	3,90	x33	2,58
x6	4,75	x21	2,46	x34	2,53
x7	4,96	x22	2,13	x36	2,71
x8	2,74	x23	1,72	x38	3,06
x10	3,07	x24	3,51	x40	3,59
x11	2,96	x25	3,40	x41	2,29
x12	4,02	x27	3,09	x43	4,82
x13	2,08	x28	4,04	x46	4,59
x14	4,41	x29	1,96	x47	3,30

Thus, in order to eliminate the mistake of the researcher based on identifying the factors of inflation variance, the following variables were excluded from the model:

- Number of established Centers for Youth Innovation Creativity
- Number of graduate students and doctoral candidates per 10,000 persons of the population
- The number of winners of the competitions of the Russian Science Foundation per 100 organizations engaged in R&D
- The number of winners of the Federal Targeted Program "Research and Development" per 100 organizations engaged in R&D
- Number of winners of the mega-grants program per 1000 organizations engaged in R&D
- The number of personnel engaged in R&D per 10,000 population
- The number of high-performance jobs created in the research and development sector, in the total number of high-performance jobs in the region,%
- The number of regional universities, participants of "5-100" project
- Cumulative number of publications in the Scopus database per 100 people engaged in R&D
- Cumulative citation of publications in the Web of Science database per 1 organization engaged in R&D
- Cumulative citation of publications in the Scopus database per 1 organization engaged in R&D

The regression model includes all available indicators and can be written as $y = \sum_i a_i \times x_i$. The model is statistically significant ($F = 2.391$, $p = 0.009$), с $R^2=0.755$ и $R^2adj = 0.439$ (R^2adj – adjusted coefficient of determination).

Results

The idea of comparing regions according to the degree of influence of the regional environment is that if you remove a certain region from the source data, resulting during the calculation of the model will increase or decrease, which can be interpreted as a result of a higher or lower influence of the regional environment on the performance of scientific organizations compared to average for Russia. As a result, you can make a ranking according to the degree of influence of individual regions (figure 2).

Figure 2. Ranking Regions According to the Regional Environment Impact Factor

Thus, the regression models for all regions turned out to be acceptable, that is, in most cases, changes in the identified indicators lead to a change in the resulting variable, described on an ordinal scale from 3 to 1 and normalized by the number of employees. The study showed that there were no significant differences between regions when comparing factors determining the regional scientific environment and the performance of scientific organizations. With the exception of Moscow and St. Petersburg, the difference between the other subjects of the Russian Federation on the impact of a set of indicators of the regional scientific environment was not statistically significant. Consequently, the hypothesis of the presence of statistically significant links, indicating the influence in each individual region of the regional scientific environment factors on the performance of scientific organizations, is rejected.

The possible reason for the study's result is also in the selected study objects, which are the research organizations financed from the federal budget. In this regard, the impact of regional factors on the performance of these organizations was not so significant.

Conclusions

Based on the study results, we can conclude that the system of management and support of budget research organizations at the regional level as a whole does not has a significant impact on the scientific productivity of organizations. Under the conditions of subsidization of most regions and dependence on interbudgetary transfers, regional funding opportunities for scientific research are extremely limited. This, in turn, leads to certain difficulties in the formation of research topics by scientific organizations that would be of interest to the regional community and authorities.

Federal funds supporting science, federal agencies acting in the role of customers for research establish criteria for the performance of conducted research based on, above all, scientometric indicators, including the citation of publications. In this regard, regional studies focused on a narrow circle of specialists, cannot attract wide attention of the scientific community to the conclusions obtained as a result of conducting scientific research.

The above allows us to talk about the need to weaken centralization in the science support system, develop and conduct a unified federal-regional science policy and tools for its implementation through the formation of regional funds for scientific and technological development, the formation and implementation of republican and regional science and technology programs and innovative projects funded from local budget and regional extra-budgetary funds, the formation of a local system of tax incentives for scientific institutions, etc.

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