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The assessment of internal factors' impact on the innovative development of Russian regions

La evaluación del impacto de los factores internos en el desarrollo innovador de las regiones rusas

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Contents

ABSTRACT:
Given the inconsistent location of productive forces across regions, spatial development strategies gain relevance in Russia. Assessing the innovative potential of regions is crucial to economic modernization. The study measures the innovation level of regions using a method offered by the authors. The innovation strength ranking is based on data as of 2017. To measure the innovation heterogeneity potential, a cluster analysis is conducted using the principal components method. Findings show that most regions overspend on R&D, with low ROI rates. Authors suggest redistributing productive forces (reducing/boosting R&D spending) to improve regional efficiency and interaction, to ensure sustainable balanced development.
Keywords: innovative potential, regions, spatial development, cluster analysis, innovative development, integral standard indicator of innovative potential of the regions

RESUMEN:
Dada la ubicación inconsistente de las fuerzas productivas entre regiones, las estrategias de desarrollo espacial adquieren relevancia en Rusia. La evaluación del potencial innovador de las regiones es crucial para la modernización económica. El estudio mide el nivel de innovación de las regiones utilizando un método ofrecido por los autores. El ranking de fuerza de innovación se basa en datos de 2017. Para medir el potencial de heterogeneidad de la innovación, se lleva a cabo un análisis de conglomerados utilizando el método de los componentes principales. Los resultados muestran que la mayoría de las regiones gastan más de lo debido en I+D, con bajos índices de rendimiento de la inversión. Los autores sugieren redistribuir las fuerzas productivas (reducir/impulsar el gasto en I+D) para mejorar la eficiencia y la interacción regional, a fin de garantizar un desarrollo sostenible y equilibrado.
Palabras clave: potencial innovador, regiones, desarrollo espacial, análisis de conglomerados, desarrollo innovador, indicador estándar integral del potencial innovador de las regiones

1. Introduction

Every year the importance of innovative development of economy increases. The government approaches this issue quite thoroughly and carefully seeks the ways to establish the most effective innovation space in the country. This is due to the fact that in modern conditions the state of the national economy is increasingly determined by the economic potential of the regions, their innovativeness and ability to modernize.

The achievement of this objective is contributed by the solution of the following tasks:

- To develop an integral indicator of innovative development degree of the region, including five key indicators of innovativeness of the subjects of the Russian Federation and to identify the nature of relationship between them;
- To determine the innovative potential of spatial development of the Russian Federation by means of an integral indicator of innovative development degree of the regions;
- To carry out cluster analysis of the regions of the Russian Federation using the method of main components;
- To develop recommendations for the redistribution of productive forces from one region to another.

The integral assessment of innovative development degree of the regions of the state is a widely discussed topic in the scientific literature. Many works are devoted to the development of indices of innovative development of a region, its calculation and analysis of received trends, see works (Roman, 2010; Abbasi et al., 2011; Chen & Guan, 2012; Foddi & Usai, 2013; Liu et al., 2014; Han et al., 2016; Broekel et al., 2018). The most widespread methods of formation of innovative development integrated indicator are DEA (Kotsemir, 2013; Valdez Lafarga and Balderrama, 2015; Yang, etc., 2016; Guan & Zuo, 2017) and weighed average of rated indicators (Sharma & Thomas, 2008; Fritsch & Slavtchev, 2011; Baburin & Zemtsov, 2014; Kou, etc., 2016). In this study the authors propose their own innovation index of epy regions, based on weighted average of normalized indicators and a complex group of indicators.

The aim of the study is to assess the innovative potential of the regions in Russia and to develop proposals for redistribution of productive forces, in particular the expenditures for scientific research and development among the regions of Russia for the balanced innovative development of the country as a whole.

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2. Materials and Methods

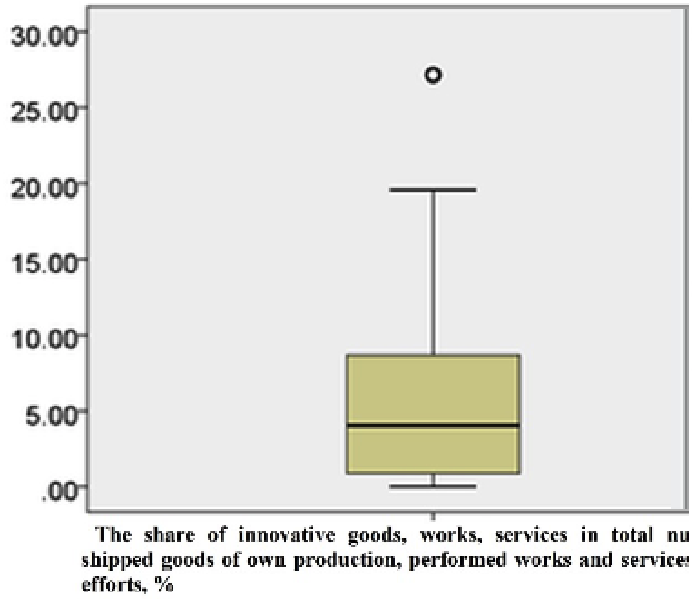
The study was based on popular scientific methods of analysis, synthesis, abstraction, as well as statistical grouping and graphical methods. Special methods of statistical analysis, research of generalizing characteristics of aggregates, regression and dispersion analysis, econometric modeling, methods of mathematical statistics were also used in the work, which ensures reliability and reasoning of the obtained results. The database on innovative indicators of the Russian regions was used.

In order to assess the innovativeness degree of the subjects of the Russian Federation, the authors compiled an integral normalized indicator of their innovative potential. The following key figures were selected as a part of it:

> The share of innovative goods, works, services in total number of shipped goods of own production, performed works and services by own efforts, %.
>
> The number of developed advanced production technologies per 1 billion rubles of internal research and development costs, units.
>
> The number of developed advanced production technologies per researcher engaged in research and development, units.
>
> The number of advanced manufacturing technologies used per researcher engaged in research and development, units.
>
> The innovative activity of organizations (the share of organizations that implement technological, organizational, marketing innovations in the reporting year, in the total number of surveyed organizations), %

For the purpose of preliminary visual analysis of the initial data, "box" diagrams of regions distribution according to the selected innovation indicators are given (see Figure 1).

Figure 1
"Box" diagrams of initial data for calculation of integral strength indicator of innovative potential of the region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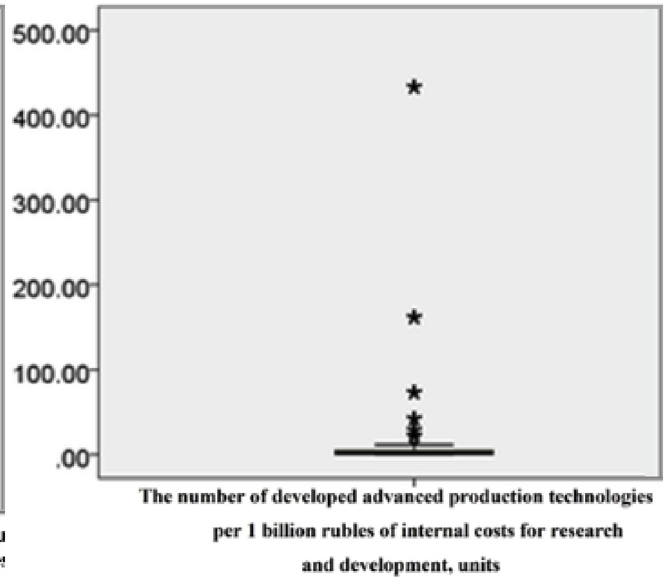
efforts, %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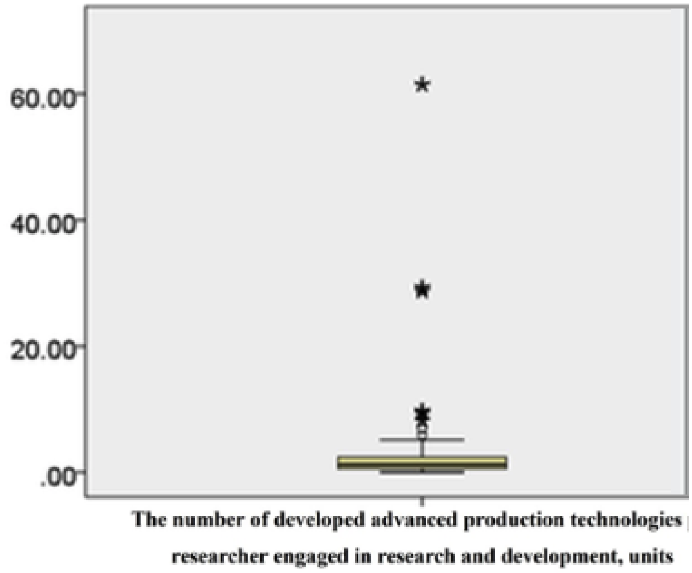
The number of developed advanced production technologies
per 1 billion rubles of internal costs for research
and development, units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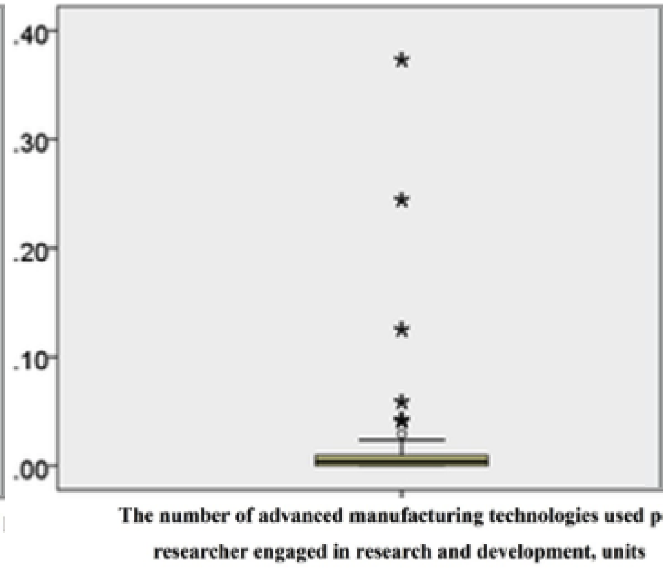
The number of developed advanced production technologies
researcher engaged in research and development, units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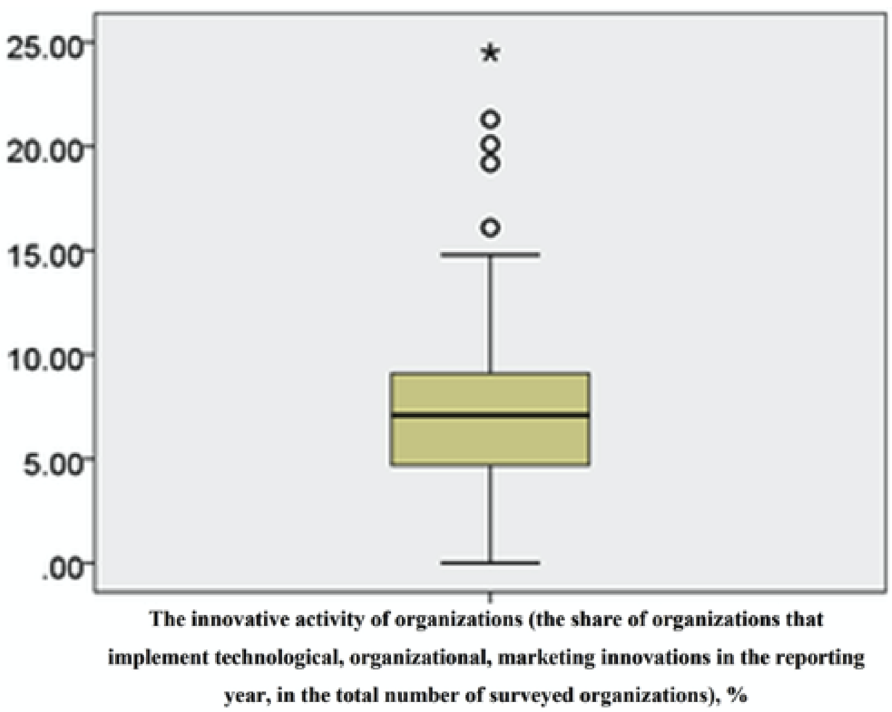
The number of advanced manufacturing technologies used p
researcher engaged in research and development, units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The innovative activity of organizations (the share of organizations that
implement technological, organizational, marketing innovations in the reporting
year, in the total number of surveyed organizations), %

As shown in Figure 1, all presented frequency distributions have positive asymmetry. This asymmetry is particularly marked for indicators of the number of advanced innovative technologies developed and used per researcher and 1 billion rubles of research and development costs.

Thus, for each indicator of innovativeness degree, a small number of clear leaders can be observed, far exceeding the rest regions.

For calculation of integral indicator of innovative potential the analyzed indicators were standardized according to the formula (1)

$$\hat{x}_{ij} = \frac{x_{ij} - \min_j(x_{ij})}{\max_j(x_{ij}) - \min_j(x_{ij})} \quad (1)$$

where x_{ij} is a reference value of *i* indicator for *j* region.

After the standardization procedure, the integral indicator was calculated as the arithmetical average of the normalized indicators (Formula 2).

$$T_i = \frac{\sum_{j=1}^{m} \hat{x}_j}{m} \quad (2)$$

where m is a number of the considered indicators characterizing the innovative potential of the region.

On the basis of the obtained integral innovativeness indicator, a rating of the regions based on the innovative potential strength was formed according to the results of 2017 (see Table 1).

Table 1
Rating of the subjects of the Russian Federation
by the innovative potential strength

The place in rating	The subject of the Russian Federation	Integral figure value
1	Yamalo-Nenets Autonomous Area	53.885
2	Republic of Kalmykia	35.260
3	Republic of Mordovia	33.787
4	Republic of Tatarstan	32.958
5	Chuvash Republic	30.632
6	Lipetsk region	27.329
7	Bryansk region	24.674
8	Moscow	23.354
9	Nizhny Novgorod Region	23.056
10	Tyumen region (without Autonomous Area)	22.568
11	Penza region	22.323
12	Udmurt Republic	21.457
13	Kostroma region	21.001
14	Belgorod region	20.821
15	Moscow region	18.953
16	St. Petersburg	18.821

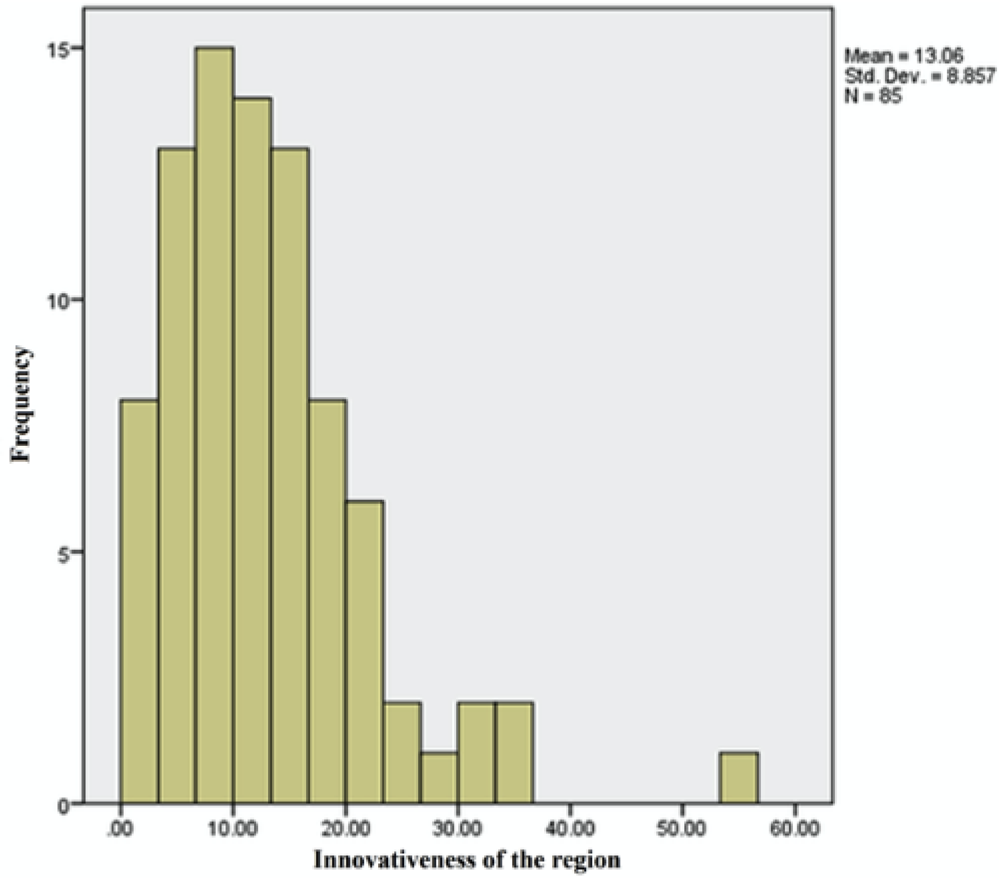
17	Perm Krai	18.634
18	Khabarovsk Krai	18.601
19	Rostov region	18.023
20	Yaroslavl region	17.942
21	Tula region	17.578
22	Samara region	17.143
23	Republic of Mari El	16.336
24	Chukotka Autonomous Area	15.902
25	Nenets Autonomous Area	15.668
26	Ryazan region	15.321
27	Sverdlovsk region	14.843
28	Voronezh region	14.436
29	Vladimir region	14.124
30	Altai Krai	14.003
31	Krasnodar Krai	13.854
32	Kirov region	13.754
33	Novosibirsk region	13.632
34	Tomsk region	13.394
35	Tambov region	13.246
36	Ulyanovsk region	13.234
37	Republic of Bashkortostan	13.168
38	Astrakhan Region	12.951
39	Vologda Region	12.678
40	Sevastopol	12.356
41	Novgorod Region	12.302
42	Kamchatka Krai	11.569
43	Republic of Adygea	11.424
44	Pskov region	11.341

45	Kursk region	11.282
46	Stavropol Krai	11.205
47	Tver region	11.163
48	Magadan region	10.683
49	Zabaykalsky Krai	10.553
50	Kaluga region	9.878
51	Chelyabinsk region	9.845
52	Smolensk region	9.803
53	Krasnoyarsk Krai	9.624
54	Orenburg region	9.278
55	Sakha Republic (Yakutia)	9.184
56	Leningrad Region	9.122
57	Omsk region	8.981
58	Ivanovo region	8.376
59	Oryol region	8.243
60	Saratov region	7.889
61	Republic of Buryatia	7.721
62	Republic of Karelia	7.446
63	Murmansk region	7.312
64	Kurgan region	6.945
65	Volgograd region	6.584
66	Arkhangelsk region (without Autonomous Area)	6.312
67	Amur region	6.287
68	Khanty-Mansi Autonomous Area - Ugra	5.919
69	Komi Republic	5.753
70	Kemerovo region	5.728
71	Republic of Altai	5.721
72	Irkutsk region	5.673

73	Jewish Autonomous Region	5.668
74	Kaliningrad region	4.691
75	Sakhalin region	4.343
76	Primorsky Krai	4.085
77	Republic of North Ossetia - Alania	3.963
78	Kabardino-Balkar Republic	3.323
79	Republic of Crimea	3.168
80	Republic of Dagestan	2.987
81	Republic of Khakassia	2.366
82	Republic of Tyva	2.223
83	Chechen Republic	1.359
84	Karachay-Cherkess Republic	0.861
85	Republic of Ingushetia	0.677

To visualize the information shown in Table 1, let us give a frequency histogram of the regions by the innovative potential strength (see Figure 2). The presented distribution is expected to have marked positive asymmetry. There is an unconditional leader represented by the Yamalo-Nenets Autonomous Area, with a large distance ahead of the nearest pursuers. Among the advanced regions in terms of the innovative potential strength there are also such regions as the Republic of Kalmykia, the Republic of Mordovia, the Republic of Tatarstan, the Chuvash Republic, the Lipets region, the Bryansk region, Moscow, the Nizhny Novgorod region, the Tyumen region (without Autonomous Area), the Penza region, the Udmurt Republic, the Kostroma region, Moscow. Among the outsiders in innovation we can consider such regions as the Republic of Ingushetia, the Republic of Karachai-Cherssy, the Chechen Republic, the Republic of Tyva, the Republic of Khakassia, the Republic of Dagestan, the Republic of Crimea, the Kabardino-Balkan Republic, the Republic of North Ossetia-Alania, Primorsky Krai, the Sakhalin region, Jewish Autonomous Region, the Irkutsk Region, the Republic of Altai and the Kemerovo Region.

Figure 2
The frequency distribution of the subjects of the Russian Federation by the innovative potential strength



In order to analyze the internal factors of innovative development of the regions, a database of statistical indicators related to the innovative development for the period 2010-2017 was compiled. The data were taken from the website of the Federal Service of State Statistics of the Russian Federation. According to the data collected, the following set of key indicators of the innovative development degree was formed for each region (see Table 2).

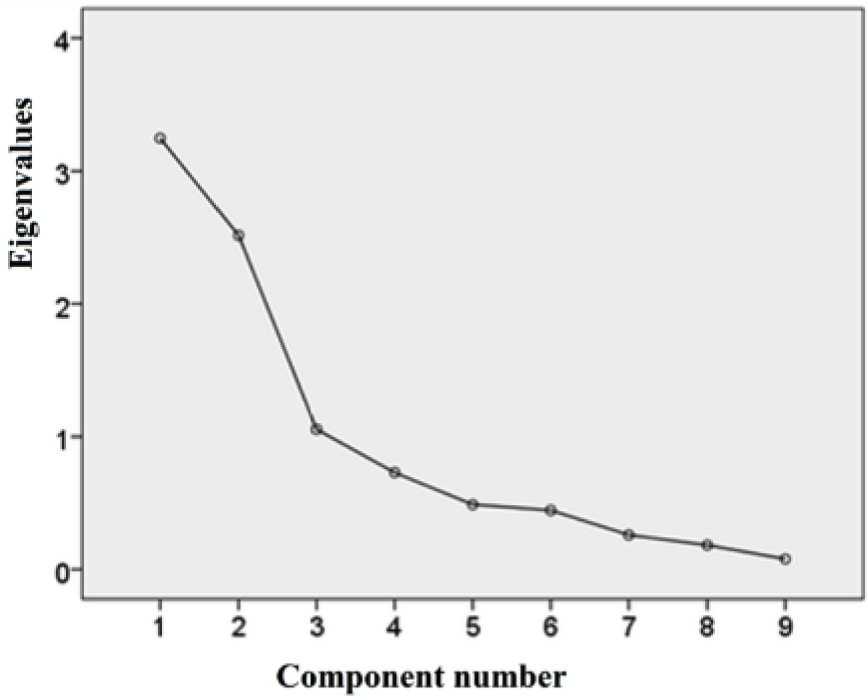
Table 2
The list of innovativeness indicators of the region

A variable code	Interpretation of an indicator
VAR1	The share of innovative goods, works, services in the total number of shipped goods of own production, performed works and services by own efforts, %
VAR2	The number of developed advanced production technologies per 1 billion rubles of internal costs for scientific research and development, units.
VAR3	The number of advanced production technologies used per researcher engaged in research and development, units.
VAR4	The number of advanced production technologies developed per researcher engaged in research and development, units.
VAR5	The share of internal research and development costs in the total number of own production goods shipped, performed works and services by own efforts, %
VAR6	The share of organizations implementing technological innovations in the reporting year, in total number of surveyed organizations, %

VAR7	The share of technological innovation costs in the total volume of goods shipped, performed works, services, %
VAR8	The share of organizations that implemented marketing innovations in the reporting year in the total number of surveyed organizations, %
VAR9	The share of organizations that implemented organizational innovations in the reporting year, in total number of surveyed organizations, %

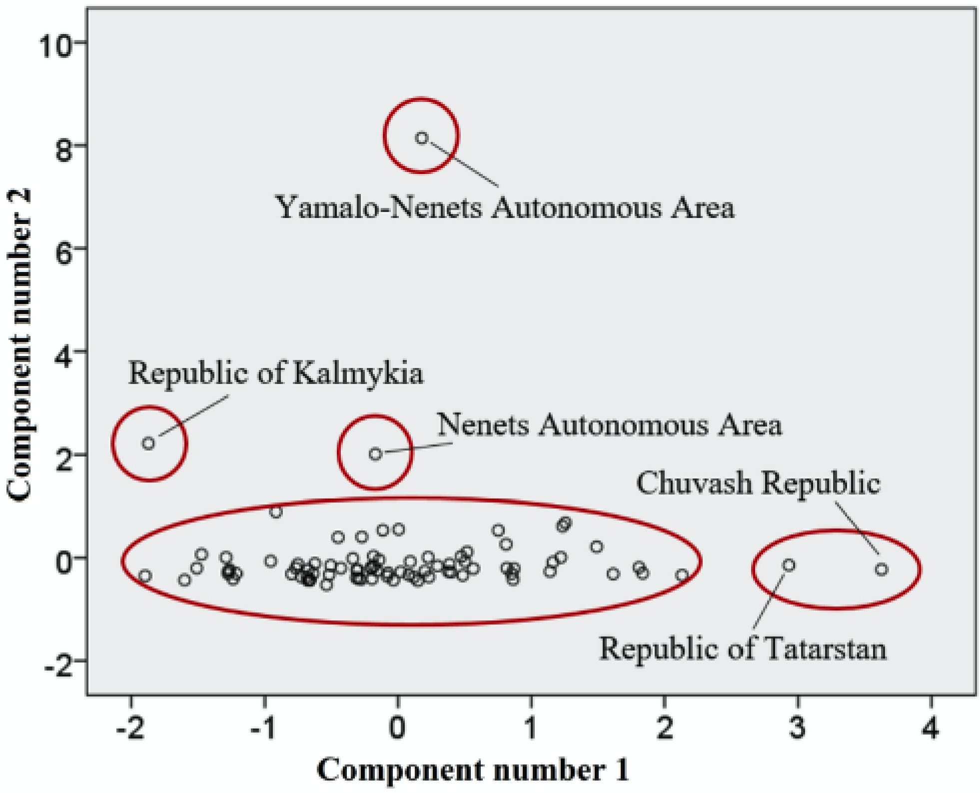
In order to identify the potential heterogeneity of the innovative state of considered subjects, we will carry out a cluster analysis of the regions of the Russian Federation using the method of the main components. Figure 3 shows the eigenvalues of the correlation matrix of analyzed indicators. As it can be seen from this figure, the eigenvalues for the first two main components are significantly greater than one, while the remaining components have eigenvalue below one. Hence it can be concluded that the first two main components explain a significant share of dispersion of the values of considered variables from their averages.

Figure 3
The dynamics of eigenvalues
by main component number



Thus, by showing the values for the first two principal components on a two-dimensional plane (see Figure 4) a cluster analysis can be performed graphically. As it can be seen from Figure 4, the apparent "outbreak" is the Yamalo-Nenets Autonomous Area, which is also confirmed by the above rating of the innovative potential strength of the regions. In addition, the Republic of Kalmykia, the Nenets Autonomous Area, the Chuvash Republic and the Republic of Tatarstan behave quite different from the main mass of regions, and the last two subjects can theoretically be combined into one cluster. The remaining regions, which make up the absolute majority, can be classified as similar in their innovativeness characteristics and combined into one massive cluster (Shavina et al., 2019).

Figure 4
Cluster analysis of the regions of the Russian
Federation by the method of main components



It follows from the graphical cluster analysis that the main part of the subjects of the Russian Federation is quite homogeneous in terms of the values of selected indicators of innovative development except some regions. As a result, we can conclude that further analysis of the given spatial data on innovative development of the regions and related conclusions can be considered correct and suitable for making recommendations on redistribution of productive forces in order to increase the efficiency of functioning and interaction of the regions of the Russian Federation and ensure sustainable and balanced innovative development.

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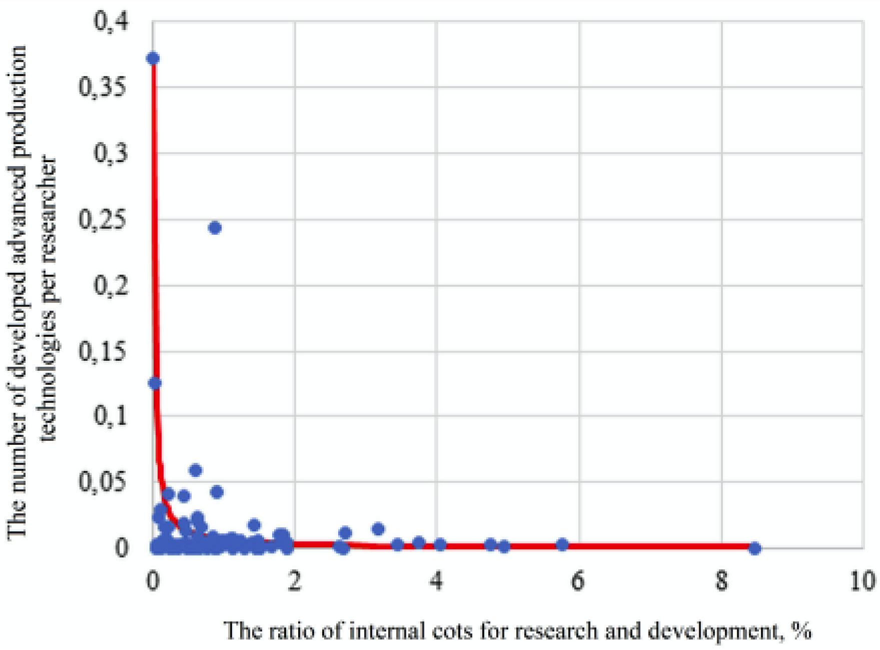
3. Results and Discussion

Let us look at the relationship between the ratio of internal research and development costs and the number of advanced production technologies developed per researcher. Figure 6 shows the scattering diagram for these two variables.

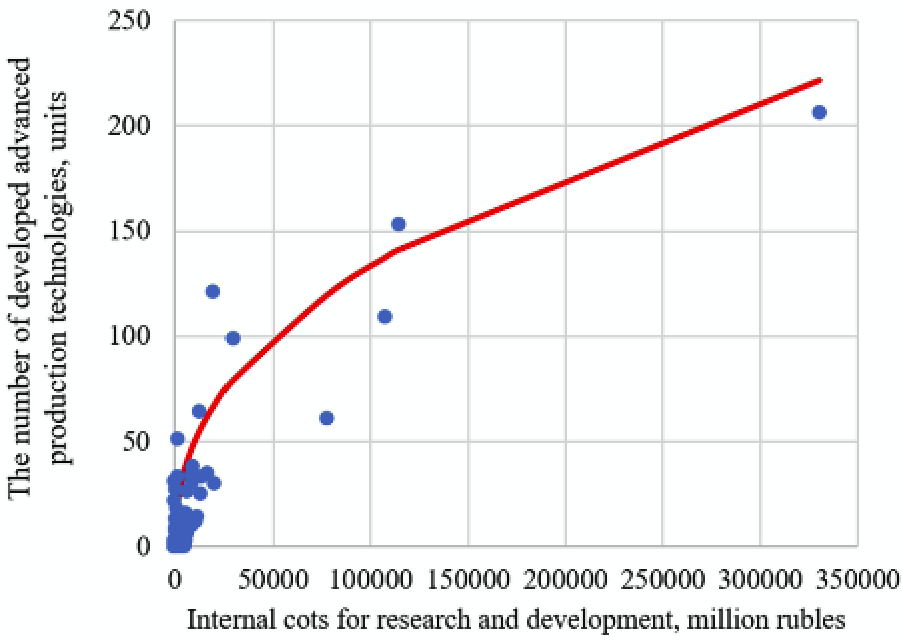
Figure 5
The dependence of the ratio of research and development costs and the effectiveness of researchers for 2017



From Figure 5, it can be seen that the dependence of the variables can be approximated quite well by a hyperbolic-type function. Thus, it can be concluded that the greater the ratio of research and development costs in the region, the lower the average efficiency of working researchers.

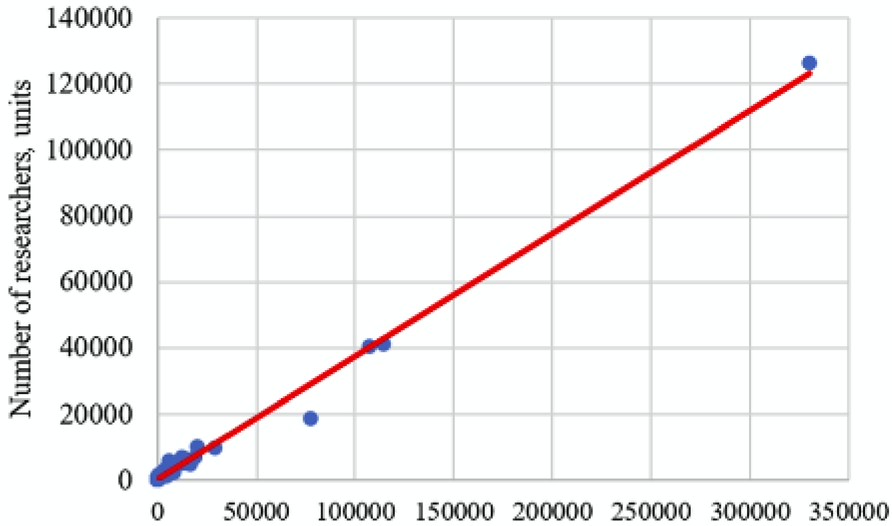
Indeed, if we depict a dissipation diagram for the indicator of internal research and development costs and the indicator of the number of advanced production technologies developed (Figure 6), one can see a characteristic production function with a monotonically decreasing marginal utility of costs.

Figure 6
The dependence of research and development costs and the number of developed technologies for 2017



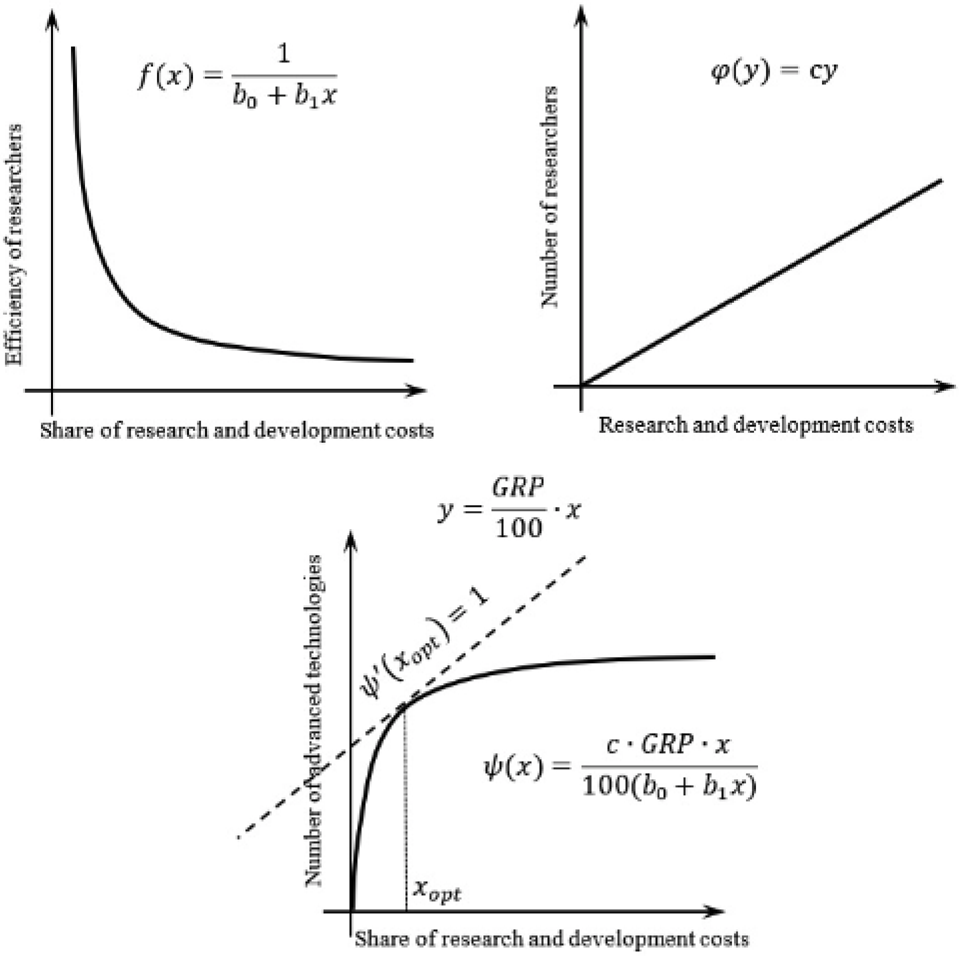
Next, we turn to the relationship between the internal costs of research and development and the number of researchers (Figure 7). As it can be seen, these indicators are linked by an almost strict linear relationship, which means that for each additional researcher there is a certain constant amount of money in spatial terms. In this case, judging by the obtained coefficients of pair linear regression the costs of scientific research increased with each additional researcher by about 2.7 million rubles per year.

Figure 7
The dependence of research and development costs and the number of researchers for 2017



By analyzing the dependencies shown in Figures 6-8, the conceptual dependencies of analyzed indicators can be formed (see Figure 8). Let us suppose that the average efficiency of researchers depends on the ratio of research costs according to the hyperbolic-type function $f(x)$ with b_0 and b_1 parameters. Also, according to Figure 8, it will be logical to assume that the dependence of the number of researchers on the scientific research costs will be described by a linear function $\varphi(y)$ without a free member with parameter c. The absence of a free member of the model is due to the fact that the lack of research costs implies the absence of officially employed researchers. Further, the research costs can be expressed through the ratio of costs multiplied by the total amount of goods shipped, works and services provided, subsequently divided by 100. Thus, having multiplied $f(x)$ and $\varphi(y)$ and having expressed y through x, we will receive function $\psi(x)$ which represents the dependence of amount of the developed advanced production technologies and the ratio of scientific research costs in the definite region.
In this work it is offered to consider being optimum the ratio of scientific research costs for every definite region such point as x_{opt} which satisfies the equality $\psi'(x_{opt}) = 1$. This means that the point of the optimum is suggested to be the value of the argument at which the derivative of function turns to one, since above this point, when the ratio of research costs increases by an infinitely small value of Δ, the number of advanced technologies will increase by an infinitely small value of $k\Delta$, where $k < 1$, which indicates a decrease in the efficiency of the costs made.

Figure 8
The dependence of the share of innovative goods and services and the share of organizations implementing technological innovations in 2017



To develop the formula for x_{opt}, let us take the derivative of the function $\psi(x)$ and equate it to one:

$$\psi'(x) = \frac{c \cdot GRP \cdot 100b_0 + c \cdot GRP \cdot 100b_1x - 100c \cdot GRP \cdot b_1x}{10000(b_0^2 + 2b_0b_1x + b_1^2x^2)} = 1 \quad (3)$$

Next, from the resulting equality, we compose a square equation:

$$10000(b_0^2 + 2b_0b_1x + b_1^2x^2) - c \cdot GRP \cdot 100b_0 = 0 \quad (4)$$

Since the coefficient at variable *x* is divided without residue by 2, we find a reduced version of determinant:

$$\frac{D}{4} = (10000b_0b_1)^2 - 10000^2b_0^2b_1^2 + c \cdot b_1^2 \cdot GRP \cdot 1000000b_0 = c \cdot b_1^2 \cdot GRP \cdot 1000000b_0 \quad (5)$$

from where we get the final solution for the optimal x_{opt} point:

$$x_{opt} = \frac{-10000b_0b_1 + \sqrt{c \cdot b_1^2 \cdot GRP \cdot 1000000b_0}}{10000b_1^2} = \frac{\sqrt{c \cdot GRP \cdot b_0}}{10b_1} - \frac{b_0}{b_1} \quad (6)$$

Thus, when accepting the above assumptions, for each specific region the ratio of research costs can be considered as optimal and calculated as:

$$x_{opt} = \frac{\sqrt{c \cdot \frac{GRP}{100} \cdot b_0} - b_0}{b_1} \quad (7)$$

Using the collected database of statistical information for 2016, the parameters of the functions $f(x)$ and $\varphi(y)$ were estimated using the least squares method (LSM). Based on the estimates obtained, the optimal values of the ratio of research and development costs for each subject of the Russian Federation were calculated according to the formula:

$$x_{opt} = \frac{\sqrt{0{,}37 \cdot \frac{GRP}{100} \cdot 0{,}98} - 0{,}98}{149{,}8} \quad (8)$$

Table 4 shows the results of the calculations the analysis of which allows us concluding that most regions spend unreasonably a lot on research and development. These costs are low efficient and have extremely low return on investment. As a result, most regions are recommended to reduce the share of research costs. However, the opposite situation is observed in 14 regions (marked in bold): such regions are recommended to increase the share of scientific costs to the suggested guidelines.

Table 4
The recommendations on changing the level of scientific research and development costs by the regions of the Russian Federation

the subject of the Russian Federation	*current share of research and development costs, %*	*recommended share of research and development costs, %*
Belgorod region	**0.24**	**0.36**
Bryansk region	0.45	0.17
Vladimir region	1.29	0.26
Voronezh region	1.39	0.27
Ivanovo region	0.58	0.16
Kaluga region	1.84	0.29
Kostroma region	**0.11**	**0.15**
Kursk region	1.53	0.21
Lipetsk region	**0.05**	**0.31**

Moscow region	4.77	0.62
Oryol region	0.37	0.17
Ryazan region	0.71	0.22
Smolensk region	0.64	0.18
Tambov region	0.88	0.18
Tver region	1.66	0.24
Tula region	0.94	0.32
Yaroslavl region	2.72	0.25
Moscow	4.94	1.04
Republic of Karelia	0.64	0.15
Komi Republic	0.45	0.29
Nenets Autonomous Area	**0.03**	**0.18**
Arkhangelsk region	0.67	0.18
Vologda region	**0.06**	**0.31**
Kaliningrad region	0.32	0.21
Leningrad Region	0.72	0.39
Murmansk region	0.88	0.21
Novgorod region	0.91	0.18
Pskov region	0.44	0.11
St. Petersburg	3.65	0.72
Republic of Adygea	0.51	0.09
Republic of Kalmykia	0.88	0.04
Republic of Crimea	1.44	0.14
Krasnodar Krai	0.64	0.39
Astrakhan region	0.22	0.18
Volgograd region	0.49	0.36
Rostov region	1.49	0.38

Sevastopol	8.45	0.05
Republic of Dagestan	1.89	0.09
Republic of Ingushetia	2.65	0.02
Kabardino-Balkar Republic	1.52	0.09
Karachay-Cherkess Republic	1.12	0.09
Republic of North Ossetia - Alania	1.45	0.08
Chechen republic	0.68	0.09
Stavropol Krai	0.47	0.27
Republic of Bashkortostan	0.63	0.49
Republic of Mari El	**0.13**	**0.16**
Republic of Mordovia	0.48	0.14
Republic of Tatarstan	0.65	0.58
Udmurt Republic	**0.24**	**0.32**
Chuvash Republic	0.86	0.17
Perm Krai	1.15	0.47
Kirov region	0.64	0.21
Nizhny Novgorod Region	5.73	0.42
Orenburg region	**0.15**	**0.35**
Penza region	1.86	0.18
Samara region	0.95	0.44
Saratov region	0.96	0.28
Ulyanovsk region	3.17	0.24
Kurgan region	0.27	0.15
Sverdlovsk region	1.79	0.56
Khanty-Mansi Autonomous Area - Ugra	**0.07**	**0.72**
Yamalo-Nenets	**0.02**	**0.46**

Autonomous Area		
Tyumen region	1.13	0.43
Chelyabinsk region	1.47	0.49
Republic of Altai	1.48	0.06
Republic of Buryatia	1.03	0.16
Republic of Tyva	1.29	0.07
Republic of Khakassia	**0.07**	**0.18**
Altai Krai	0.58	0.22
Zabaykalsky Krai	0.28	0.16
Krasnoyarsk Krai	1.13	0.55
Irkutsk region	0.48	0.39
Kemerovo region	**0.14**	**0.48**
Novosibirsk region	4.01	0.29
Omsk region	0.78	0.36
Tomsk region	3.44	0.27
Sakha Republic (Yakutia)	0.39	0.33
Kamchatka Krai	1.82	0.12
Primorsky Krai	2.64	0.17
Khabarovsk Krai	0.84	0.24
Amur region	0.28	0.19
Magadan region	0.78	0.13
Sakhalin region	**0.18**	**0.35**
Jewish Autonomous Region	0.92	0.05
Chukotka Autonomous Area	**0.05**	**0.13**

The study devoted to the analysis and modeling of dependence of innovative activity on investment in research and development includes such works as (Fritsch, 2003; Xu & Cheng, 2013; Kaihua, and Mingting, 2014; Leshukov et al., 2015; Tarnawska & Mavroeidis, 2015). However, the works mentioned above do not pay sufficient attention to the development of econometric models that would develop the optimal distribution of investment flows among the regions to ensure the most balanced and dynamic innovative development. This section of the work is devoted to the development of such model.

4. Conclusion

Thus, based on the analysis carried out, it is recommended to redistribute productive forces, in particular from the regions with excessive research and development costs to the regions with insufficient costs. It is also recommended to redistribute the R & D budget in favor of 14 regions identified by the authors. It is necessary to develop a system of motivation for researchers to encourage them to change the region of work, to use a wide arsenal of such forms of spatial organization of innovative activities as clusters, territories of advanced development, special economic zones, support zones and others to ensure the balance of innovative development of Russia.

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