DETERMINATION OF DEGREE OF THE INFLUENCE OF THE REGIONAL SCIENTIFIC ENVIRONMENT ON THE PERFORMANCE OF SCIENTIFIC ORGANIZATIONS

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Abstract

The article analyzes the influence of various factors of the regional scientific environment on the performance of scientific organizations. 541 research institutions located on the territory of 65 Russian Federation' subjects were selected as the study's object. The study used the statistical data of the Federal Monitoring System of Scientific Organizations (FMSSO), Federal State Statistics Service, the Ministry of Justice and other open sources. The indicators proposed in the methodology of the FMSSO were used as indexes of scientific organizations performance. According the methodology three types of scientific organizations were distinguished - scientific organizations-leaders; stable scientific organizations that demonstrate satisfactory performance; and scientific organizations that have lost their scientific profile and development prospects. Data analysis showed that performance of scientific organizations is greatly influenced by such factors as a set of material, technical and financial conditions of the development of scientific activity.

Keywords: regional scientific environment, scientific organization, factor analysis, performance of scientific activity

JEL classification: R19

1. Introduction

The development of the national scientific and technological complex, the systematic creation and introduction of new knowledge and technologies in modern conditions are a necessary factor in the socio-economic development of the regions. In addition, the current foreign policy situation has escalated the need to ensure Russia's technological independence. In this context the development of science and technology, increasing the socio-economic importance of research, scientific, technical and innovation activities became a particular relevant.

Only through the organization of effective public administration in the scientific and technical sphere, including at the level of the Russian Federation' subjects, the conditions for carrying out fundamental scientific studies, scientific and technical activities and translating their results into an innovative product can be created (Lepskiy, 2018).

The support ways of the science field at the regional level are varied - the popularization of science among young people, the financing of scientific research, the coordination of scientific activities, etc.

Thus, one of the support way of scientific and technological development at the regional level is the promotion of various forms of intellectual integration (Maltseva, 2014). Currently in the regions there are a large number of educational and scientific collaborations of various sizes, the number of organizations and research topics (Maltseva, et al., 2015).

Under the new conditions, some regions are actively switching to a new model of organizing and supporting science and technology, including through the harmonization of institutions and the effective adaptation of best international practices to regional conditions.

In this regard, the purpose of this article is to identify the factors of a regional scientific environment that influence the development of scientific organizations based on the analysis of empirical data. At the same time, scientific organizations are institutions for which research is the main activity.

2. Literature background

This article analyzes the impact of various exogenous factors on the performance of scientific organizations, including the training of personnel reserve, the infrastructure basis for research, the organization of interaction with external stakeholders, including government bodies, etc.

The authors were guided by a systematic approach for solving research problems in the framework of this article. Within this approach a scientific organization is viewed not in isolation, but in interaction with the external environment, serving, on the one hand, as a source of resources, including personnel, and, on the other hand, serving as the sphere of application of the results of activities in the form of goods and services.

The concept of Bronfenbrenner's ecological systems (2009) which allows to describe the systemic nature of the mutual influence of various environmental factors can serve as the conceptual basis of the article. By interpreting this theory into the development of a scientific organization, it can be argued that a regional scientific environment is a mesosystem which includes various elements, among them objects of regional innovation infrastructure, for example, technology parks, youth innovation technology centers, engineering centers, etc., influence development and performance of a scientific organization.

At the same time, the article did not set out the task to identify and determine the degree of influence of the macrosystem factors, for example, national science and technology policy, federal centers of science support, etc., on the performance of scientific institutions. Determining the nature, direction of interaction of various factors of micro, meso and macrosystems is a promising research task that has to be solved in the future.

It is possible to identify several hypotheses about the influence of various factors of the regional environment on the performance of scientific organizations based on the analysis of the literature:

Hypothesis 1. The performance of scientific organizations is influenced by the conditions for promoting the involvement of young people in science and raising awareness of science careers.

Knowledge is one of the main products of research organizations. Accordingly, the mission of scientific institutions is to disseminate knowledge through publications, as well as, in some cases, to commercialize the results of applied research. In this regard, the ability to generate knowledge becomes the main competitive advantage of scientific institutions. The search for talents, that is, people who possess a certain set of competencies and are capable of generating new knowledge has the particular importance for research organizations (Akhilesh, 2014).

Numerous studies proves the need to attract young people to science and innovation. At the same time, an increase of the number of young people who have opted for a career in STEM areas is considered not only as a factor of growing the country's competitiveness, strengthening its technological leadership (Promising practices for strengthening the regional STEM workforce development ecosystem, 2016), but also as an important resource of region's modernization (Leonidova et al., 2016).

Hypothesis 2. The performance of scientific organizations is influenced by the set of material, technical and financial conditions of the scientific activity development.

In addition to human capital, an important resource necessary for the scientific organization to implement its mission is the availability of funds and the material conditions of research, including equipment (Best Practices in Assessment of Research and Development Organizations, 2012).

The amount of R&D expenditures in both absolute and relative terms (for example, R&D/GDP intensity) is an indicator that characterizes the level of science support at the national and regional levels by various sectors of the economy and is reflected in the documents of strategic development of territories, countries and supranational entities (for example, the most well-known is the goal of the European Union, which implies an increase in total investment in R&D to 3% of GDP by 2020 (Communication from the commission. Europe 2020. A strategy for smart, sustainable and inclusive growth, 2010)). In the researchers, conducted on the basis of cross-country analysis, a close relationship was found out between the performance of the applied research sector, the amount of its targeted financing and the growth of the economy in individual sectors (Dranev et al., 2018).

At the same time, studies show that the performance of scientific organizations (in terms of scientometric indicators) is influenced not only by the amount of funding, but also by its source (Coccia et al., 2015). Moreover, business-supported think-tanks are widely used in Western countries, which in some cases act as lobbyists, conducting research and in their interests (Kotler, 2017).

Hypothesis 3. The performance of research organizations is influenced by the conditions for communication and collaboration between researchers, the commercialization of research and development.

The process of transferring the knowledge gained by scientific organizations to the private sector of the economy is carried out, as is the case with universities (Roesler and Broekel, 2017) through the creation of small innovative enterprises, performing contract R&D, the conducting joint research projects with enterprises, the transferring of intellectual property and the assignment of rights to their use, etc. (De Fuentes and Dutrenit, 2012). At the same time, researchers proved that collaborations between academic institutions and enterprises has a positive impact on the innovative activities of companies that specialize in product and process innovations (Pippel and Seefeld, 2016). An important role in the development of cooperation is also played by the geographical proximity of partner organizations. It has been found out that the company's choice in favor of a nearby partner organization allows an enterprise to reduce the risks associated with evaluating partner resources and ensuring control over the progress of work during the implementation of joint projects (Martinez-Noya, and Narula, 2018). Thus, the presence of such channels for the scientific organizations' knowledge transfer to the real economy sector as clusters, technology parks, small innovative enterprises has an impact on the performance of research institutions.

Hypothesis 4. The performance of scientific organizations is influenced by the system of management and coordination of scientific activities in the region.

The state's role in scientific and technological development is not limited to issues of research funding, determining its priority areas, but also includes policies aimed at increasing the prestige of scientific professions, developing the mechanisms for transferring knowledge and technology from the public to the private sector, etc. Using the example of analyzing the effectiveness of biotechnological projects, including those ones that were performed on the budget funds, it was shown that in Korea, public research institutions were ahead of research and development organizations in scientometric indicators (Park and Shin, 2018). In addition, Chinese researchers have identified the positive influence of state science and technology policy on the development of collaborations between government research institutions, universities and enterprises (Zhang, et al., 2016). At the same time, the role of regional authorities, according to researchers, is to create conditions for the development of the economy on an innovative basis, including using the potential of research institutions (Lewandowska and Stopa, 2018). In this regard, the policy of regional authorities to create mechanisms to support researchers is considered as a factor of improving the performance of scientific organizations.

Hypothesis 5. The performance of scientific organizations is influenced by the conditions for the integration of Russian science into international space.

Currently, the concept of local buzz and global pipelines (Bathelt, et al., 2004) is widely used in scientific literature. According to the concept, the exchange of knowledge between organizations located in a certain area (local buzz) leads to the development of technology in the case when these regional networks are the part of global pipelines. In recent years, this concept has been revised to reflect country specifics. So, based on empirical data, it was shown that the development of regional cooperation is influenced by investment in R&D while international cooperation depends largely on the availability of skilled labor (Fitjar and Rodriguez-Pose, 2015). Thus, it can be assumed that there is a feedback between the performance of scientific organizations and the conditions for the integration of Russian science into international space.

3. Results

We made the regression analysis using the R package to assess the impact of the regional scientific environment on the performance of scientific organizations.

For the regional environment, the indicators, that are its components, were divided into groups: “Conditions for promoting the involvement of young people in science and raising awareness of science careers”, “A set of logistical, technical and financial resources to promote knowledge generation”, “Conditions for communications and collaborations between researchers, commercialization of R&D”, “Effective system of management and coordination of scientific activities in the region” and “Conditions for the integration of Russian science into international space”. Used indicators are given in table. 1. Regression analysis was made separately for each group in order to identify the factors that has the greatest impact.

The dependent variable was a category of scientific organization 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 FMSSO(Minutes of the meeting from 03.22.2018of the Interdepartmental Commission for the Evaluation of the Performance of Scientific Organizations performing research, development and technological works for civil purposes). The sample includes 541 organizations that received the FMSSO rating. The number of regions where scientific organizations are geographically located and has been rated is 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.

The variables that are used as the basis for building models and are indicators included in the assessment system of the regional scientific environment are below (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 R&D	
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

Source: Authors' calculations

Within the framework of the study, it is proposed to use regression analysis, for which additive multiple regression models are used:

(1)y=a1*x1+a2*x2+a3*x3+a4*x4+a5*x5+a6*x6+a7*x7+a8*x8+a9*x9+C1

(2)y=a10*x10+a11*x11+a12*x12+a13*x13+a14*x14+a15*x15+a16*x16+a17*x17+a18*x18+a19*x19+a20*x20+a21*x21+C2

(3)y=a22*x22+a23*x23+a24*x24+a25*x25+a26*x26+a27*x27+a28*x28+C3

(4)y=a29*x29+a30*x30+a31*x31+a32*x32+a33*x33+a34*x34+a35*x35+a36*x36+a37*x37+C4

(5)y=a38*x38+a39*x39+a40*x40+a41*x41+a42*x42+a43*x43+a44*x44+a45*x45+a46*x46+a47*x47+C5

To eliminate the problems associated with the possible multicollinearity of variables in regression models, the variance inflation factors (VIF) were calculated (Table 2).

Table 2. - The results of multicollinearity test for models

Indicator	VIF	Indicator	VIF	Indicator	VIF	Indicator	VIF	Indicator	VIF
x1	1,24	x10	1,48	x22	1,22	x29	1,14	x38	1,68
x2	2,24	x11	1,52	x23	1,20	x30	1,12	x39	1,31
x3	1,04	x12	1,08	x24	1,27	x31	1,31	x40	1,92
x4	1,14	x13	1,14	x25	1,29	x32	1,52	x41	1,05
x5	1,41	x14	1,89	x26	1,26	x33	1,16	x42	7,19
x6	1,99	x15	3,62	x27	1,25	x34	1,77	x43	9,26
x7	2,47	x16	1,92	x28	1,07	x35	6,73	x44	27,18
x8	1,25	x17	3,98			x36	1,53	x45	26,21
x9	2,16	x18	3,32			x37	6,12	x46	3,34
		x19	3,89					x47	1,92
		x20	1,74						
		x21	1,17						

Source: Authors' calculations

As the table show, most of the variables have the value VIF<5 and, therefore, does not have a linear relationship between themselves. The only exceptions are x35 and x37 for the fourth and x42, x43, x44, x45 for the fifth models. This requires the elimination of variables with a high degree of correlation.

To determine the excluded variable in the fourth model, a correlation matrix was built, table 3.

Table 3. - Correlation matrix for the fourth model

	x29	x30	x31	x32	x33	x34	x35	x36	x37
x29	1,000	-0,044	0,282	0,011	0,082	0,152	0,056	0,049	0,107
x30	-0,044	1,000	0,162	0,203	-0,010	0,040	0,174	-0,021	0,105
x31	0,282	0,162	1,000	0,327	0,182	0,109	0,263	0,244	0,208
x32	0,011	0,203	0,327	1,000	0,106	0,220	0,473	0,365	0,304
x33	0,082	-0,010	0,182	0,106	1,000	0,066	0,180	0,005	0,051
x34	0,152	0,040	0,109	0,220	0,066	1,000	0,547	0,300	0,645
x35	0,056	0,174	0,263	0,473	0,180	0,547	1,000	0,531	0,878
x36	0,049	-0,021	0,244	0,365	0,005	0,300	0,531	1,000	0,432
x37	0,107	0,105	0,208	0,304	0,051	0,645	0,878	0,432	1,000

Source: Authors' calculations

Since the x35 variable has higher correlation coefficients with other variables than x37, than x35 variable is excluded from the final equation. The final multicollinearity test, demonstrating the compliance of all indicators with the VIF<5 criterion, is presented in the Table 4.

Table 4. - The results of multicollinearity test for the fourth model

Indicator	x29	x30	x31	x32	x33	x34	x36	x37
VIF	1,13	1,09	1,31	1,33	1,05	1,75	1,38	1,98

Source: Authors' calculations

Thus, the final version for the fourth model is:

(4) y=a29*x29+a30*x30+a31*x31+a32*x32+a33*x33+a34*x34+a36*x36+ +a37*x37+C4

Similarly, the correlation matrix for the fifth model is given in the Table 5.

Table 5. Correlation matrix for the fifth model

	x38	**x39**	**x40**	**x41**	**x42**	**x43**	**x44**	**x45**	**x46**	**x47**
x38	1,000	0,224	0,426	0,066	0,318	0,388	0,438	0,454	0,497	0,380
x39	0,224	1,000	-0,019	-0,013	-0,015	0,039	0,424	0,407	0,416	0,331
x40	0,426	-0,019	1,000	-0,027	0,442	0,559	0,291	0,319	0,201	-0,013
x41	0,066	-0,013	-0,027	1,000	0,016	-0,040	-0,054	-0,043	-0,043	-0,091
x42	0,318	-0,015	0,442	0,016	1,000	0,911	0,304	0,319	0,258	0,118
x43	0,388	0,039	0,559	-0,040	0,911	1,000	0,437	0,429	0,376	0,150
x44	0,438	0,424	0,291	-0,054	0,304	0,437	1,000	0,976	0,798	0,526
x45	0,454	0,407	0,319	-0,043	0,319	0,429	0,976	1,000	0,781	0,566
x46	0,497	0,416	0,201	-0,043	0,258	0,376	0,798	0,781	1,000	0,581
x47	0,380	0,331	-0,013	-0,091	0,118	0,150	0,526	0,566	0,581	1,000

Source: Authors' calculations

Studying these tables data, you can see that the number of publications strongly correlates with the number of citations in the corresponding citation systems (x42-x43 and x44-x45 pairs). At the same time, x43 (the number of WoS publications) and x44 (aggregate citation in WoS) have the greatest correlation with other indicators. Thus, in the final scorecard there are indicators of the number of publications of citations in the Scopus database.

The test for multicollinearity is presented in the table 6.

Table 6. - The test results for multicollinearity for the fifth model

Indicator	x38	x39	x40	x41	x42	x45	x46	x47
VIF	1,68	1,30	1,61	1,03	1,33	3,12	3,00	1,79

Source: Authors' calculations

The remaining indicators in the fifth model have VIF<5 and, therefore, are not multicollinear. Thus, the final version for the fifth model is:

(5) y=a38*x38+a39*x39+a40*x40+a41*x41+a42*x42+a45*x45+a46*x46+
+a47*x47+C5

The results of the regression analysis of each of the above models using the basic function lm of the statistical package R are below.

1. Model of the dependence of the performance of scientific organizations in the region on the conditions for promoting the involvement of young people in science and raising awareness of science careers:

```
lm(formula = y ~ x1…x9, data = ModelData1)

Residuals:
    Min       1Q   Median       3Q      Max
-0.97292 -0.34263  0.06938  0.34388  1.24271

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.339682   1.068425   0.318   0.7517
x1          -0.087490   0.096221  -0.909   0.3672
x2           0.002562   0.018530   0.138   0.8906
x3           0.129381   0.056203   2.302   0.0251 *
x4           0.031596   0.031551   1.001   0.3210
x5           0.029198   0.051174   0.571   0.5706
x6           0.017524   0.018167   0.965   0.3389
x7           0.021016   0.059634   0.352   0.7259
x8           0.005122   0.010298   0.497   0.6209
x9           0.020230   0.023052   0.878   0.3840
---
```

```
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.5207 on 55 degrees of freedom
Multiple R-squared:  0.261,   Adjusted R-squared:  0.1401
F-statistic: 2.158 on 9 and 55 DF,  p-value: 0.03945
```

From the presented listing it is clear that the model explains only 26.1% of the total number of factors affecting the performance of scientific organizations. The model itself, according to the Fisher criterion, describes the available data well (F = 2.158, p = 0.039), but most of the variables are not significant (p> 0.05). The only significant variable is x3 (“Number of types of regional awards in science”). It can be concluded that the factor “Conditions for promoting the involvement of young people in science and raising awareness of science careers” has a weak influence on the performance of scientific organizations. Therefore, hypothesis 1 is rejected.

(1) y=0.087*x1-0.003*x2-0.129*x3-0.032*x4-0.029*x5-0.018*x6--0.021*x7-0.005*x8-0.020*x9+3.660

2. Model of the dependence of the performance of scientific organizations in the region from the set of logistical, technical and financial resources to promote knowledge generation

```
lm(formula = y ~ x10…x21, data = ModelData2)

Residuals:
    Min       1Q   Median       3Q      Max
-0.82974 -0.22027  0.01336  0.26398  0.97994

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.841e+00  1.434e-01  12.839   <2e-16 ***
x10         -6.046e-03  2.872e-03  -2.105   0.0402 *
x11          4.376e-04  6.352e-04   0.689   0.4939
x12          9.549e-03  4.092e-03   2.334   0.0235 *
x13         -2.425e-01  1.183e-01  -2.050   0.0454 *
x14         -7.112e-02  9.228e-02  -0.771   0.4443
x15         -1.796e-03  2.176e-03  -0.825   0.4130
x16          4.707e+00  4.115e+01   0.114   0.9094
x17         -7.775e-03  1.231e-02  -0.631   0.5305
x18          1.968e-03  1.383e-03   1.423   0.1608
x19          2.800e-03  3.191e-03   0.877   0.3844
x20          3.538e-07  5.911e-07   0.599   0.5520
x21         -1.438e-04  8.374e-04  -0.172   0.8643
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.446 on 52 degrees of freedom
Multiple R-squared:  0.4874, Adjusted R-squared:  0.3691
F-statistic:  4.12 on 12 and 52 DF,  p-value: 0.000163
```

Dependent variables explain 48.7% of the performance assessment in the total number of factors, the model describes the available data well (F = 4.12, $p = 1 *10^{-4}$). Significant variables are only x10 (Number of established engineering centers per 1,000 research and development organizations), x12 (Number of unique scientific installations per 10,000 researchers) and x13 (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). Thus, the logistical, technical and financial resources to promote knowledge generationis significantly affects the performance of scientific organizations. Therefore, hypothesis 2 is accepted.

(2) y=0.006*x10-0.0004*x11-0.009*x12+0.243*x13+0.071*x14+
+0.002*x15-4.707*x16+0.008*x17-0.002*x18-0.003*x19-
-3*10^{-7}*x20+0.0001*x21+2.159

3. Conditions for communications and collaborations between researchers, commercialization of research and development

```
lm(formula = y ~ x22…x28, data = ModelData3)

Residuals:
    Min       1Q   Median       3Q      Max 
-0.91347 -0.26247  0.09008  0.31516  1.21090 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)    
(Intercept)  1.8032019  0.1920636   9.389  3.6e-13 ***
x22          0.0004469  0.0011926   0.375   0.7093    
x23         -0.0108368  0.0091063  -1.190   0.2390    
x24          0.0069314  0.0186196   0.372   0.7111    
x25         -0.0009898  0.0014439  -0.685   0.4958    
x26          0.0037379  0.0016080   2.324   0.0237 *  
x27          0.0003517  0.0010418   0.338   0.7369    
x28         -0.0009293  0.0088073  -0.106   0.9163    
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.5423 on 57 degrees of freedom
Multiple R-squared:  0.1693, Adjusted R-squared:  0.06725 
F-statistic: 1.659 on 7 and 57 DF,  p-value: 0.1377
```

The impact of the conditions for communications and collaborations between researchers, the commercialization of research and development on performance is very weak (16.9%). The model is not statistically significant (F = 1.659, p = 0.14). The only significant variable is x26 (Number of winners of the mega-grants program per 1000 organizations engaged in R&D). It can be concluded that the factor “Conditions for communications and collaborations between researchers, the commercialization of research and development” does not have a significant impact on the performance of scientific organizations. Therefore, hypothesis 3 is rejected.

(3)y=-0.0004*x22+0.011*x23-0.007*x24+0.001*x25-0.004*x26-
0.0004*x27+0.001*x28+2.197

4. Effective management system and coordination of scientific activities in the region

```
lm(formula = y ~ x29…x37, data = ModelData4)

Residuals:
    Min       1Q   Median       3Q      Max 
-0.97739 -0.23516  0.07575  0.31220  1.23108 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)    
(Intercept)  1.6895695  0.2820674   5.990 1.58e-07 ***
x29         -0.1089097  0.1563081  -0.697   0.4888    
x30         -0.0211853  0.1799795  -0.118   0.9067    
x31         -0.0369386  0.1555543  -0.237   0.8132    
x32          0.0742386  0.0536846   1.383   0.1722    
x33          0.2793225  0.1464072   1.908   0.0615 .  
x34         -0.0405645  0.2214751  -0.183   0.8553    
x36         -0.0005732  0.0049357  -0.116   0.9080    
x37          5.8856510  3.5039213   1.680   0.0986 .  
---
```

```
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.5393 on 56 degrees of freedom
Multiple R-squared:  0.1929, Adjusted R-squared:  0.07762
F-statistic: 1.673 on 8 and 56 DF,  p-value: 0.1254
```

The variables explain 19.3% of the performance assessment of the total number of factors affecting the performance. The model is not statistically significant ($F = 1.673$, $p = 0.13$), there are no significant variables. Thus, the factor "Effective management system and coordination of scientific activities in the region" does not have a significant impact on the performance of scientific organizations. Therefore, hypothesis 4 is rejected.

(4) y=0.109*x29+0.021*x30+0.037*x31-0.074*x32-.0279*x33+
+0.041*x34+0.001*x36-5.886*x37+2.310

5. Conditions for the integration of Russian science into the international space

```
lm(formula = y ~ x38…x47, data = ModelData5)

Residuals:
    Min       1Q   Median       3Q      Max
-0.91808 -0.33271  0.07664  0.28793  1.20143

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.6463274  0.1290810  12.754   <2e-16 ***
x38         -0.0002269  0.0006815  -0.333    0.740
x39         -0.0017122  0.1882227  -0.009    0.993
x40         -0.0005626  0.0084120  -0.067    0.947
x41          0.0001461  0.0003717   0.393    0.696
x42          0.0008564  0.0014809   0.578    0.565
x45          0.0002547  0.0002709   0.940    0.351
x46          0.0056119  0.0074619   0.752    0.455
x47          0.0019331  0.0017240   1.121    0.267
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.5329 on 56 degrees of freedom
Multiple R-squared:  0.2119, Adjusted R-squared:  0.09935
F-statistic: 1.882 on 8 and 56 DF,  p-value: 0.08104
```

Conditions for the integration of Russian science into international space explain 21.2% of the performance assessment of the total number of factors, there are no significant factors. The model is not statistically significant ($F = 1.882$, $p = 0.08$). It can be concluded that the factor "Conditions for the integration of Russian science into international space" does not have a significant impact on the effectiveness of scientific organizations. Therefore, hypothesis 5 is rejected.

(5) y=0.0002*x38+0.002*x39+0.001*x40-0.0001*x41-0.001*x42-
-0.0003*x45-0.006*x46-0.002*x47+2.354

Since the total number of factors is very large (47), the building of a generalized model with the aim of highlighting significant factors was made using inverse step-by-step regression. The essence of this method comes down to the fact that initially all the available indicators are included in the model, then at each step an exception or inclusion of one of the previously excluded indicators in the model is made. The indicator is selected based on the Akaike Information Criterion (AIC):

$$AIC = 2K + n[\ln(\hat{\sigma}^2)],$$

where K is the number of model parameters, n is the number of observations, $\hat{\sigma}^2 = \frac{SSE}{n-2}$ is the dispersion of the excesses, SSE is the sum of the squares of the excesses. It is believed that the best model corresponds to the minimum value of the Akaike criterion. The steps are made until the exclusion or addition of the indicator don't stop the decreasing of AIC. The resulting set of indicators is considered optimal. This method is made in the step function of the statistical package R, which was used to calculate the parameters of the model.

Multicollinear variables were excluded from the original model based on the calculation of the variance inflation factors (VIF) by analogy with previous calculations. The final variables of their VIF are shown in the table 7.

Table 7. - Variables of the resulting model

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

Source: Authors' calculations

The execution of the inverse step-by-step regression consisted of 22 steps, on the each of which the effect of excluding or including variables was evaluated. As an example, a part of the listing is given (step 10):

```
Step:  AIC=-110.55
y ~ x1 + x3 + x4 + x5 + x6 + x8 + x10 + x12 + x13 + x14 + x15 +
    x17 + x21 + x22 + x23 + x25 + x27 + x28 + x30 + x31 + x32 +
    x33 + x34 + x36 + x38 + x43 + x46

Df Sum of Sq    RSS      AIC
- x33   1   0.01164 5.0250 -112.398
- x17   1   0.02245 5.0358 -112.258
- x27   1   0.03452 5.0479 -112.103
- x8    1   0.03821 5.0515 -112.055
- x14   1   0.04746 5.0608 -111.936
- x34   1   0.08455 5.0979 -111.461
- x30   1   0.08863 5.1020 -111.409
- x15   1   0.09470 5.1080 -111.332
- x1    1   0.11088 5.1242 -111.127
- x22   1   0.12082 5.1342 -111.001
- x25   1   0.14873 5.1621 -110.648
<none>              5.0133 -110.549
- x31   1   0.16939 5.1827 -110.389
- x5    1   0.17493 5.1883 -110.319
- x38   1   0.17633 5.1897 -110.302
- x46   1   0.19656 5.2099 -110.049
+ x7    1   0.01449 4.9988 -108.737
+ x20   1   0.01397 4.9994 -108.730
```

```
+ x47  1  0.01263 5.0007 -108.713
+ x41  1  0.00215 5.0112 -108.576
+ x24  1  0.00167 5.0117 -108.570
+ x11  1  0.00060 5.0127 -108.556
+ x40  1  0.00042 5.0129 -108.554
+ x29  1  0.00025 5.0131 -108.552
+ x16  1  0.00004 5.0133 -108.549
- x43  1  0.33936 5.3527 -108.291
- x6   1  0.38930 5.4026 -107.687
- x12  1  0.40510 5.4184 -107.498
- x4   1  0.41545 5.4288 -107.374
- x21  1  0.46944 5.4828 -106.730
- x23  1  0.49677 5.5101 -106.407
- x28  1  0.67682 5.6902 -104.317
- x36  1  0.79870 5.8120 -102.940
- x10  1  0.94831 5.9617 -101.288
- x32  1  1.26660 6.2799  -97.907
- x13  1  1.63164 6.6450  -94.234
- x3   1  1.78645 6.7998  -92.737
```

All steps are summarized in the table 8.

Table 8. - Stages of inverse step-by-step regression ("- x29" means elimination of the variable "x29")

Step	Variable	AIC
0		-93.351
1	- x29	-95.351
2	- x40	-97.338
3	- x24	-99.295
4	- x16	-101.231
5	- x11	-103.164
6	- x41	-105.130
7	- x7	-106.979
8	- x48	-108.730
9	- x20	-110.549
10	- x33	-112.398
11	- x17	-114.183
12	- x8	-115.762
13	- x14	-117.102
14	- x34	-118.319
15	- x5	-119.173
16	- x25	-120.176
17	- x30	-121.449
18	- x31	-122.150
19	- x1	-123.029
20	- x22	-123.890
21	- x12	-124.560
22	- x38	-125.525

Source: Authors' calculations

After completing the inverse step-by-step regression, the resulting regression equation was obtained. The calculation of the coefficients and significance of the variables is shown in the following listing:

```
lm(formula = y ~ x3 + x4 + x6 + x10 + x13 + x15 + x21 + x23 +
x27 + x28 + x32 + x36 + x43 + x46, data = ModelData)
```

```
Residuals:
     Min       1Q   Median       3Q      Max
-0.59658 -0.16816 -0.01141  0.19616  0.74936

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.3619723  0.8081056  -0.448  0.65614
x3           0.1617020  0.0394012   4.104  0.00015 ***
x4           0.0450795  0.0210854   2.138  0.03743 *
x6           0.0404422  0.0135979   2.974  0.00451 **
x10         -0.0101984  0.0020693  -4.928 9.51e-06 ***
x13         -0.4873941  0.1021543  -4.771 1.63e-05 ***
x15         -0.0024019  0.0009062  -2.650  0.01074 *
x21         -0.0011036  0.0006362  -1.735  0.08897 .
x23         -0.0099746  0.0057623  -1.731  0.08962 .
x27          0.0011418  0.0006918   1.650  0.10513
x28         -0.0246862  0.0074043  -3.334  0.00162 **
x32          0.0851483  0.0352422   2.416  0.01938 *
x36         -0.0075662  0.0034223  -2.211  0.03165 *
x43          0.0092052  0.0016191   5.685 6.72e-07 ***
x46         -0.0103010  0.0046909  -2.196  0.03276 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.3447 on 50 degrees of freedom
Multiple R-squared:  0.7056, Adjusted R-squared:  0.6232
F-statistic:  8.56 on 14 and 50 DF,  p-value: 5.304e-09
```

The resulting regression equation takes into account 70.56% of all factors affecting the performance of scientific organizations. The model describes the available data well ($F = 8.56$, $p = 5.3*10^{-9}$).

It should be noted that x3 ("Number of types of regional awards in science"), x10 (Number of established engineering centers per 1,000 research and development organizations) and x13 (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) are included in both intermediate and final regression equation. In addition to them, important factors include: x4 (Number of types of individual scholarships for regional researchers), x6 (Grade point average of Unified State Exam passed by school leavers who are accepted to state-funded places in regional higher educational establishments), x15 (Amount of regional funds budgeted for fundamental and applied research per one researcher, thousand rubles), x28 (Indicator of the number of potentially commercialized patents per 1000 researchers), x32 (The number of state programs in the region, including the main activities to support scientific research), x36 (Average salary in the research and development sector, thousand rubles), x43 (Cumulative number of publications in the Web of Science database per 100 people engaged in R&D) and x46 (The number of articles prepared jointly with foreign organizations, per 1 organization engaged in R&D).

Final regression equation:

y=0.162*x3+0.045*x4+0.040*x6-0.010*x10-0.487*x13-0.002*x15-0.001*x21-0.010x23+0.001*x27-0.025x28+0.085*x32-0.008*x36+0.009x43-0.010*x46-0.36

4. Conclusion

Thus, the analysis of empirical data showed that the performance of scientific organizations is influenced by a set of logistical, technical and financial resources to promote knowledge generation. At the same time, the data does not allow to found out a direct correlation between other factors of the scientific environment on the performance of scientific institutions. In this regard, it can be argued that the publication and patent activity of scientific institutions depend on the level of financial support for research from the region, as well as on the availability of research infrastructure. The material and technical conditions create the opportunity for scientific institutions to fulfill their main mission - the generation of new knowledge and its dissemination.

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