INNOVATION POTENTIAL OF TERRITORIAL DEVELOPMENT

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THE RELATIONSHIP BETWEEN THE SCIENTIFIC AND TECHNOLOGICAL DEVELOPMENT INDEX AND THE ECONOMIC STRUCTURE OF RUSSIAN REGIONS

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This paper continues our research on the regional analysis of scientific and technological development. The relationship between the level of scientific and technological development and economic indicators reflecting a region's specialization has not been sufficiently analyzed in the literature, which defines the relevance of this study. The aim of the work is to identify the presence or absence of relationship between the scientific and technological development index and the established industrial specialization of a region. The importance of identifying such patterns is driven by the fact that the Strategy for Technological Development presupposes the creation of a matrix for scientific and technological development programs in the regions. The research was based on 2022 statistical data published on the websites of Rosstat and the Russian Ministry of Science and Higher Education. We applied an original aggregated index proposed earlier by us for the analysis. The study relied on methods of mathematical statistics: cluster, variance, and correlation analysis. As a result, we established a fairly stable relationship between the economic

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structure and scientific and technological development: regions with a more diversified economic structure have a higher scientific and technological development index. As expected, a strong correlation was found between the share of scientific activity in a region and its scientific and technological development, particularly for the sub-index responsible for science funding. This paper can be useful for creating the aforementioned matrices for regional state programs of scientific and technological development, taking into account the type of region and the criteria by which a region can be classified as a particular type.

Rating, region, regional development, scientific and technological development, technological sovereignty, cluster analysis.

Introduction

This article continues a series of studies dedicated to regional issues of scientific and technological development (STD) and the closely related questions of the country's technological sovereignty. The work aims to address scientific gaps concerning STD, specifically to identify the presence or absence of a relationship between the STD index and the established sectoral specialization of a region under modern conditions that require ensuring the economy's technological sovereignty.

The scientific hypothesis put forward by the authors is that the values of the aggregated STD index depend on the sectoral specialization of a region: regions with more diversified economies have higher STD indices. To this end, the work aimed to solve the following tasks: conduct a cluster analysis based on two sets of features characterizing innovative development and economic structure; compare the clusters identified by the two partitions; and perform correlation analysis to determine the presence and strength of the relationship.

Identifying such patterns is relevant because the Strategy for Technological Development, adopted by Presidential Decree 145, dated February 28, 2024, envisions the creation of a regional STD program matrix taking into account the region's specialization.

Research on technological sovereignty and regional STD has been reflected in the scientific literature. However, in our view, the relationship between the level of STD and other economic indicators, as well as the contribution of regions to scientific and technological development, has not been sufficiently examined. This constitutes another aspect of the scientific novelty of this study.

Methods

The study employed an author's methodology for constructing an aggregated index of scientific and technological development, described in (Volkova, 2024), and a number of statistical analysis methods. At the first stage, the initial data were transformed into standardized variables using the min-max method. Then, indices of the 3rd and 2nd levels and the general index of the 1st level were calculated as simple averages of the corresponding number of features. For the initial investigation, the authors considered it entirely acceptable to use equal weights for the features, since assigning different weights requires additional research or expert assessments. Subsequently, as a result of a double cluster analysis – based on the 2nd-level indices and on the features of production structure – two cluster partitions with similar characteristics within clusters were obtained (Soshnikova et al., 1999).

To assess the significance of differences between the obtained clusters, analysis of variance (ANOVA) with post-hoc criteria was used (Kremer, 2000; Dubina, 2010).

To identify the dependence of the calculated STD indices on the features of the regions' economic structure, a correlation analysis was performed for all identified clusters.

The research was conducted on statistical data for 2022, available from open sources. On the one hand, this is the most recent data available at the time of writing the article; on the other hand, it allowed for accounting for geopolitical shocks. The authors intend to continue the research with more recent data and analyze the dynamics of STD processes in the regions.

Theory

Technological sovereignty at the macro level

It is believed that the concept of "technological sovereignty" (TS) was introduced by P. Grant. He interpreted TS as the ability and freedom to choose, create or acquire, as well as apply and exploit for commercial purposes, the technologies necessary for industrial innovation (Grant, 1983). A more specific formulation, with which the authors agree, is given in (Edler et al., 2023), where TS is defined as a means for authorities to achieve innovation policy goals in order to maintain national competitiveness and build economic potential. This interpretation reflects the essence of the phenomenon (achieving competitiveness in the global market) and identifies development directions, especially in connection with the sanctions imposed on the Russian Federation, which are largely aimed at limiting the country's technological capabilities.

The connection between sanctions and states' turn toward TS is also discussed in foreign sources. For instance, Indian economists note that the use of the TS concept is increasing in various countries due to the growing number of Western sanctions imposed against Iran, North Korea, Venezuela, and Russia (Bhagwat, Zaikov, 2024).

The discussion on this issue continues in the literature[1]. Primarily, there is a debate regarding the very concept of TS. For example, L.S. Nevyantseva describes different facets of the definition's essence, particularly touching upon aspects such as the link between TS and national security, and the necessary degree of economic openness (Nevyantseva, 2024). E.V. Krasilnikova and A.A. Nikonova focused their attention on the interpretation of TS by different economic agents, such as legislation, authorities, business, and researchers (Krasilnikova, Nikonova, 2023).

Foreign experience in TS research is presented in the work (Yasinskii, 2023), which discusses the system of managing science and technology development in China, as well as in a collective work dedicated to the concept of technological autonomy in the EU[2].

In an article by V.E. Dementiev, it is suggested to consider the experience of foreign approaches to strengthening TS, but the need to account for the turbulence of economic development is noted (Dementiev, 2023). TS is discussed in a similar vein in an article (Krupnov, 2023).

At the state level, significant attention is also paid to TS issues. As an example, one can cite Federal Law 523-FZ dated December 28, 2024, "On Technological Policy in the Russian Federation and on Amending Certain Legislative Acts of the Russian Federation"[3]. The law is aimed at enhancing the competitiveness of high-tech products and the efficiency of their production through the introduction of technological innovations in the Russian Federation. One of the objectives stated in the document is "creating conditions for economic development and ensuring competition in the sphere of technological development", and one of the tasks is "conducting monitoring of the effectiveness of technological policy and assessing the effectiveness of state incentive

[1] A detailed analysis is provided in the work (Volkova, 2024).

[2] Geopolitics and Economic Statecraft in the European Union (2024). Rosa Balfour and Sinan Ülgen, editors. Carnegie Endowmentfor International Peace. Available at https://carnegie-production-assets.s3.amazonaws.com/static/files/Geopolitics%20and%20Economic%20Statecraft%20in%20the%20European%20Union-2.pdf

[3] Federal Law 523-FZ dated December 28, 2024, "On Technological Policy in the Russian Federation and on Amending Certain Legislative Acts of the Russian Federation". Available at: http://pravo.gov.ru/proxy/ips/?docbody=&firstDoc=1&lastDoc=1&nd=608103518 (accessed: 23.03.2025).

measures". However, regarding regional TS issues, the law only declares that constituent entities of the Russian Federation exercise powers to formulate technological policy within the framework of this law.

In 2024, a list of priority TS project areas was approved, including those critical for its provision, with a total cost of 977 billion rubles (as of November 2024)[4].

The concepts of TS and STD are closely interrelated. In our view, STD is one of the means to achieve TS. All of the above pertains to the macro level – the state level. In relation to regions, the issues under investigation have a number of nuances.

Regional aspect of TS and STD

It is difficult to speak of TS in relation to a region, which "by definition" cannot be sovereign. TS is closely linked to the country's sovereignty, and regions, even in a federal state, do not possess full independence. We agree with the opinion expressed in (Akberdina, Potaptseva, 2023) that, from a regional perspective, one should speak of the contribution of regions to the state's TS. Thus, in this aspect, the issue of TS should be considered from the angle of technological development, which is precisely what has been done in this article.

The contribution of regions to achieving TS is given great importance at the governmental level. For instance, at a meeting of the Commission for Scientific and Technological Development of the Russian Federation in May 2024, Deputy Prime Minister D. Chernyshenkov reported that in 80 Russian regions, leaders for STD have already been appointed, as provided for by the Strategy[5], and that 20 constituent entities have prepared state programs for STD[6].

Some sources, for example (Tufetulov, 2007), consider general issues of the sectoral structure of the regional economy within the framework of the concept of Kondratiev's long technological waves. The work (Efimov, 2022) analyzes regional STD in specific entities, particularly in the south of Russia. The study (Ivanchenko, 2023) examines the main industrial regions of the Urals.

In the context of this article, the work of German economists (Kroll, Neuhäusler, 2020) is of interest. They study regional aspects of STD in China and concluded that the most developed industrial regions of China make the greatest contribution to development.

The monograph (Priorities..., 2020) analyzes aspects of innovation policy across regions, describing the potential of relatively new regional elements of innovation infrastructure, such as scientific and educational centers, which in the future will create conditions for productive partnerships between research organizations, leading universities, and major industry (Priorities..., 2020, pp. 88–89).

Measuring the level of STD

To determine the level of STD in regions, it would be useful to have some objective criterion reflecting changes; therefore, it is necessary to measure the level of TS. Questions of its measurement, both at the national and regional levels, have been discussed in the literature. For example, the work (Glazunova, 2023) investigated innovative potential and its connection to technological sovereignty.

Various approaches to assessing the level of TS and a region's contribution to its achievement were studied by the authors in previous works (Volkova, 2024; Volkova, Romanyuk, 2024).

Some approaches to measuring the level of STD outlined in the works listed above are currently difficult to apply due to the lack of reliable statistical information, especially at the regional level. As an example, one can refer

[4] Technological sovereignty of Russia. Available at: https://www.tadviser.ru/index.php/Статья:Технологический_суверенитет_России (accessed: 17.02.2025).
[5] Available at: http://www.kremlin.ru/acts/bank/50358 (accessed: 23.03.2025).
[6] Available at: http://government.ru (accessed: 23.03.2025).

to the article (Yankovskaya, 2023), which states that quantitative analysis of TS is hampered by the absence of published indicators of technological sovereignty. The work (Sukharev, 2023) also notes the incompleteness of statistical information related to STD.

Nevertheless, measuring the level of STD in a region is desirable, as it allows for adjusting scientific and technological policy within it. The lack of reliable and complete regional information on this issue leads to the construction of ratings becoming a compromise between data availability and the need to account for all aspects of the process as comprehensively as possible.

The task of assessing STD has recently received particular attention in the literature due to the current geopolitical situation. For instance, the article (Myslyakova, 2022) evaluates the effectiveness of using regional scientific and technological potential, using as an example the constituent entities of the Federation that are leaders in the share of basic industrial sectors in GRP and the country's GDP as a whole. In it, regional potential is compared based on a system of indicators consolidated into an aggregated index. However, the analysis was limited to only a number of regions.

The work (Sukharev, 2019) examines models of regional technological development and postulates that their development policies should be individually differentiated.

Government bodies also attach great importance to regional innovative development. In 2022, a methodology for calculating the regional rating was published[7].

At a meeting of the Commission for Scientific and Technological Development on September 30, 2024, Deputy Minister of Science and Higher Education of the Russian Federation (Minobrnauki) D.S. Sekirinsky emphasized that "…the STD strategy involves the development and approval of indicators that will be used to assess the effectiveness of measures and instruments of state policy in the field of scientific and technological development. Such an assessment becomes a tool for monitoring the implementation of the STD strategy…"[8].

Various instruments are used to assess STD. For example, the work (Govorova, 2021, p. 28) proposes considering the inventive activity of universities as an important indicator of a region's technological development. Other studies discuss the need to introduce a system of indicators for monitoring the state of TS (Yankovskaya, 2023, p. 84). Most often, various indices are used, combining different aspects of the scientific and technological process into a single indicator.

The use of aggregated indicators has its advantages and disadvantages, like any other formal methods. On the one hand, they often mask differences in their components, which complicates making correct management decisions, and are poorly suited for describing qualitative processes. On the other hand, they allow for obtaining generalized information covering its different facets.

This issue also receives attention in government and expert circles. For example, the Association of Innovative Regions of Russia (AIRR)[9] maintains a database of best practices in regional governance, including examples of the most effective activities of constituent

[7] National Rating of Scientific and Technological Development of the Russian Federation's Constituent Entities. Available at: https://www.minobrnauki.gov.ru/ (accessed: 27.02.2025).

[8] Website of the RF Government. Available at: http://government.ru/news/52844 (accessed: 27.02.2025).

[9] The AIRR includes 19 regions: Altai, Krasnoyarsk, Perm territories; Irkutsk, Kaluga, Lipetsk, Nizhny Novgorod, Novgorod, Novosibirsk, Samara, Tyumen, Tomsk and Ulyanovsk regions, Republic of Bashkortostan, Republic of Mordovia, Republic of Sakha (Yakutia), Republic of Tatarstan (Tatarstan), Khanty-Mansi Autonomous Area – Yugra.

entities in this direction[10]. This organization also calculates the AIRR Scale[11], which allows for assessing regional efforts aimed at STD, although it must be acknowledged that it is more focused on innovative activity.

Since 2022, the Russian Ministry of Science and Higher Education (Minobrnauki) has been calculating the regional STD rating, developed in response to Presidential Directive Pr-290, paragraph 10v, dated December 24, 2021[12]. The Minobrnauki website also publishes the annual rating's passport[13]. According to Russian Minister of Education and Science V. Falkov, in the 2024 rating, the number of indicators was increased from 33 to 43. These criteria are still grouped into 3 blocks, "which reflect the involvement of regional authorities in the scientific and technological development of the subject, the level of conditions created for attracting knowledge-intensive business to the region, and the level of conditions for the researchers themselves"[14]. The work (Dorzhiyeva et al., 2022) reviewed the methodologies existing at that time, including the governmental one, highlighted their advantages and disadvantages, and proposed an author's methodology for assessing a region's contribution to STD. The need for its development was driven by the fact that the aforementioned ratings, in addition to regular statistical data, utilized expert assessments and special surveys[15]. In creating our own author's methodology, we proceeded from the need to use only regular statistical data, containing, where possible, comprehensive coverage of information on STD.

Aggregated Index of Scientific and Technological Development

The authors have been engaged with this issue since 2019, therefore the methodology has been revised several times and adjusted to the statistical data available at the moment. It should be noted that regional data on STD is more scarce than federal data, especially recently, as a number of indicators have been discontinued.

The final list of indicators used at this stage of research is presented in *Fig. 1*.

Compared to the initial dataset, some indicators in this study have been changed; for example, instead of the total number of researchers, an indicator of their number in STEM fields has been introduced. In our opinion, it more accurately reflects staffing demands in scientific and technological development. Thus, according to research by the Association of Innovative Regions of Russia, there is a trend in the economy towards growing demand for STEM specialists. According to AIRR data, over 12 months – from March 2024 compared to March 2023 – this indicator grew by 26%[16].

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[10] An open directory of the best regional practices of the subjects of the Russian Federation – members of the Association of Innovative Regions of Russia. Available at: https://i-regions.ru/images/books/AIRR_Best_practise2.pdf (accessed: 27.02.2025).

[11] Regional scale of innovation development. Available at: https://i-regions.ru/reiting/regionalnyy-indeks-razvitiya-innovatsiy-i-index (accessed: 06.02.2025).

[12] List of instructions following the joint meeting of the State Council and the Presidential Council on Science and Education on December 24, 2021. Available at: http://www.kremlin.ru/acts/assignments/orders/67752 (accessed: 06.02.2025).

[13] The latest available rating (the rating of STD of Russian regions based on the results of 2023) was published on December 25, 2024..

[14] Available at: https://www.minobrnauki.gov.ru/press-center/news/novosti-ministerstva/93149/?sphrase_id=8585800 (accessed: 06.02.2025).

[15] For example, in the ratings compiled by the Russian Rating Agency, or the rating published on the website of the Russian Ministry of Science and Higher Education.

[16] The regional index of demand for personnel for the innovative economy. Available at: https://i-regions.ru/reiting/ezhemesyachnyy-reyting-regionov-po-dostupnosti-kadrov-dlya-innovatsionnoy-ekonomiki (accessed: 06.02.2025).

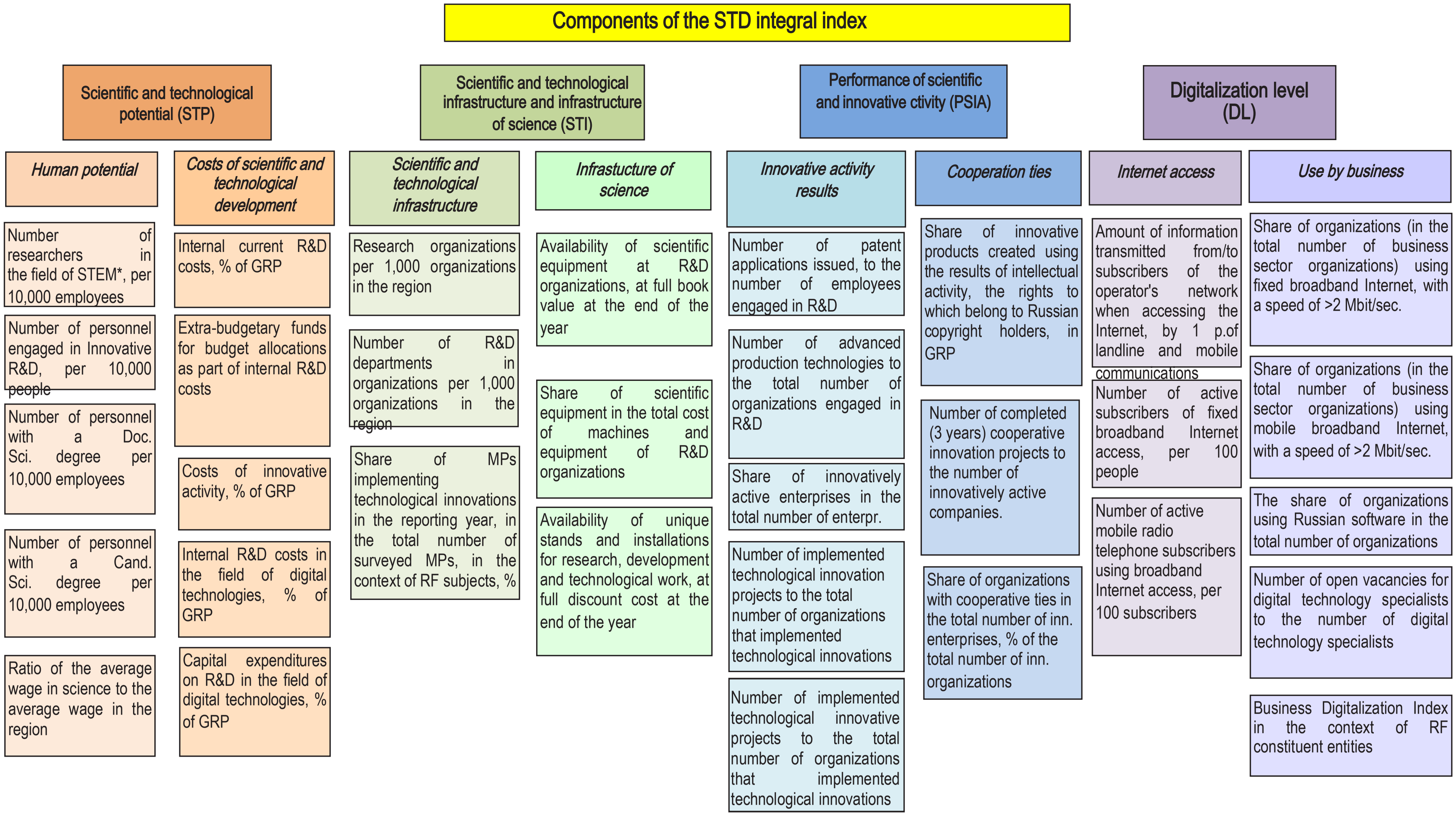

Figure 1. Aggregated index

* STEM disciplines include natural sciences: biology, physics, chemistry, as well as mathematics, logic, and statistics.
Source: Compiled based on (Volkova, 2024, pp. 57–59).

A lower limit for connection speed for broadband access was also added, since according to the Rosstat methodology, broadband access implies a speed of only 256 Kbit/s, which is very low for modern applications.

Discussion of results

The work (Volkova, Romanyuk, 2024) already investigated the relationship between the scientific and technological index and the economic structure; however, it was presented only within the framework of the GRP structure, and a conclusion was made about its certain influence on the STD index: regions with a higher share of manufacturing had a higher STD index. At the same time, it was noted that the issue requires further research.

In this study, the authors added the structure of manufacturing industries for consideration. This is important because the new technological paradigm (Glazyev, 2012) is characterized precisely by subsections within the classification of manufacturing industries (Garmashova, 2019, p. 63).

Rosstat does not provide the share of manufacturing in GRP, so it was determined as follows: the share of manufacturing in total GRP (data from Rosstat in the "National Accounts" section[17]) was divided proportionally to the share of the corresponding industries in shipped products. This approach assumes that the structure of intermediate consumption corresponds to the structure of shipped products. It is clear that this is not always the case, but this technique at a high level of aggregation does not introduce significant distortions and can be applied at the preliminary analysis stage; however, the results should be interpreted with caution.

The industries used for the analysis are presented in *Fig. 2* and highlighted in color.

The dataset was standardized using the min-max method, and cluster analysis was also conducted in two versions – based on STD indices and based on the GRP structure. The cluster centers resulting from the partitions are presented in *Tables 1* and *2*, and the regions are shown in *Fig. 3*.

In Figure 3, the clustering is based on the production structure, and the numbers correspond to the cluster numbers obtained for the partition by indices (see Tab. 1).

Let us briefly characterize the resulting clusters. In the first case (see Tab. 1), the set was divided into 5 clusters, ordered in Table 2 by descending aggregated index. Cluster 1 includes only one element – Moscow. The second cluster includes 6 subjects[18], the third – 22 regions[19], the fourth cluster consists of 35 subjects[20]. Finally, the fifth cluster combines 22 subjects with the lowest level of STD[21].

[17] Available at: https://rosstat.gov.ru/storage/mediabank/VRP_OKVED2_s_2016.xlsx (accessed: 06.03.2025).

[18] Moscow Region, Saint Petersburg, Republic of Tatarstan, Nizhny Novgorod, Novosibirsk, Tomsk regions. Here and below, the regions are listed in descending order of the aggregated index.

[19] Vladimir, Voronezh, Kaluga, Tula, Yaroslavl, Leningrad regions, Krasnodar Territory, Rostov Region, Republic of Bashkortostan, Perm Territory, Samara, Saratov, Ulyanovsk, Sverdlovsk, Tyumen, Chelyabinsk regions, Altai, Krasnoyarsk territories, Irkutsk, Omsk regions and Primorye Territory.

[20] Belgorod, Bryansk, Ivanovo, Kostroma, Kursk, Lipetsk, Orel, Ryazan, Smolensk, Tambov, Tver regions, Republic of Karelia, Komi Republic, Arkhangelsk, Vologda, Kaliningrad, Murmansk, Novgorod, Volgograd regions, Stavropol Territory, Republic of Mordovia, Udmurt Republic, Chuvash Republic, Kirov, Orenburg, Penza, Kurgan regions, Khanty-Mansi Autonomous Area – Yugra, Yamal-Nenets Autonomous Area, Kemerovo Region, Republic of Sakha (Yakutia), Kamchatka, Khabarovsk territories, Amur and Magadan regions.

[21] Nenets Autonomous Area, Pskov Region, Republic of Adygea, Republic of Kalmykia, Republic of Crimea, Astrakhan Region, Sevastopol, Republic of Dagestan, Republic of Ingushetia, Kabardino-Balkarian Republic, Karachay-Cherkess Republic, Republic of North Ossetia–Alania, Chechen Republic, Republic of Mari El, Republic of Altai, Republic of Tyva, Republic of Khakassia, Republic of Buryatia, Trans-Baikal Territory, Sakhalin Region, Jewish Autonomous Region, Chukotka Autonomous Area.

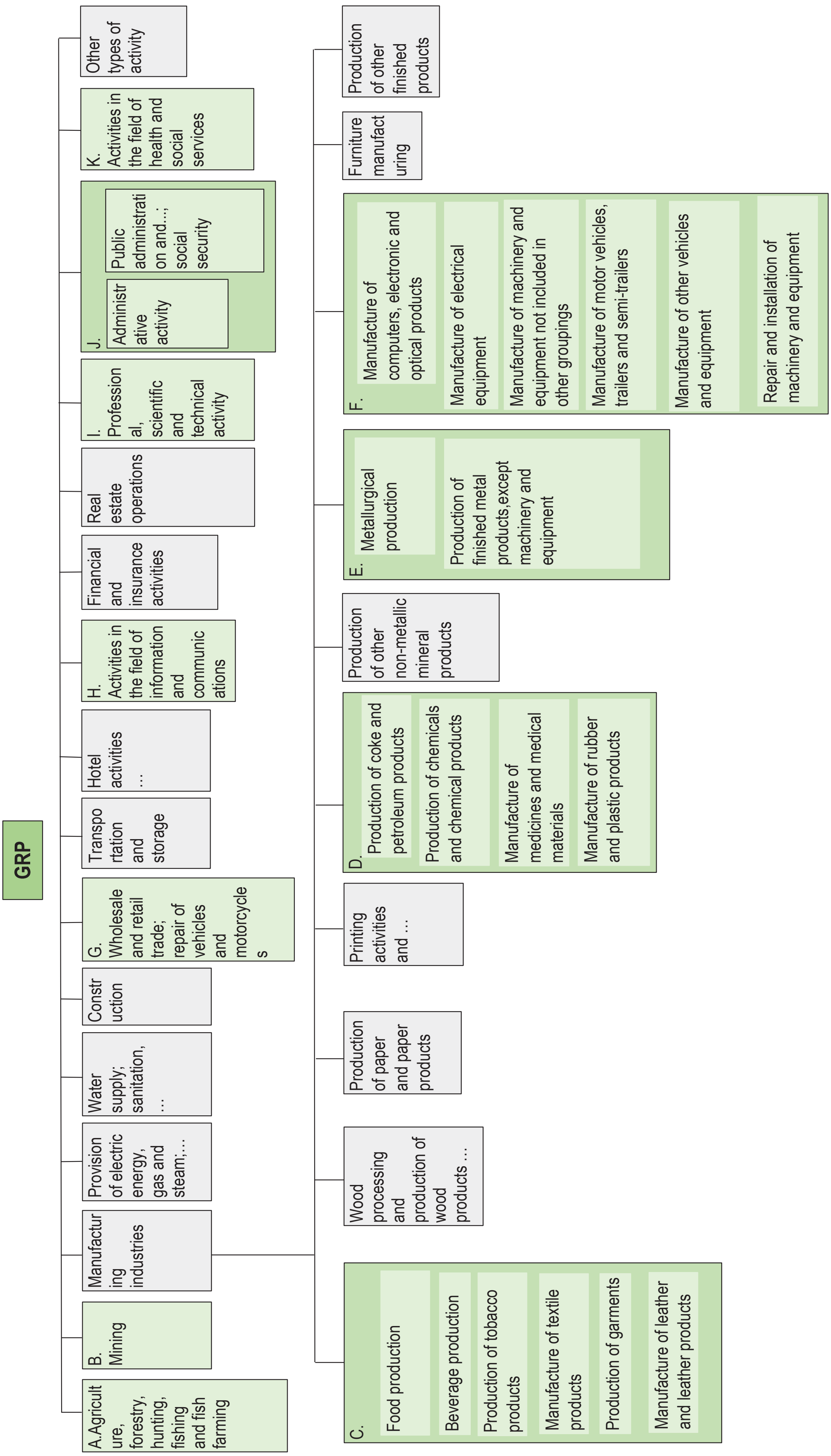

Figure 2. Types of activities included in the analysis

Source: All-Russian Classifier of Types of Economic Activity (approved by Order of Rosstandart 14-st dated January 31, 2014, as amended on April 9, 2025. Available at: https://www.consultant.ru/document/cons_doc_LAW_163320/).

Cluster 1: Moscow, Saint Petersburg, Moscow Region, Nizhny Novgorod Region, Novosibirsk Region, Sverdlovsk Region, Ivanovo Region.

Cluster 2: Chelyabinsk Region, Kaluga Region, Republic of Bashkortostan, Yaroslavl Region, Tula Region, Leningrad Region, Vladimir Region, Omsk Region, Lipetsk Region, Murmansk Region, Tver Region, Smolensk Region, Ryazan Region, Chuvash Republic, Kirov Region, Vologda Region, Novgorod Region.

Cluster 3: Republic of Tatarstan, Tomsk Region, Perm Territory, Samara Region, Krasnodar Territory, Irkutsk Region, Belgorod Region, Kursk Region, Republic of Karelia, Komi Republic, Arkhangelsk Region.

Cluster 4: Tyumen Region, Republic of Sakha (Yakutia), YaNAA, Magadan Region, KhMAA, Sakhalin Region, Nenets AA.

Cluster 5: Krasnodar Territory, Rostov Region, Ulyanovsk Region, Voronezh Region, Saratov Region, Primorye, Altai Stavropol territories, Republic of Mordovia, Volgograd Region, Khabarovsk Territory, Penza Region, Kaliningrad Region, Kostroma Region, Karachay-Cherkess Republic, Kamchatka Territory, Tambov Region, Bryansk Region, Orel Region, Republic of Buryatia, Kurgan Region, Amur Region, Republic of Crimea, Sevastopol Republic of North Ossetia–Alania, Pskov Region, Republic of Mari-El, Kabardino-Balkar Republic, Republic of Dagestan, Republic of Altai, Chechen Republic, Republic of Adygea, Republic of Kalmykia, Republic of Tyva, Republic of Ingushetia.

Figure 3. Partition of regions into clusters

Note: The map is compiled as of 2022, which was the year of the study.
Source: own calculations.

In the cluster analysis by the sectoral structure of GRP, 4 clusters were initially identified, but one of them, which included regions with a predominantly diversified economic structure, turned out to be too heterogeneous, so it was split again into 2 clusters. In Table 2, the clusters are arranged in descending order of the average aggregated index for the cluster. The letters correspond to the letters of the industries in Figure 2. In our case, the intersections of the partitions are of greatest interest, which are clearly visible in Figure 3.

Cluster 1 (see Tab. 2) has a large share of wholesale and retail trade, as it combines large cities and logistics centers. It also has the maximum value among all for the share of professional, scientific, and technical activities (hereinafter referred to as scientific), as well as the information and communication sector. The share of public administration and military security, and administrative activities in this cluster is also high.

This circumstance is not surprising, since the constituent entities of the Russian Federation included in this cluster are administrative centers of large regions[22]. As can be seen in Figure 3, according to the clustering presented in Table 1, these regions belong to clusters 1–2, i.e., they are regions with the highest STD index values. The Sverdlovsk Region, which falls into the third cluster by aggregated index, occupies the top position there, and its indices differ only slightly from the values of regions in the lower part of Cluster 2.

Cluster 2 has the most diversified economic structure. Its center has the highest shares among all clusters in chemical, metallurgical, and machine-building production. As seen in Figure 3, the regions of this cluster, according to the aggregated index, are "mid-tier" – represented by numbers 3 and 4 in Figure 1.

A number of regions in Cluster 2 do not occupy very high positions by aggregated index. It should be noted that all of them have a significant share of

Table 1. Cluster centers broken down by indices

Region	Aggregated index	STP	STI	PSIA	DL
Russian Federation	0.168	0.191	0.089	0.114	0.253
Cluster 1	0.796	0.749	0.788	0.779	0.877
Cluster 2	0.336	0.436	0.252	0.240	0.370
Cluster 3	0.168	0.141	0.089	0.155	0.275
Cluster 4	0.106	0.065	0.025	0.092	0.232
Cluster 5	0.066	0.037	0.025	0.043	0.155
Source: own calculations.					

Table 2. Cluster centers broken down by structure

Region	Aggregated index	A	B	C	D	E	F	G	H	I	J	K
Russian Federation	0.17	4.50	14.40	3.11	5.90	3.73	2.89	14.50	3.20	4.30	7.30	3.80
Cluster 1	0.37	2.20	1.17	4.17	4.37	5.40	4.08	**20.94**	3.76	5.93	**8.11**	4.26
Cluster 2	0.13	6.51	1.55	6.55	**8.93**	**9.56**	5.69	**10.69**	1.72	2.39	6.88	4.54
Cluster 3	0.13	**5.22**	**31.54**	2.21	3.08	3.91	2.40	**7.25**	1.43	1.89	7.40	4.15
Cluster 4	0.11	1.43	**67.94**	0.54	1.72	0.21	0.11	2.86	0.51	0.89	4.24	2.37
Cluster 5	0.10	**14.14**	2.38	4.67	1.66	1.41	3.04	**12.11**	2.06	1.98	**12.07**	6.00
Source: own calculations.												

[22] To a lesser extent, this applies to the Ivanovo Region, but it is located on the periphery of the cluster.

trade, public administration, and administrative and economic management in their GRP.

In regions with not very high aggregated indices, such as the Smolensk, Ryazan, Kirov, Volgograd, and Novgorod regions, the share of chemical production is high, and in some of them, metallurgy and machine-building make a fairly significant contribution to GRP. Consequently, these industries and activities currently lack STD potential and are oriented towards the old technological paradigm[23]. A large share of public and administrative-economic management diverts necessary resources from STD.

Cluster 3 is characterized by a high share of extractive industries, though it is lower than in Cluster 4. It also has a large share of agriculture, trade, public administration, and the administrative-economic sphere.

According to the STD index, this cluster includes regions that predominantly have low aggregated index values (numbers 4 and 5 in Fig. 3). This cluster also includes two constituent entities of the Russian Federation (Republic of Tatarstan and Tomsk Region) that have a fairly high aggregated index but a more diversified structure with a high share of oil refining (Tatarstan) and science (Tomsk Region) in GRP.

Furthermore, a number of regions show a relatively high STD index (number 3 in Fig. 3):

– Perm Territory with a high share of chemical and petrochemical production; the share of science there is higher than the cluster average (2.4 and 1.89%, respectively);

– Samara Region, where the share of machine-building production is greater than the Russian average (2.5 times – 7.22 and 2.89%, respectively); the share of science in the region is also relatively high – 3.6%;

– Krasnoyarsk Territory, which has a very high share of metallurgical production (24.8%).

Cluster 4 includes extractive regions; the share of other industries in them is insignificant. In terms of STD level, these regions mostly belong to the third and fifth clusters.

Cluster 5 comprises regions with a high share of agriculture, food production, trade, and public administration. From the perspective of clustering by STD index, these regions are among the weakest – clusters 4 and 5. Nevertheless, the constituent entities of the Russian Federation within this cluster that have relatively high STD indices are characterized by a comparatively high share of science relative to the cluster average of 1.98%. For example, in the Voronezh Region it is 4.5%, in the Krasnodar Territory – 3.2%, in the Rostov Region – 2.7%, in the Saratov Region – 2.8%.

A preliminary analysis of Tables 1 and 2 suggests that the values of the aggregated STD index depend on the sectoral specialization of a region. A more diversified economic structure leads to a higher STD index, which aligns with the conclusions of the aforementioned study on China's economy (Kroll, Neuhäusler, 2020), stating that regions with diversified economies make the greatest contribution to innovative development.

To confirm this hypothesis, a correlation analysis was conducted; its results are presented in *Table 3*. The column names in it correspond to the designation of industries above. Initially, for the entire dataset and for each individual cluster, Spearman's rank correlation was calculated, for which the distribution of the original series is not important.

However, the results obtained for cluster 1 were unsatisfactory, so after checking the normality of the distribution for it, Pearson correlation coefficients were calculated[24].

Analysis of Table 3 showed that interdependence between the aggregated STD index, its components, and the GRP structure is present for all clusters, but it varies depending on the region's specialization.

[23] The distribution of industries according to technological patterns is considered in the work (Garmashova, 2019, p. 63).

[24] Table 3 shows only the values of the correlation coefficients. Significant coefficients are shown in bold.

Table 3. Results of correlation analysis

Region	A	B	C	D	E	F	G	H	I	J	K
Russian Federation											
Aggregated index	**-0.24**	-0.04	**0.24**	**0.64**	**0.48**	**0.42**	**0.26**	**0.30**	**0.70**	**-0.44**	**-0.46**
STP	-0.19	-0.09	**0.23**	**0.46**	**0.35**	**0.36**	**0.32**	**0.33**	**0.74**	**-0.24**	**-0.29**
STI	-0.06	-0.12	**0.29**	**0.50**	**0.31**	**0.38**	**0.38**	**0.36**	**0.70**	**-0.21**	**-0.25**
PSIA	-0.20	-0.14	**0.23**	**0.70**	**0.53**	**0.47**	**0.29**	**0.32**	**0.55**	**-0.53**	**-0.45**
DL	**-0.38**	0.10	0.05	**0.55**	**0.44**	**0.27**	0.14	0.11	**0.51**	**-0.51**	**-0.59**
Cluster 1 (Pearson)											
Aggregated index	-0.62	-0.31	-0.66	**0.91**	-0.29	-0.51	0.23	**0.85**	**0.90**	-0.16	**-0.76**
STP	-0.43	-0.29	-0.73	**0.90**	-0.31	-0.25	0.28	0.73	**0.96**	-0.42	**-0.85**
STI	-0.51	-0.18	-0.58	**0.82**	-0.40	-0.69	0.22	**0.89**	**0.82**	-0.06	-0.60
PSIA	-0.73	-0.36	-0.55	**0.84**	-0.16	-0.54	0.17	**0.79**	**0.77**	-0.01	-0.66
DL	-0.69	-0.34	-0.59	**0.87**	-0.23	-0.55	0.20	**0.82**	**0.82**	-0.06	-0.69
Cluster 2											
Aggregated index	-0.34	**0.67**	0.04	-0.09	-0.04	0.32	-0.15	0.06	**0.59**	-0.19	-0.18
STP	-0.07	**0.51**	0.13	-0.21	0.02	0.25	-0.20	0.06	0.41	-0.15	-0.28
STI	-0.28	**0.58**	0.10	0.05	-0.20	0.40	-0.21	-0.03	**0.66**	-0.13	-0.02
PSIA	-0.46	0.43	0.04	0.20	0.02	0.21	-0.18	0.15	**0.55**	-0.45	-0.13
DL	-0.28	0.77	-0.26	-0.28	0.26	0.05	-0.16	-0.04	0.30	0.06	-0.05
Cluster 3											
Aggregated index	0.16	-0.28	**0.59**	**0.69**	0.30	**0.55**	0.43	0.52	**0.82**	**-0.55**	-0.43
STP	0.12	-0.32	**0.58**	**0.69**	0.18	**0.50**	0.33	0.38	**0.85**	**-0.50**	-0.41
STI	0.17	-0.11	0.40	**0.65**	0.13	**0.53**	0.37	0.44	**0.64**	**-0.53**	**-0.54**
PSIA	0.12	-0.20	**0.48**	**0.74**	0.44	**0.62**	**0.5**	0.44	**0.65**	**-0.73**	**-0.58**
DL	0.05	-0.14	0.43	**0.58**	0.31	**0.52**	0.21	0.29	**0.62**	-0.42	-0.41
Cluster 4											
Aggregated index	-0.11	-0.32	-0.28	0.68	0.09	**0.79**	0.19	0.35	0.55	-0.20	-0.02
STP	0.42	-0.74	-0.13	-0.00	0.55	0.26	0.73	**0.84**	**0.84**	0.45	0.61
STI	0.11	-0.55	-0.17	0.23	0.27	0.55	0.49	0.67	0.74	0.11	0.33
PSIA	-0.40	0.00	-0.29	**0.92**	-0.21	**0.87**	-0.19	-0.03	0.20	-0.53	-0.38
DL	-0.30	-0.07	-0.31	**0.83**	-0.10	**0.87**	-0.07	0.05	0.34	-0.44	-0.30
Cluster 5											
Aggregated index	0.08	0.09	**0.48**	**0.72**	**0.53**	**0.46**	0.25	0.22	**0.68**	**-0.51**	-0.59
STP	-0.09	0.36	0.19	0.31	0.09	0.18	0.26	0.05	**0.68**	-0.12	-0.24
STI	0.19	0.16	**0.40**	**0.52**	0.25	0.24	0.30	0.05	**0.55**	**-0.36**	**-0.43**
PSIA	0.17	-0.21	**0.50**	**0.75**	**0.69**	**0.59**	0.32	0.29	**0.45**	**-0.70**	**-0.56**
DL	0.04	0.03	**0.39**	**0.59**	**0.54**	**0.37**	0.29	0.18	**0.50**	**-0.52**	**-0.67**

Thus, for the Russian Federation as a whole, almost all coefficients are significant, except for those related to extractive industries. The strongest positive relationship exists between science and the aggregated STD index and its sub-indices. This circumstance is quite predictable. It is clear that science acts as the driving force of scientific and technological development.

Among the sub-indices, the strongest positive relationship with science is shown by the scientific and technological potential, which includes indicators of science funding and the quality of human resources, which also indirectly depends on the former. Thus, the volume of science funding has a significant connection with the level of STD.

Fairly high positive and significant coefficients characterize chemical and petrochemical, as well as metallurgical productions, especially concerning the sub-index of innovation activity performance, which includes indicators characterizing completed innovation projects both in general and in cooperation with other participants. This can be explained by the presence of corporate scientific divisions in large oil and gas corporations. For example, PJSC "NK "Rosneft" has 29 corporate research and design institutes employing over 13.5 thousand people[25]; the "LUKOIL-Engineering" division collaborates with leading universities within the framework of scientific and engineering support centers[26]; in Gazprom, LLC "Gazprom VNIIGAZ" is a constituent element of the corporation – the leading scientific center of PJSC "Gazprom"[27].

Significant and sufficiently large in magnitude, but negative coefficients are observed for such activities as public administration and military security, as well as activities in healthcare, especially regarding the performance of innovation activity and the level of digitalization. This is likely related to competition for state funds, as these activities are predominantly funded from the state budget. It can also be assumed that regions with a hypertrophied share of the public sector are, due to bureaucratization, less interested in business activation.

A rather high negative coefficient for Russia as a whole is observed between the sub-index of digitalization level and agricultural activity. This can be explained by the lower population density in rural areas and, consequently, higher costs for infrastructure development.

In Cluster 1, there are not many significant coefficients (see Tab. 3). Here, large significant coefficients are also found for science, chemical production, and information and communication activities, while a significant negative coefficient is noted for healthcare. The explanations are similar to those stated above; it can also be added that many scientific subdivisions of petrochemical enterprises are located in large cities belonging to Cluster 1.

As noted earlier, Cluster 2, from the perspective of GRP structure, is quite heterogeneous. For instance, it includes such diverse regions as the Murmansk Region, where the share of agriculture, forestry, hunting, fish farming and fishing is 11.5%, and metallurgical production is 27%, and the Novgorod Region with almost 22% chemical and petrochemical production and only 1.6% metallurgy. Perhaps for this reason, Cluster 2 shows significant correlation coefficients only for science. The cluster includes old industrial regions of Russia[28] with outdated fixed assets. Thus, the degree of fixed assets wear and tear on average

[25] Available at: https://www.rosneft.ru/Development/knpk (accessed: 27.04.2025).
[26] Available at: https://engineering.lukoil.ru/ru/Activities/CooperationWithUniversities (accessed: 27.04.2025).
[27] Available at: https://vniigaz.gazprom.ru/about (accessed: 27.04.2025).
[28] See (Sorokina, 2024).

for this cluster was higher than the Russian average. For comparison, this indicator for Russia as a whole was 48% in 2022, while for cluster 2 it was 51%, which is higher than for all other clusters (in Cluster 1 the average wear was 46%, in Cluster 3 – 49%, in Cluster 5 – 47%). Only Cluster 4, concentrating on extractive industries, had higher fixed assets wear – 54%[29]. The mentioned work (Sorokina, 2024) also points to the insufficient innovativeness of these regions.

Cluster 3, where extractive industries and agriculture are developed, traditionally has significant positive coefficients for science, with the highest values of these coefficients for the first sub-index, which depends on science funding. A close connection is also observed with the share in GRP of such productions as chemical and petrochemical, as well as machine-building. There is a close but negative connection with such activities as public administration and healthcare; possible reasons for this phenomenon were mentioned above.

Cluster 4, oriented toward mineral extraction, shows correlation links for only a small number of variables. Thus, the aggregated index overall correlates only with the share of machine-building production, and the sub-indices of innovation activity performance and digitalization level correlate with the share of chemical production. It should be noted that neither in this cluster nor in Cluster 3, where the share of extraction is also high, is there a correlation between the level of extractive production in GRP (neither positive nor negative). The reason for this may be that in these regions only extraction is carried out, while extraction and processing technologies are researched in regions belonging to other clusters, particularly Cluster 1.

In Cluster 5, there is traditionally a close connection between the aggregated index overall and all its sub-indices and science. A negative dependence between the indices and public administration and healthcare is also traditionally observed. In this cluster, a fairly close dependence has emerged between the combined indicators of food and textile production and the STD indices, which are precisely the specializations of the territories in this cluster.

Conclusion

In conclusion, it must be said that regional analysis is limited by the block of regional data in open access. From the authors' point of view, statistics in this area require improvement, which would contribute to enhancing the quality of decision-making.

It is also necessary to state that at the meso level – the regional level – one can only speak of their contribution to the country's achievement of TS, for which STD is one of the mechanisms.

In accordance with the Strategy for Technological Development, the construction of STD program matrices in regions is envisaged, which requires taking into account the specifics of each region.

To assess the level of STD for each region, an author's aggregated index was calculated. The conducted cluster analysis based on 2022 data for two groups of features – by the GRP structure of regions and by the level of STD – allowed for identifying established clusters and analyzing their overlap.

The study showed that a fairly stable dependence between the economic structure and scientific and technological development can be traced. However, in different clusters, different economic sectors come to the fore. This makes it possible to identify key elements

[29] Calculated according to: Regions of Russia. Socio-economic indicators. 2023: Statistical collection. Rosstat. Moscow, 2023. P. 509.

in each type of region, the development of which could give impetus to STD.

The presence of a diversified economic structure has a beneficial effect on STD. On average, regions with a balanced economic structure have a higher STD index.

In all clusters, a dependence is observed between the share of science and the aggregated index and its sub-indices. This is especially true for the sub-index directly or indirectly responsible for science funding.

In almost all clusters, a close negative correlation is observed between the aggregated STD indices and the shares of public administration and healthcare in GRP. The reason for this may be competition for limited financial resources, since the share of state funding for science is still very high. According to HSE data, state funding accounts for 66.6% of all domestic expenditure on research and development. Furthermore, a large share of public administration leads to bureaucratization, which reduces incentives for technological development.

Thus, an increase in non-state funding for research and development could accelerate scientific and technological development. One can agree with the opinion of colleagues cited above that the development of scientific and educational centers integrating research centers and industrial enterprises could contribute to solving emerging problems in industry.

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