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The Specific Structure and Regional Proportions of Innovation Costs in the Russian Economy

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Abstract. The most important choice of a company in the implementation of innovative activities is the decision on the method of mastering new technologies. There is a distinction, first of all, between the development of technologies through their research and through their operation. The assessment of the ratio of these two methods of technology development in the economy of Russian regions has significant research potential. The study implements a methodology for comparative analysis of the spatial dynamics of various types of innovation activities, which allows overcoming the methodological limitations of official statistics. The coefficients of elasticity according to the time trend for the total costs of innovation activities, including research and development costs, costs for the purchase of machinery and equipment, and costs for industrial design (engineering) and design by groups of regions of Russia in 2011–2015, 2016–2018 and 2019–2022 were obtained. The results of the study detail the trends in the innovative development of groups of regions in 2011–2022 with a specification of the dynamics in the pre–sanctions and sanctions periods. It has been established that the systematic development of technologies through their research was carried out mainly in the pre-sanctions period and only in the most developed regions. During the period of increasing sanctions pressure, research and development are localized in metropolitan centers, and remote and underdeveloped regions begin to systematically master new technologies through the purchase of machinery and equipment, as well as industrial design (engineering) and design. The system of econometric estimates obtained in the study, which takes into account both the economic specifics of innovations and the methodological problems of their statistical accounting, made it possible to specify

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the role of the most important ways of mastering new technologies in the country's regions within the framework of the pre-sanctions and sanctions periods.

Key words: innovations, research and development, purchase of machinery and equipment, engineering, regions of Russia, sanctions shock, official statistics.

Introduction

The specific structure of innovations has traditionally been in the focus of research – from the classical works of J. Schumpeter to the latest taxonomic and econometric research. The effect of innovations on the economy and society depends both on the type of specific innovation and on the diversity of innovations in general (Schumpeter, 1934; Edwards-Schachter, 2018; Domnich, 2022). In Russian official statistics, the largest amount of information on the specific structure of innovations is provided by the structure of innovation costs of organizations[1] by type of innovation activity, formed on the basis of annual surveys of large and medium enterprises performed with the use of Form 4–innovations[2]. According to Rosstat, in 2011–2022, innovation costs of Russian enterprises increased at current prices from 733.8 to 2662.6 billion rubles, which highlights the importance of the indicator. However, due to methodological limitations, the economic interpretation of this data set is difficult. The study overcame the most important of such limitations, which hinder spatial and temporal comparisons of the structure and dynamics of innovation costs in the country's regions.

The aim of the work is to provide a generalized quantitative spatial and temporal characteristic of the change in the volume of organizations' costs for these types of innovative activities in the regions of Russia in 2011–2022. The objectives of the research are as follows: to study global experience related to the analysis of the structure of innovations in terms of two main ways of learning new technologies (exploration and exploitation); to analyze the spatial dynamics of innovations of these types in Russia's regions, taking into account methodological limitations imposed by official statistics; and to formulate stylized facts about the spatial and temporal changes in the structure of innovations in the regions of the country, taking into account significant heterogeneity of the latter.

The subject of the study is spatial and temporal differentiation of the volume and rate of change in innovation costs in the entrepreneurship sector of Russia's regions in the context of major types of innovation activities: research and development, purchase of machinery and equipment, industrial engineering and design. The object of the study includes 81 regions[3] in 2011–2022 with detailed description for three periods: 2011–2015, 2016–2018 and 2019–2022, due to changes in the methodology of statistical observation.

[1] The actual expenditures, expressed in monetary form, on the implementation of one, several or all types of innovation activities (related to the process of developing and implementing technological innovations and other innovations) performed in the organization. Current and capital expenditures are taken into account as part of innovation costs. At the same time, it does not matter at what stage the innovation process is: at the final stage, when the equipment is already working, has been put into operation, that is, production has been established and goods (works, services) are being produced, or at the initial, intermediate stage, for example, when new equipment is still being installed or it is only ready for operation, but it has not been in operation yet, has not been tested in production and has not been used in the production of goods (works, services). Order of Rosstat (Federal State Statistics Service) 424, dated July 30, 2020. Available at: https://www.garant.ru/products/ipo/prime/doc/74357805/ (accessed: August 1, 2024).

[2] Innovation costs of organizations (since 2010). Available at: https://rosstat.gov.ru/storage/mediabank/Innov-5.xls (accessed: July 1, 2024).

[3] Sevastopol, as well as the republics of Ingushetia, Crimea and Chechnya were excluded from the sample.

Theoretical foundations of the research

According to Rosstat, the most important types of innovation activities are research and development, as well as the purchase of machinery and equipment. Their total share in the total innovation costs in 2011–2022 increased from 68.3% to 78.6%[4]. It is important that we are talking only about those types of research, development and investments in means of production, “which, during the observation period, are aimed at or lead to the creation of new or improved products (goods, services) that differ significantly from products previously produced by the organization, intended for market introduction, new or improved business processes, significantly different from previous relevant business processes intended for use in practice”[5]. In this regard, it is appropriate to consider these indicators as cost estimates of the intensity of implementation of two different ways of mastering new technology: research and operation. Research is defined as studying and adding technical knowledge in a new field, unfamiliar to the company before. Operation is the development of technologies that the company itself and (or) the firms surrounding it already possess (Lennerts et al., 2019; Clauss et al., 2020; Mahmood, Mubarik, 2020).

Exploration and exploitation of technology have different effects on the company’s performance. This urges enterprises to seek a compromise between them due to limited resources (Cho, 2020; Wen et al., 2020). When a firm directs funds to both exploration and exploitation (which is allowed by Form 4 –innovations), the redistribution of resources between them entails two types of effects. When the amount of resources devoted to the exploitation of new technologies increases, then the amount of resources devoted to their exploration decreases. Thus, short-term performance of the company improves, but the opportunities for improving long-term performance decrease. On the other hand, if investments in exploration increase, then short-term performance of the firm becomes difficult to improve, but the opportunities for improving long-term performance of the firm increase. In this way, enterprises adapt to long term changes while maintaining short-term management performance through an appropriate balance between exploration and exploitation (Cho, 2020; Johnson et al., 2022).

The discussion about comparative importance of exploration and exploitation, and also about their confrontation and synergistic effect has been unfolding since the early 1990s[6]. However, the study of publication databases Google Scholar, Web of Science, Scopus and elibrary.ru showed that this discussion had never touched on the Russian experience. Therefore, the most important scientific problem of research on Russian material, according to the author, should be the most reliable assessment of the scale and dynamics of the phenomena under discussion, including in the regions of a large country.

According to official statistics and current prices, the most noticeable changes in the ratio between research and development costs and the purchase of machinery and equipment occurred in the first five years of the period under consideration, i.e. in 2011–2015. In 2011, R&D costs accounted for 23.6% of innovation costs, and the cost of

[4] Calculated according to: Innovation costs of organizations (since 2010). Available at: https://rosstat.gov.ru/storage/mediabank/Innov-5.xls (accessed: July 1, 2024).

[5] Order of Rosstat (Federal State Statistics Service) 424, dated July 30, 2020. Available at: https://www.garant.ru/products/ipo/prime/doc/74357805/ (accessed: August 1, 2024).

[6] For an overview of relevant research, see, for example (Li et al., 2023).

purchasing machinery and equipment – 44.8%. In 2012, the share of R&D costs increased to 35.9%, while the cost of purchasing machinery and equipment decreased to 42.1%. By 2015, the share of the indicators in innovation costs was 44.4% and 33%, respectively, and this ratio generally remained until 2022[7].

The third most expensive, but not the most important, type of innovation activity is industrial engineering and design[8]. Engineering is considered as a link between all other types of innovation, and design is considered as a link between technology and the consumer (Medyanik, 2017; Charyton, 2015; Gershman et al., 2020). The share of industrial engineering and design in innovation costs decreased from 23.2% in 2011 to 9.8% in 2012 and further to 5% by 2022[9].

Thus, in the whole country, the economic weight of R&D as a way of mastering new technologies is increasing and consolidating due to the outstripping growth of this type of cost compared with the purchase of machinery and equipment, and industrial engineering and design. The most significant changes occurred in 2011–2015. However, to answer the question of how universal this trend is in the context of regions – Central, Northern, Southern and Eastern, with an industrial or agricultural type economy, with a developed or insignificant scientific and production base, it is necessary to overcome significant methodological limitations.

[7] Calculated according to: Innovation costs of organizations (since 2010). Available at: https://rosstat.gov.ru/storage/mediabank/Innov-5.xls (accessed: July 1, 2024).

[8] In 2011–2014 Rosstat published the total cost of industrial engineering and design, and in 2015–2022 separately for industrial engineering and design. Accordingly, in order to ensure comparability, these costs have been added together.

[9] Calculated according to: Innovation costs of organizations (since 2010). Available at: https://rosstat.gov.ru/storage/mediabank/Innov-5.xls (accessed: July 1, 2024).

Methodological problems of the study

Rosstat has been collecting data on the innovation activities of Russian organizations for three decades, but this does not contribute to the formation of an array of regional innovation statistics. The methods of collecting, processing and publishing statistics according to Form 4–innovations change regularly, which devalues the accumulated statistics from the point of view of longitudinal retrospective studies. Over 12 years (from 2011 to 2022), the coverage of the surveyed organizations changed four times: in 2011, 2015, 2016 and 2019[10]. Moreover, Rosstat does not publish comparable data on "old" techniques, and regional and sectoral detailing of innovation indicators for most regions does not make sense: if a single enterprise carried out innovation costs in industry j of region i per year t (a very frequent case), then Rosstat will not show information, referring to "ensuring confidentiality of primary statistical data"[11]. Such data gaps are typical even for individual regions with small economies, including several innovatively active enterprises. The resulting cost indicators of technological innovations (the cost

[10] In 2011, Form 4–innovations began to be distributed to organizations that engage exclusively in R&D, whose innovation costs in this year amounted to 15.9% of the total volume. Less significant changes occurred in 2015, when the range of industries surveyed was expanded and included construction of buildings and facilities made of prefabricated structures, and performance of other construction works. In the total pool of innovation costs in 2015 the above-mentioned industries accounted for only 0.001%, which makes it possible to consider 2015 as part of the period 2011–2015, and to start the next time period from 2016, when the agricultural sectors that were included in the survey already provided 1.2% of total innovation costs. Noticeable changes in sectoral coverage occurred in 2019, when "new" industries (construction, transportation and storage, healthcare and social services) raised total innovation costs by 13.2%, which makes it necessary to distinguish the periods 2016–2018 and 2019–2022. Calculated according to: Innovation costs of organizations (since 2010). Available at: https://rosstat.gov.ru/storage/mediabank/Innov-5.xls (accessed: July 1, 2024).

[11] See Federal Law 282-FZ, dated November 11, 2007 "On official statistical accounting and the system of state statistics in the Russian Federation" (Paragraph 5, Article 4; Paragraph 1, Article 9).

of innovative activities and the volume of innovative goods, works, services) cannot be normalized by the number of innovatively active enterprises and (or) the number of employees employed at such enterprises, since the relevant indicators are not made publicly available. There is also no official explanation about which deflators should be used to convert cost indicators of innovations into comparable prices; this procedure (if performed at all) is entirely at the discretion of the researcher, which gives rise to a wide arbitrariness in the methodology of empirical research.

In addition to these technical problems, there are objective statistical challenges caused by the economic nature of innovation as a phenomenon. Introducing a specific innovation is always a non-trivial social process with an unpredictable outcome (Domnich, 2022, p. 100). Russian regional innovation indicators are characterized by unsteady dynamics, high range of variation, abundance of zero values and unpredictability of cost indicators in terms of the comparative size of regional economies.

The very possibility of implementing large innovative projects in a particular region is conditioned primarily by the history of its exploration and development (the "track effect") and the opportunity to attract funding from the federal budget[12]. There is a pronounced differentiation of regions into a few territories that regularly absorb significant amounts of innovation costs, and regions whose innovation costs are incomparably small, even taking into account the relative size of their economies. There is often a situation when the innovation system of a particular region regularly allocates funds for innovative activities, but hardly engages in shipping innovative products, and vice versa (Domnich, 2018). Therefore, economic analysis of innovation costs is valid both together with the volume of innovative goods, works and services, and separately from it.

The literature on innovative development of Russian regions does not usually take into account these methodological limitations (see, for example, Golova, 2024; Dementiev, 2024; Tereshchenko, 2024; Shorokhova, 2024). This makes a methodology that takes into account these methodological limitations even more relevant.

Research methodology

The solution of the stated tasks was carried out in four stages.

At the first stage, regional data on innovation costs, including research and development, purchase of machinery and equipment, and industrial engineering and design, hidden by Rosstat in order to "ensure the confidentiality of primary statistical data" were restored (*Tab. 1*). In the simplest case, when in year t within a particular federal district, Rosstat hid data for only one region i, then they were restored as a difference obtained by subtracting from the value of the total indicator for the district the sum of the indicator values of all other regions within the district. If data for two or more regions within the district were hidden, they were restored by proportionally distributing this difference across regions based on information about past and (or) future values of regional indicators. In total, according to four indicators for 2011–2022, 119 observations were restored, which were then used on a par with the official Rosstat data. Balanced data panels for 2011–2015, 2016–2018 and 2019–2022 were formed.

[12] The share of federal budget funding in the total innovation costs of Russian enterprises in 2010–2022 increased from 4.7 to 23.6% (Indicators of innovation activity: 2012: Statistical collection, Moscow: HSE, 2012. P. 411; Vlasova V.V., Gokhberg L.M., Gracheva G.A. et al. (2024). Indicators of innovation activity: 2024: Statistical collection; Moscow: ISIEZ VShE. P. 208. Available at: https://www.hse.ru/primarydata/ii?ysclid=m2fjt7afyx658656305 (accessed: October 19, 2024).

Table 1. Restored data by region and year

Region	Innovation costs	including		
		Research and development	Purchase of machinery and equipment	Industrial engineering and design
Republic of Adygea	-	2021, 2022	2020	2020
Republic of Altai	-	2020–2022	2020	2020–2022
Republic of Buryatia	-	-	2020	2020–2022
Republic of Dagestan	-	-	-	2022
Republic of Kalmykia	2022	2021, 2022	2020, 2021	2020–2022
Kabardino-Balkarian Republic	-	-	2021	2020, 2022
Karachay-Cherkess Republic	2021, 2022	2020	2021, 2022	2020–2022
Republic of Karelia	-	-	-	2020, 2022
Republic of Komi	-	-	-	2021
Republic of Sakha (Yakutia)	-	-	-	2022
Republic of North Ossetia-Alania	2022	2021, 2022	2020	2020–2022
Republic of Tyva	-	2020	-	2020–2022
Republic of Khakassia	-	2020–2022	2020	2020–2022
Trans-Baikal Territory	-	2020	-	2021, 2022
Kamchatka Territory	-	-	-	2022
Amur Region	-	-	-	2020–2022
Arkhangelsk Region	2011, 2012, 2021, 2022	2020	2022	2020, 2022
Astrakhan Region	-	-	-	2020–2022
Vologda Region	-	-	-	2022
Ivanovo Region	-	2021	-	2020, 2022
Kaliningrad Region	-	-	-	2022
Kostroma Region	-	2021, 2022	-	2020, 2022
Magadan Region	-	2022	2021, 2022	2020–2022
Orel Region	-	2022	-	-
Pskov Region	-	-	-	2020–2022
Sakhalin Region	-	-	-	2022
Tyumen Region	2011, 2012	2011, 2012	-	2011, 2012
Ulyanovsk Region	-	-	-	2020
Nenets Autonomous Area	2021, 2022	2020	2022	2021, 2022
Chukotka Autonomous Area	-	2021	-	2021, 2022
Jewish Autonomous Region	-	2020–2022	2020–2022	2021, 2022
Restored, total, units	12	28	17	62
Source: own elaboration.				

Table 2. Sample characteristics and deflators used

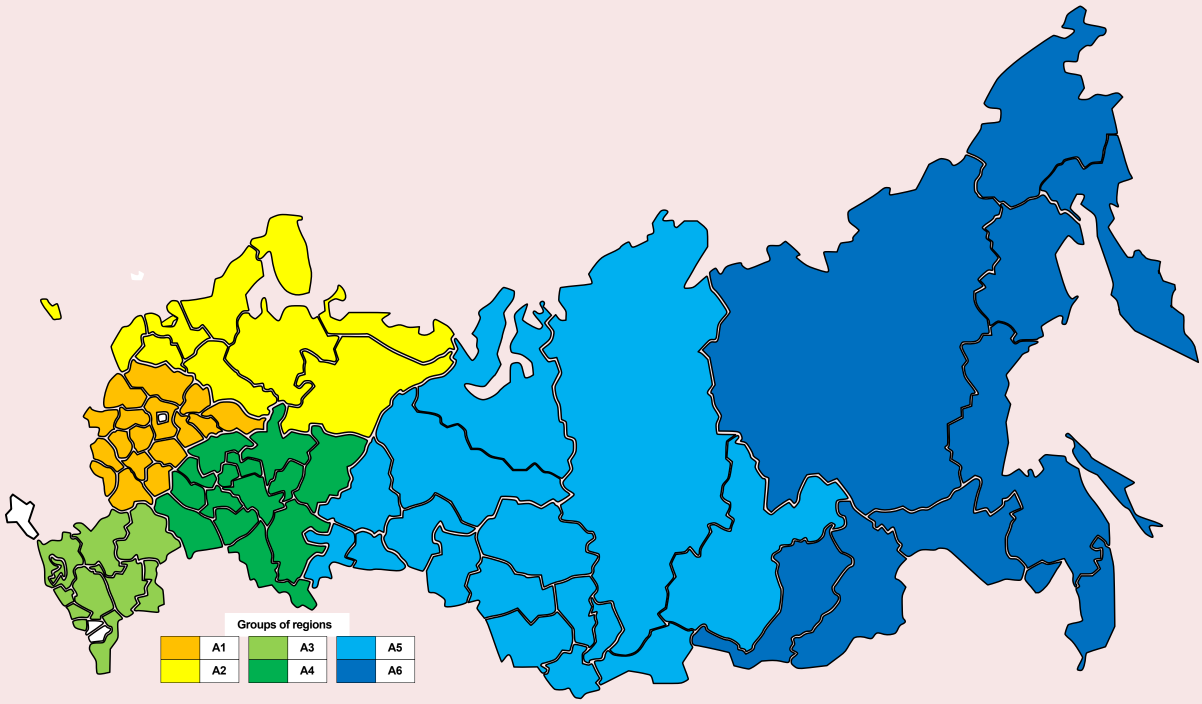
Indicator		Innovation costs	including		
			Research and development	Purchase of machinery and equipment	Industrial engineering and design
Sectoral coverage	2011–2015	Industry, communications, activities related to the use of computer and information technology, research and development, provision of other services			
	2016–2018	+ agriculture, construction of prefabricated buildings and facilities, construction of roofs of buildings and structures, performance of other construction works			
	2019–2022	+ construction, transportation and storage, activity in the field of healthcare and social services			
Mean (st. deviation) by region, billion rubles*	2011–2015	12.8 (25.6)	4.9 (14.9)	5.0 (8.6)	1.6 (5.8)
	2016–2018	17.1 (35.6)	7.5 (21.9)	5.7 (10.9)	1.8 (4.2)
	2019–2022	28.1 (75.4)	12.2 (37.3)	10.0 (25.2)	1.9 (4.8)
Number of zeros in the sample		-	53	9	61
Deflators used		Price indices for products (costs, services) for investment purposes: total for the surveyed types of activity	Price indices for products (costs, services) for investment purposes: scientific research and development**	Indices of prices of machinery and equipment for investment purposes: total for the surveyed types of activity***	Price indices for other products (costs, services) for investment purposes: total for the surveyed types of activity****

* Calculated according to: Innovation costs of organizations (since 2010). Available at: https://rosstat.gov.ru/storage/mediabank/Innov-5.xls (accessed: July 1, 2024).
** Price indices for products (costs, services) for investment purposes up to 2016. Available at: https://www.fedstat.ru/indicator/31111 (accessed: July 1, 2024); Price indices for products (costs, services) for investment purposes since 2017. Available at: https://www.fedstat.ru/indicator/56591 (accessed: July 1, 2024).
*** Indices of prices of machinery and equipment for investment purposes up to 2016 (percent). Available at: https://www.fedstat.ru/indicator/31104 (accessed: July 1, 2024); Indices of prices of machinery and equipment for investment purposes since 2017. (percent). Available at: https://www.fedstat.ru/indicator/65804 (accessed: July 1, 2024).
**** Price indices for other products (costs, services) for investment purposes up to 2016 (percent). Available at: https://www.fedstat.ru/indicator/40609 (accessed: July 1, 2024); Price indices for other products (costs, services) for investment purposes since 2017 (percent). Available at: https://www.fedstat.ru/indicator/57798 (accessed: July 1, 2024).
Source: own elaboration.

At the second stage, the cost indicators are brought to a comparable form by converting into 2011 prices using the most relevant, in our opinion, price indices for products, machinery and equipment and other investment products (*Tab. 2*). Thus, a deflator index was selected for each of the four indicators.

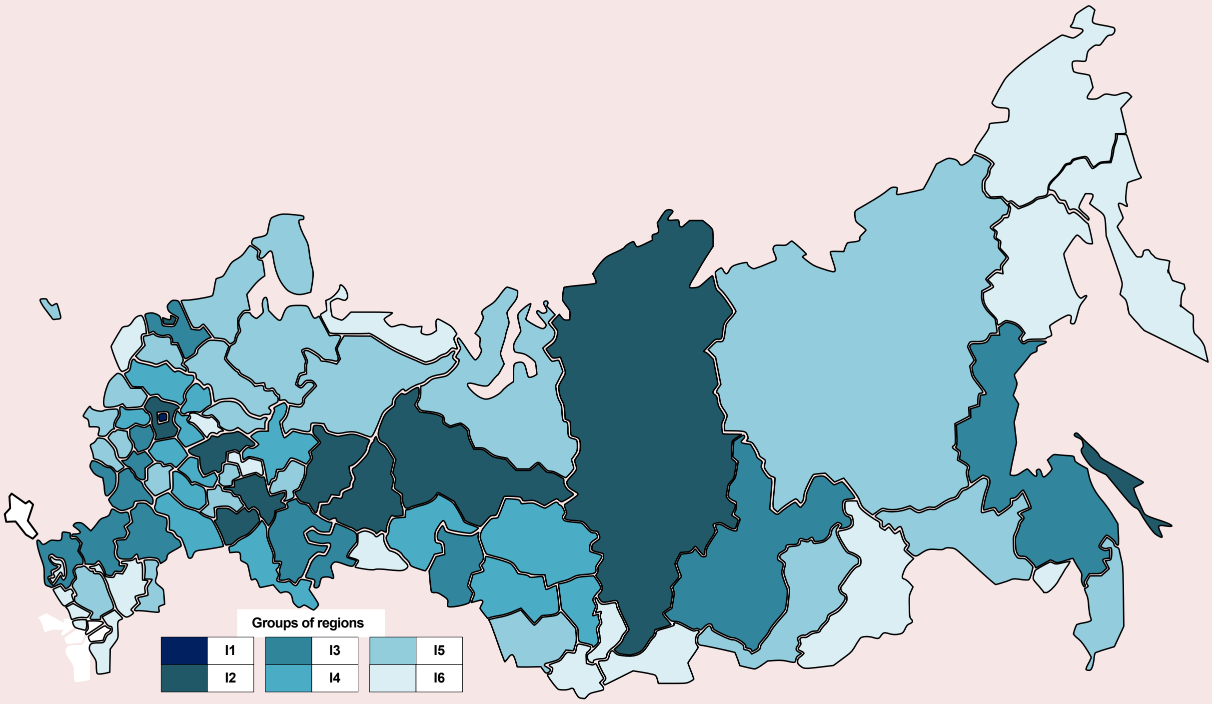
At the third stage, the regional analysis of the dynamics of innovation costs was limited to two groupings of regions (*Fig. 1, 2*). The first grouping (A1... A6) is based on the administrative division of Russia’s constituent entities (see Fig. 1). Group A1 corresponds to the Central Federal District except Moscow, Group A2 – Northwestern Federal District, Group A3 – Southern and North Caucasus federal districts, Group A4 – Volga Federal District, Group A5 – Ural and Siberian federal districts, and Group A6 – Far Eastern Federal District.

Figure 1. Grouping of regions according to administrative division



Source: own elaboration.

Figure 2. Grouping of regions by the total amount of innovation costs



Source: own elaboration.

The second grouping (I1... I6) is based on the total innovation costs for 2011–2022 in 2011 prices for each region (see Fig. 2). In it, Group I1 is represented by Moscow, a unique entity that stands out from all others with distinctively high innovation costs. In 2011–2022, their total volume in Moscow (in 2011 prices) amounted to about 2.7 trillion rubles (21.5% of all-Russian indicator), including R&D costs – 1.3 trillion rubles, costs for the purchase of machinery and equipment – 641 billion rubles, costs for industrial engineering and design – 242 billion rubles.

The 10 largest regions in terms of innovation costs after Moscow are included in Group I2: Saint Petersburg, the Republic of Tatarstan, the Krasnoyarsk and Perm territories, the Moscow, Nizhny Novgorod, Samara, Sakhalin, Sverdlovsk regions and the Khanty-Mansi Autonomous Area. This is the most economically powerful of all the identified groups with a total cost of 5.6 trillion rubles for the period under consideration (44.9% of all-Russian indicator), including 2.7 trillion rubles for R&D, 1.9 trillion rubles for the purchase of machinery and equipment, 421.8 billion rubles for industrial engineering and design.

Group I3 includes regions, in each of which the total amount of innovation costs in 2011–2022 in 2011 prices ranged from 100 to 250 billion rubles: the Republic of Bashkortostan, the Krasnodar and Khabarovsk territories, the Belgorod, Voronezh, Irkutsk, Lipetsk, Leningrad, Volgograd, Omsk, Rostov, Tula and Chelyabinsk regions. In total in 2011–2022 these regions spent 2.4 trillion rubles for innovation activities (18.8% of all-Russian indicator), including 481.9 billion rubles for R&D, 1.1 billion rubles for the purchase of machinery and equipment, 331.8 billion rubles for production design (engineering) and design.

Group I4 includes regions with innovation costs ranging from 50 to 100 billion rubles for 2011–2022: the Republic of Mordovia, the Vladimir, Kaluga, Kemerovo, Kirov, Novosibirsk, Orenburg, Penza, Ryazan, Saratov, Tver, Tomsk, Tyumen and Yaroslavl regions. In total in 2011–2022 these regions carried out innovation expenditures in the amount of 956.5 billion rubles (7.6% of all-Russian indicator), including R&D costs – 344.2 billion rubles, costs for the purchase of machinery and equipment – 382.6 billion rubles, costs for industrial engineering and design – 123.5 billion rubles.

Group I5 includes regions with total innovation costs from 10 to 50 billion rubles for 2011–2022: the republics of Buryatia, Karelia, Komi, Udmurtia, Chuvashia, Yakutia, Altai, the Primorye and Stavropol territories, the Amur, Arkhangelsk, Astrakhan, Bryansk, Vologda, Kaliningrad, Kostroma, Kursk, Murmansk, Novgorod, Oryol, Smolensk, Tambov, Ulyanovsk regions and the Yamal-Nenets Autonomous Area. In total in 2011–2022 these regions allocated 696.1 billion rubles on innovations (5.6% of all-Russian indicator), including R&D – 162.7 billion rubles, purchase of machinery and equipment – 362.7 billion rubles, industrial engineering and design – 95.3 billion rubles.

Group I6 is represented by regions with total innovation activity costs of up to 10 billion rubles for 2011–2022: the republics of Altai, Adygea, Dagestan, Kabardino-Balkaria, Kalmykia, Karachay-Cherkessia, Mari El, North Ossetia, Tyva, Khakassia, the Trans-Baikal and Kamchatka territories, the Ivanovo, Pskov, Kurgan, Magadan regions, the Nenets and Chukotka autonomous areas, as well as the Jewish Autonomous Region. In total in 2011–2022 these regions provided 70.9 billion rubles of innovation costs (0.6% of all-Russian indicator), including R&D – 14.3 billion rubles, purchase of machinery and equipment – 39.6 billion rubles, industrial engineering and design – 9.2 billion rubles.

At the fourth stage, for the periods 2011–2015, 2016–2018 and 2019–2022, we estimated the elasticity of the indicators of innovation costs $inno_{it}$ in 2011 prices according to time trend t with detailing for groups A1... A6 and I2... I6 based on the generated data panel. This made it possible to quantify changes in the innovation costs within each period, with adjustments for spatial heterogeneity.

The elasticity of the total innovation costs according to the time trend was estimated by a linear equation on panel data with fixed effects of regions:

$$\ln inno_{it} = c + \beta^a t + \varphi_i^a + \varepsilon_{it}, \qquad (1)$$

where c – constant, t – time trend, φ_i – individual effect of the i-th region, ε_{it} – equation residuals. Since the data under consideration are characterized by a significant range of fluctuations in values (see Tab. 2), the problem of heteroscedasticity of the residuals of equation (1) is relevant; robust estimates of variance obtained by the Huber – White method (Huber, 1967; White, 1980) were used in its estimation.

Data on the costs of R&D, purchase of machinery and equipment, and industrial engineering and design have a significant number of zeros in the samples; therefore, a fixed-effect Poisson model for regions and variance adjustment using the Huber – White method was used to assess their elasticity according to the time trend. The Poisson model assumes that observations $inno_{i1},...,inno_{iT}$ are distributed independently, regressor t is strictly exogenous, and the individual effects of regions φ_i^b have a Poisson distribution with parameter μ_{it}:

$$\Pr(inno_{it} = y|\mu_{it}) = \exp(-\mu_{it})\mu_{it}^{y}/y! \quad \text{where } \mu_{it} = \exp(\beta^b t + \varphi_i^b). \qquad (2)$$

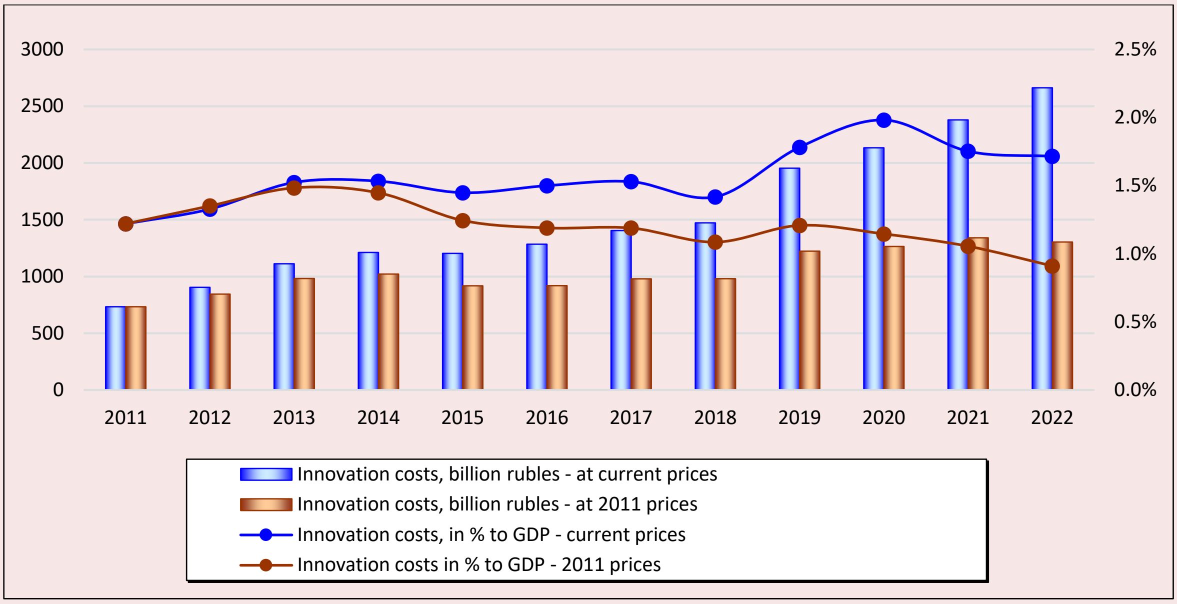
Regarding the quality of the data used, it is important that the Poisson regression provides a consistent estimate of the parameters, even if the data do not correspond to the Poisson distribution (Lukman et al., 2021).

We focus our attention on the elasticity coefficients of innovation costs indicators according to time trend β^a and β^b, interpreted as the average rate of change of the indicator over the period. The most important parameters in this case are the magnitude and statistical significance of elasticity coefficients. The latter is interpreted as a degree of consistency of the dynamics of innovation costs indicator within a group of regions. High statistical significance of elasticity coefficients according to the time trend means that during the period under consideration, innovation costs in all regions included in the group, on average, changed in one direction: they either increased or decreased. Low statistical significance of β^a and β^b, on the contrary, indicates multidirectional or unsystematic trends in the changes in innovation costs in the regions.

Research results

Innovation costs in 2011–2022 were growing almost exclusively at current prices and mainly due to the expansion of the sectoral coverage of statistical observation (*Fig.* 3). At constant 2011 prices the indicator increased during this time from 733.8 to 1,304 billion rubles, i.e. by 77.7%. Only in 2011–2014, the increase in the indicator at current prices was accompanied by its increase at constant 2011 prices, with the sectoral coverage remaining unchanged; this short period is the only period of innovation activity growth at Russian enterprises. Subsequent years show stagnation of innovation costs, converted into comparable prices. In comparable terms, the national economy is growing faster than innovation costs, so their economic weight in GDP is decreasing: from 1.4% to 0.9%

Figure 3. Total innovation costs in 2011–2022



Source: own calculation.

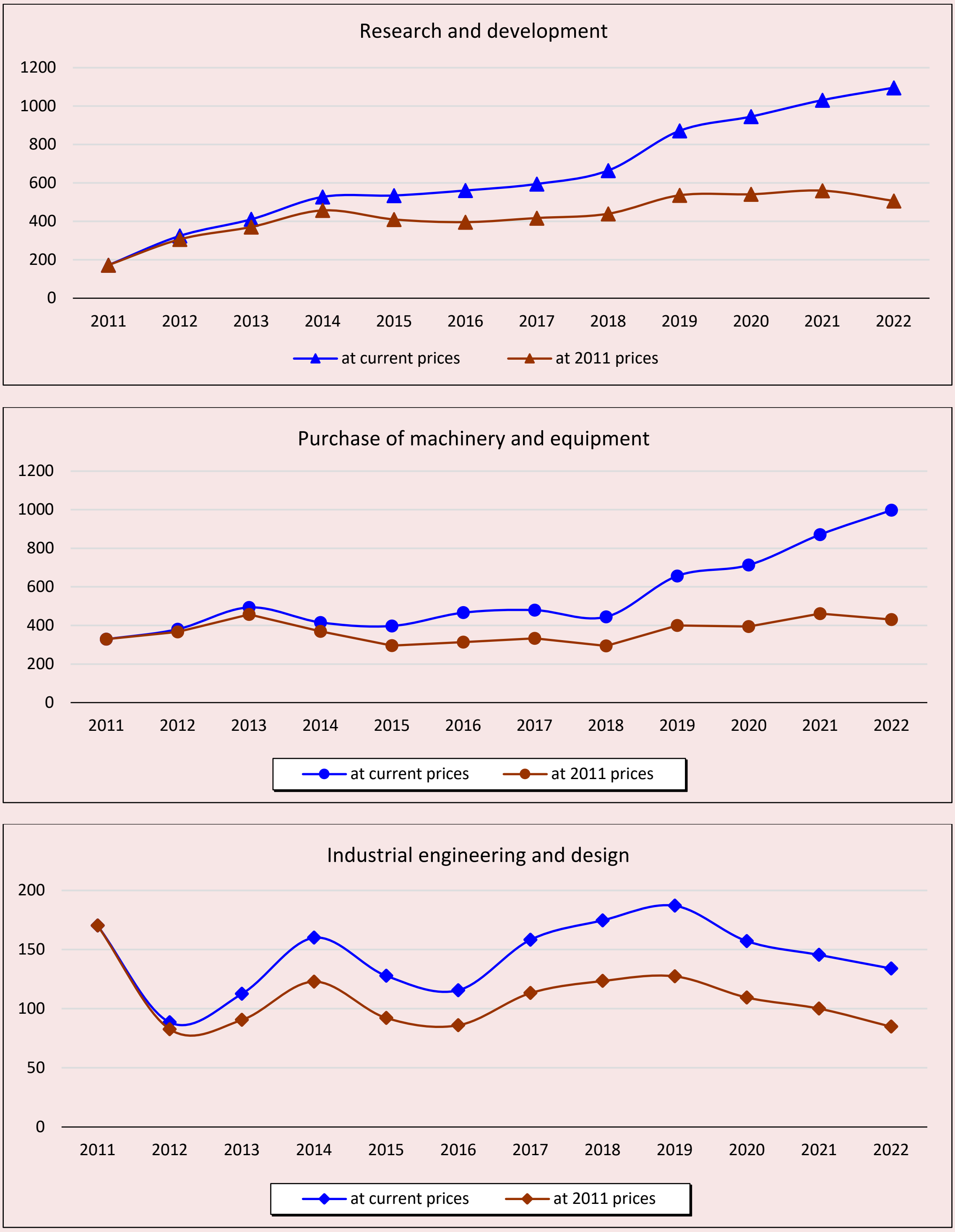
in 2014–2022[13]. Thus, we can draw a cautious conclusion about a decrease in the "quality" of the technological component of Russia's economic growth after 2014.

The dynamics of the aggregate indicator is determined by trends in the costs of R&D and purchase of machinery and equipment (*Fig. 4*). Consistent growth in 2011–2014 was associated with an increase in R&D costs, while the level of costs for the purchase of machinery and equipment at comparable prices decreased from 2014 and then stagnated. The dynamics of industrial engineering and design costs are characterized by wave-like changes with peak values in 2011, 2014 and 2019, followed by a downward trend.

In the country as a whole, total innovation costs in the regions did not have clear dynamics either in 2011–2015, 2016–2018, or 2019–2022: elasticity coefficients according to time trend β^a in the full sample of regions are statistically insignificant in all periods (*Tab. 3*).

[13] Calculated according to: Gross domestic product (in current prices, billion rubles). Available at: https://rosstat.gov.ru/storage/mediabank/VVP_god_s_1995-2023.xlsx (accessed: August 1, 2024); Indices of physical volume of gross domestic product (as a percentage of the previous year). Available at: https://rosstat.gov.ru/free_doc/new_site/vvp/vvp-god/tab3.htm (accessed: August 1, 2024).

Figure 4. Innovation costs in the regions of Russia
in major areas in 2011–2022, billion rubles



Source: own calculation.

Table 3. Dynamics of innovation costs indicators broken down by group of regions in 2011–2022

Group of regions	Innovation costs (equation (1))			including (equation (2))								
				Research and development			Purchase of machinery and equipment			Industrial engineering and design		
	2011–2015	2016–2018	2019–2022	2011–2015	2016–2018	2019–2022	2011–2015	2016–2018	2019–2022	2011–2015	2016–2018	2019–2022
Russia – total	-0.033	0.041	0.016	0.181***	0.054	-0.006	-0.019	-0.036	0.035	-0.098	0.156*	-0.142*
Russia without Moscow	-0.033	0.042	0.016	0.191***	0.095**	-0.061*	-0.019	0.054	0.090	0.071	0.147	-0.112
A1	0.001	-0.125*	0.000	0.290***	-0.025	-0.018	-0.126	0.049	0.047	-0.042	-0.025	0.069
A2	-0.200*	0.057	0.064	0.124***	-0.047***	-0.022***	-0.180**	0.190	-0.100	0.077***	-0.270***	0.219
A3	-0.026	0.062	0.127	0.276***	0.127***	-0.221***	0.156	-0.091	0.030	-0.045	0.319*	0.109*
A4	0.067**	0.095	-0.005	0.102	0.286***	-0.021	0.015	0.082**	0.064	0.203*	0.167	-0.075
A5	-0.050	0.131	-0.057	0.224***	0.110	-0.105**	-0.023	-0.023	0.228*	-0.014	0.278*	-0.109
A6	-0.032	0.072	0.013	0.058	0.034	-0.303	0.130	0.141***	0.258***	-0.171	0.351	0.177*
I2	0.167***	0.080	0.036	0.225***	0.107*	-0.062	0.052	0.045	0.118	0.192**	0.139	-0.076
I3	0.061	0.019	-0.065	0.127***	0.036	-0.140***	-0.058	0.030	0.100	-0.061	0.289**	-0.308
I4	0.008	-0.074	-0.071	0.081***	0.080	-0.042	-0.057	0.005	0.000	-0.053	-0.180***	0.053
I5	-0.089	0.142	0.014	0.056	0.170	0.121	-0.193**	0.241*	-0.005	0.092	0.077	0.197***
I6	-0.164**	-0.002	0.127	0.069	-0.084	0.034	-0.141**	-0.064	0.001	-0.126	-0.072	0.204

* – significance at 10%;
** – significance at 5%;
*** – significance at 1%.
Source: own calculation.

Consistent nationwide growth of the indicator in 2011–2015 was provided by the top 10 regions after Moscow[14] (Group I2). Among the groups of territories allocated on an administrative basis, the Volga regions (Group A4) made a significant positive contribution, where four regions of Group I2 are localized. At the same time, a statistically noticeable negative trend during this period is recorded in the least developed (Group I6) and Northwestern (Group A2) regions of the country. Thus, the only period during the entire observed period when there was an increase in innovation costs contains serious contradictions at the regional level, since a consistent increase in the indicator took place only in the most developed regions, there was no statistically significant dynamics in the median regions, and the least developed regions showed a consistent decrease.

In 2016–2018 and 2019–2022, no consistent dynamics of innovation costs were recorded within the groups under consideration, except for a negative trend in the central regions (Group A1) in 2016–2018. Thus, the seven-year period from 2016 to 2022, in terms of innovative development, which is not possible without innovation costs, appears to be a time of prolonged stagnation both in the sample as a whole and within individual groups of regions.

Breaking down innovation costs into types shows that the greatest dynamism (the largest number of statistically significant elasticity coefficients according to time trend β^b) was shown by R&D costs. In 2011–2015 their volume consistently increased both nationwide and within the majority of the groups under consideration: A1, A2, A3, A5, I1, I2, I3, I4. In 2016–2018 R&D costs began to increase in the Volga regions (Group A4) and continued to increase in the southern regions (Group A3), as well as in the most developed regions (I1 and I2). At the same time a consistent decline in the indicator began in the northwestern regions (Group A2). The period 2019–2022 is characterized by significant negative trends in R&D costs in the nationwide sample, in the groups of regions A2, A3, A5, I3 and a positive trend in Moscow.

Here we should point out three facts: first, the absence of significant β^b coefficients within all three periods in the regions of the Far East (Group A6) and the two least developed groups of regions (groups I5 and I6); second, a sharp decrease in the number of groups of regions with significant positive coefficients β^b in 2016–2018; in terms of grouping regions by total innovation costs, significant positive dynamics remained only in the group of the most developed regions. Third, we observe extremely negative statistically significant coefficients β^b in 2019–2022, except for Moscow.

These facts show a specific picture regarding the development of corporate research and development in the regions. A consistent and relatively widespread increase in R&D costs was possible only in the period before the 2014–2015 sanctions shock. But even then, it did not affect the most remote (Far East) and least developed (innovation costs up to 50 billion rubles in total for 2011–2022) regions. As part of the grouping of regions by total value of innovation costs, the values of β^b decreased from the most developed groups of RF constituent entities to the least developed. Starting from 2016–2018, the number of groups of regions characterized by consistent R&D growth has been rapidly decreasing, and the city of Moscow ceases to fit into all-Russian trends, becoming the only stable research center in the business sector. Finally, in 2019–2022, despite significant expansion of the sectoral coverage of statistical observation, there is a widespread collapse in R&D volume, with the exception of Moscow.

[14] The amount of innovation costs in Moscow remained at the level of, approximately, 160 billion rubles in 2011–2018, and after a significant expansion of the sectoral coverage of statistical observation – at 352 billion rubles in 2019–2022 (at 2011 prices).

The spatial patterns of changes in the cost of purchasing machinery and equipment were in many ways the opposite of the spatial patterns of R&D costs. The dynamics of this type of costs in a nationwide sample of regions remained inelastic in terms of the time trend throughout all three periods. In 2011–2015 significant negative β^b coefficients were recorded in the Northwestern regions (Group A2), as well as in regions with total innovation costs of up to 50 billion rubles in 2011–2022 (groups I5 and I6). Thus, while groups I1, I2, I3 and I4 consistently increased R&D costs, groups I5 and I6 consistently reduced the costs of purchasing machinery and equipment. In the period before the sanctions shock, the least developed regions were forced to reduce the intensity of technology learning, including even through exploitation, while the more developed regions increased the intensity of technology learning through exploration.

In 2016–2018, there was a consistent increase in the cost of purchasing machinery and equipment in the Volga (group A4) and Far Eastern (Group A6) regions, as well as in regions with total innovation costs in the range from 10 to 50 billion rubles in 2011–2022 (Group I5). In 2019–2022, positive statistical elasticity according to the time trend is observed in the Ural-Siberian (Group A5) and Far Eastern (Group A6) regions. Thus, in the context of the growing sanctions pressure, Far Eastern territories that were deprived of the opportunity to consistently increase the volume of R&D (i.e., to learn new technology through exploration) most consistently increased the intensity of learning new technology embodied in a new technique through exploitation. Over time, this process has been intensifying, as evidenced by a noticeable increase in β^b coefficient of Far Eastern regions in 2019–2022 compared to 2016–2018.

The decrease in the economic weight of the costs of industrial engineering and design in 2011–2022 was accompanied by their transfer from the most developed regions to the least developed ones. Thus, in 2011–2015 a consistent increase in innovation costs of this type was recorded in the regions of Group I2, while in 2016–2018 – in the regions of Group I3, and in 2019–2022 – in the regions of Group I5. We should note that this result is the least reliable due to the fact that the costs of production engineering and design are characterized by the largest range of fluctuations, the number of restored data and zeros in the sample (see Tab. 1, 2).

Conclusion

In the course of the research, we sought to answer a simple question: what are the comparative dynamics of innovation costs in the country's regions, including in terms of the most important types of innovation costs. Individual trajectories of innovative development of regions are interrupted by considerable statistical outliers, zero values of indicators, and observations hidden by Rosstat. This makes their private analysis unproductive, overly time-consuming and unrepresentative. We propose a methodology that includes comparative analysis of the spatial dynamics of innovation costs indicators based on the selection of price deflators, administrative and economic grouping of regions, as well as calculation of elasticity according to time trend, including within the framework of the Poisson model.

The disadvantages of the proposed methodology include tight time frame of periodization, arbitrariness in the use of price deflators, a priori grouping of regions and, probably, limited attention to the trajectories of innovative development of individual territories. These shortcomings determine the potential of future research. At the same time, the results of the work provide an opportunity to see more non-obvious facts about the dynamics and specific structure of innovation costs in Russia's regions in 2011–2022.

Innovation costs at comparable prices, both aggregate and in terms of the most important areas, showed the most consistent dynamics during the period when the 2014–2015 sanctions shock did not have a systems effect on the economy. R&D costs (learning new technologies through exploration) have consistently increased during this period, and the costs of purchasing machinery and equipment (learning new technologies through exploitation) have consistently decreased. The period from 2016 to 2022, when sanctions apparently came into full force, appears to be a depressing time for searching for new configurations of innovative development, which, in the light of the proposed methodology, is expressed as the lack of consistent dynamics of innovation costs in most regions. In particular, the dynamics of R&D costs during this period remained steadily positive only in Moscow, while in the Northwestern, Southern and Ural-Siberian regions it became steadily negative.

Regions' access to new technologies and opportunities for their generation vary. There is a connection between the spatial and specific structures of innovation in the national economy, but this connection changes its functional forms depending on the period and the strength of sanctions pressure. Thus, in 2011–2015, a consistent increase in R&D costs was observed in the most developed groups of regions, and in proportion to the amount of total innovation costs for 2011–2022. At that time, in the least developed regions the cost of purchasing machinery and equipment was consistently decreasing, i.e. these territories could not afford even the simplest way to master technologies through the operation of existing ones. During periods of increased sanctions pressure in 2016–2018 and 2019–2022 the consistent increase in the simplest forms of technology development – acquisition of machinery and equipment in combination with industrial engineering and design – was carried out far from the major metropolitan centers of science and innovation: in the Far East, as well as in the least developed regions.

Scientific significance of the results obtained is due to the fact that the discussion on the comparative economic significance of various ways of learning new technologies is shifting toward taking into account Russian specifics, and also due to the clarification of the patterns of spatial dynamics of various innovations in the regions of the country at the present stage of development. In practical terms, the results can be used to improve federal and regional innovation policy.

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