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Empirical analysis and forecasting of the dynamics of the innovative development of Russian regions

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Subject. Innovative development of Russian regions. Dynamics of the basic parameters of innovative activity which characterise three blocks of innovation functions: process block, result block, and resource block.
Objectives. To research basic parameters of innovative activity, to establish whether there is balance/disbalance between the process, result, and resource blocks of the innovative development of regions.
Experimental. Theoretically, the study is based on the dialectical method, which was used to formulate the hypothesis of the study: the low level of innovative development of regions is due to the spatial and functional disbalance of their innovation subsystems, which include process, resource, and result blocks. To identify the state and dynamics of the innovative development of Russian regions, an empirical analysis of the basic parameters of this process was carried out. These parameters reflect various aspects of the innovative development of regions: the state of innovation processes, results, and used resources. Model regions (representative regions) were selected as a result of cluster analysis. The dynamics of the basic parameters for the period of 2010–2021 was estimated by the correlation-regression method. The forecast for the period of 2022–2024 was created by extrapolating the data for each function describing the actual dynamics with a sufficient degree of reliability.
Results and discussion. We propose to assess innovation processes by five innovation functions combined into three blocks: process block (functional diversification, technological diversification, and technological concentration); result block (production concentration); and resource block (resource concentration). The results of the analysis showed that the development of functional diversification is unstable in most model regions, which makes it impossible to reliably predict its further dynamics. There is a steady growth, though of varied degree, in technological diversification and technological concentration in all model regions. Production concentration (result block) and resource concentration (resource block) are characterised by unstable trends and an overall tendency towards deterioration over the period of 2010–2021.

Keywords: innovation, region, empirical analysis, innovation functions, forecasting.

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Introduction

Over a long period, federal administrative institutions have been focused on the innovative development of Russian regions and their functional (primarily industrial and research) subsystems. More attention has been paid to innovation processes since 2011 after the adoption of the Strategy for the Innovative Development of the Russian Federation for the period up to the year 2020[1]. The tasks set by the strategy involved significant improvement of the parameters of the innovative development of all spatial and functional subsystems of Russia.

Adoption of the strategy stimulated theoretical and empirical studies in this area of technical, technological, socio-economic, and institutional development (Treshchevsky et al., 2021; Vertakova et al., 2022; Endovitsky et al., 2022, etc.). These studies are dedicated to various aspects of the innovative development of Russia.

Bykova used empirical analysis to conclude that there is a direct linear dependence of the GRP of donor regions and recipient regions on the costs of organisations spent on innovative activities (Bykova, 2022). The author believes that innovation costs are a factor in increasing GRP, however, it is likely that this works in the opposite direction: the volume of GRP determines the ability of organisations to invest in innovation processes. It should be noted that the coefficient of determination of 0.38 indicated by the author does not allow us to draw an unambiguous conclusion about a factor relationship between these indicators in the group of recipient regions, although theoretically this relationship should exist. Many researchers talk about a relative independence of innovation and economic processes. For example, Lavrikova claims that relationships between innovation and market processes and their indicators are indirect (Lavrikova, 2021).

Napolskikh, who conducted an extensive empirical analysis, claimed that clusterization of innovation processes in Russian regions is highly important (Napolskikh, 2020). Larionova, Napolskikh, and Yalilieva believe that it is necessary to add regional components to the cluster-based policy of the federal level (Larionova et al., 2020), which we think is fully justified.

Koroleva used theoretical and empirical methods of research to draw an important conclusion about the main obstacle to the development of innovation processes in the regions of the Far Eastern Federal District: a higher profitability of traditional activities in relation to innovative ones (Koroleva, 2020). At the same time, the author did not deny a well-known fact that taxation policy can influence the expansion of innovation.

Kartseva substantiated a set of measures aimed at modernising the system of higher education in Russian regions to enable using effectively the model of innovative development based on the "Triple Helix" model (Kartseva, 2020).

Bitarova, Volkova, Getmantsev, Minenkova, and Iliasova point out that innovative development of regions requires specialised infrastructure (Bitarova et al., 2018a; Bitarova et al., 2018b).

Shchepina and Borodina speak about the importance of digital technologies in the transformation of the nature of economic activity (Shchepina & Borodina, 2019).

We agree with Romashchenko, Kisova, and Gersonskaya who believe that the main factor for the innovative development of any system is the potential provided by the human capital (Romashchenko et al., 2022). The degree of its development should be taken into account not only for the development of theoretical and methodological concepts of innovative

[1] Strategy for the Innovative Development of the Russian Federation for the period up to the year 2020. Approved by order of the Government of the Russian Federation of 8 December 2011 No. 2227-r. URL: https://docs.cntd.ru/document/902317973

development of socio-economic systems of various levels, but also for their empirical evaluation.

Azarova also points out that there is a close relationship between the innovative development of regions and the development of human capital (Azarova, 2022).

As we can see, researchers record a high variety of relationships between innovative and other socio-economic phenomena, which raises the problem of choosing the most significant ones and to analyse them in relation to Russian regions.

Research methods

It is a well-known problem that to assess the state of innovation processes it is necessary to choose from a wide range of indicators presented in the scientific literature and statistics. For example, Matvienko uses 30 indicators in her study (Matvienko, 2020), each of which has a different degree of significance, however, it is challenging to use all of them for practical calculations, forecasts, and the development of government inventories.

In our opinion, the large number of indicators used to assess innovation processes makes it difficult to analyse them and obtain generalised results. Therefore, we used five indicators for the analysis, three of which characterise the process function of the innovative development of regions and an indicator for each of the other functions: result and resource.

Input data for calculations were obtained from official statistical sources[2]. Standardised values of indicators were used for calculations to compensate the influence of the sizes of regions and to bring parameters with different units of measurement into a form which will allow comparing them.

It is also difficult to choose regions that would characterise not only their own status, but also the status of a certain group of administrative-territorial entities. In the presented study, the selection of representative regions (model regions) included two stages. At the first stage, we formed groups of regions (virtual clusters) which were homogeneous in terms of the set of indicators used for the analysis. For this purpose, we used the method of cluster analysis whose theoretical foundations had been developed by Hartigan, Wong and a number of other researchers (Hartigan & Wong, 1979). In works by Russian scientists, this method has become widespread thanks to the studies by Bystryantseva, Shchepina and Yakunina who developed the theoretical and methodological concept of cluster analysis for classification of Russian regions according to various parameters of their subsystems. This concept is widely used nowadays (Bystryantseva & Shchepina, 2019; Yakunina, 2022). During calculations, five virtual clusters were formed designated as A, B. C, D, E by a decreasing level of overall innovative development. These clusters relate to four periods: 2014–2015; 2016–2019; 2021; and 2014–2021.

At the second stage, model regions were selected by the shortest distance from the virtual centre of each cluster. The analysis showed that none of the clusters had a region that consistently occupied the position closest to the virtual centre. Hence, to select model regions, we used cluster data for the period of 2014–2021. As a result, the following regions were chosen as model regions for the clusters: (A) Saint Petersburg; (B) Yaroslavl Region; (C) Volgograd Region; (D) Murmansk Region; (E) Kaliningrad Region.

The dynamics of each parameter was evaluated by five specifications: linear, degree, polynomial (second degree), logarithmic, and exponential. To ensure sufficient representativeness of the data we conducted analysis for the period from 2010 to 2021.

Results

The following results were obtained for the model region of A cluster (Saint Petersburg).

The level of innovation activity in the region fluctuated abruptly over the analysed period, none of the specifications chosen for the analysis describes it with a sufficient degree of reliability. The degree model has the highest coefficient of determination of 0.0375, which characterises functional diversification in the region as being unstable and does not allow presenting any reliable forecasts.

[2] Science, innovation, technology. URL: https://rosstat.gov.ru/statistics/science

Technological diversification is represented by the percentage of organisations engaged in technological innovation (both their own and those developed by other economic entities). Their dynamics are shown in Fig. 1.

The dynamics of the indicator is described with a sufficient degree of reliability by four specifications (Table 1).

In models 1–4 and beyond: x is the number of the year from 1 (2010) and beyond; y is the values of indicators in units of measurement indicated in the figures and the text accompanying the formula.

Forecasting based on the presented models shows that the most optimistic alternative allows us to expect an increase in the indicator from 34.7 % in 2021 to 56.5 % in 2024; the most pessimistic alternative (degree model), on the contrary, forecasts a decrease in the value to 30.7 %. It should be taken into account that the multiple alternatives are associated with a sharp increase in the indicator values in 2018, which, in our opinion, allows us to consider the forecast

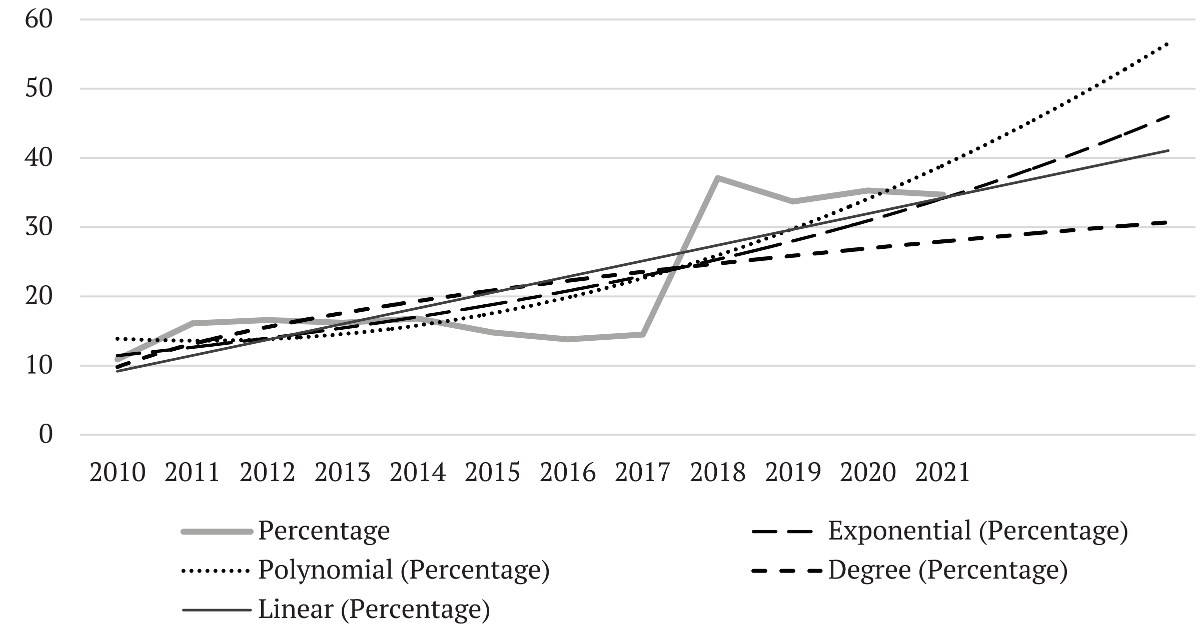

Fig. 1. The percentage of organisations that were involved in technological innovations, of the total number of surveyed organisations in Saint Petersburg, % (calculated by the authors based on the materials of the Federal Service for National Statistics. URL: https://rosstat.gov.ru/statistics/science)

Table 1

Assessment results of trend models (Saint Petersburg)

Independent variables	Model 1 (linear)	Model 2 (exponential)	Model 3 (polynomial)	Model 4 (degree)
x	2.277*** [*t* = 4.391]	0.099*** [*t* = 4.406]	–1.069 [*t* = –0.51]	–
x^2	–	–	0.257* [*t* = 1.639]	–
ln *x*	–	–	–	0.422*** [*t* = 3.312]
(*Intercept*)	6.91* [*t* = 1.811]	2.339*** [*t* = 14.103]	14.717** [*t* = 2.483]	2.283*** [*t* = 9.87]
R^2	0.659	0.66	0.737	0.523
p(*F*)	0.000	0.000	0.001	0.003

Note. The square brackets indicate *t*-statistics. Parameter estimates that are significant at levels of 10, 5, and 1% are marked with *, **, and ***, respectively.

based on the linear model to be as the most realistic, 41.0 % in 2024.

The function of production concentration, which is characterised by the indicator "percentage of innovative goods, jobs, and services in their total volume, %" and which, in our opinion, reflects the overall effectiveness of innovation activities in the region, in general shows insignificant growth rates and low stability (the coefficients of determination for all models do not exceed 0.06). This does not allow predicting the dynamics of the function even for the medium-term period (2022–2024).

The dynamics of the function of resource concentration, which is characterised by the percentage of innovation costs in the total volume of shipped goods (%), is unstable (coefficients of determination for all models do not exceed 0.2). This does not allow us to predict its further development.

The function of technological concentration, which is expressed by the indicator "used advanced production technologies, etc.", is closely related to the function of technological diversification and is represented by five models with a high coefficient of determination (models 5–9).

The most optimistic forecast is presented by the exponential model, the pessimistic by the polynomial model, and the most realistic by the linear model. Their numbers are expected to change from 10,839 units in 2021 to 14,153 units, 10,304 units, 12,474 units, respectively.

Thus, we can talk about unstable dynamics of functions in the model region of cluster A, which does not allow establishing the integral effectiveness of innovation activity. Positive processes are observed only in the process block of indicators which reflect technological diversification and technological concentration of innovation activity.

Let us present a further analysis of innovation activity in model regions in a functional context.

Functional diversification is unstable (similar to Saint Petersburg) in the Yaroslavl, Volgograd, and Kaliningrad Regions. The polynomial model describes functional diversification in the Murmansk Region with a sufficient degree of reliability, which allows forecasting positive dynamics for the period of 2022–2024.

Technological diversification shows steady positive dynamics (similar to Saint Petersburg) in all model regions: the Yaroslavl, Volgograd, Murmansk, and Kaliningrad Regions.

Production concentration showed a steady growth only in the Murmansk Region (Fig. 2).

Table 3 shows that the maximum value of R^2 belongs to the polynomial model; an optimistic forecast can be made based on the polynomial and exponential models, a realistic forecast can be based on the linear model, and a pessimistic forecast is based on the degree model. It should be noted that a significant discrepancy in the values of the analysed indicator in the presented models is due to radical changes in the results of

Table 2

Assessment results of trend models (Saint Petersburg)

Independent variables	Model 5 (linear)	Model 6 (exponential)	Model 7 (logarithmic)	Model 8 (polynomial)	Model 9 (degree)
x	515.413*** [t = 11.232]	0.069*** [t = 8.392]	–	982.958*** [t = 7.117]	–
x^2	–	–	–	–35.965*** [t = –3.478]	–
ln x	–	–	2,495.639*** [t = 14.506]	–	0.349*** [t = 19.442]
(*Intercept*)	4,742.985*** [t = 14.044]	8.518*** [t = 140.188]	3,936.427*** [t = 12.6]	3,652.045*** [t = 9.352]	8.388*** [t = 257.58]
R^2	0.927	0.876	0.954	0.969	0.974
$p(F)$	0.000	0.000	0.000	0.000	0.000

Note. The square brackets indicate t-statistics. Parameter estimates that are significant at levels of 10, 5, and 1 % are marked with *, **, and ***, respectively.

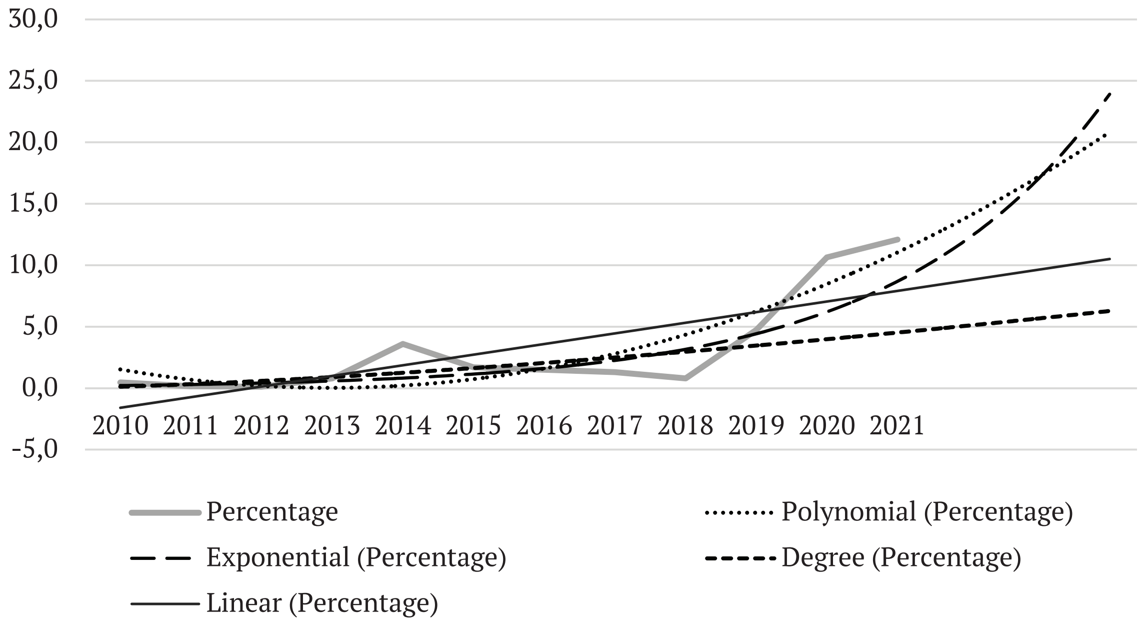

Fig. 2. The percentage of innovative goods, jobs, and services in the total volume of shipped goods and performed jobs and services in the Murmansk Region, % (calculated by the authors based on the materials of the Federal Service for National Statistics. URL: https://rosstat.gov.ru/statistics/science)

Table 3

Assessment results of trend models (Murmansk Region)

Independent variables	Model 10 (linear)	Model 11 (exponential)	Model 12 (polynomial)	Model 13 (degree)
x	0.865*** [*t* = 3.743]	0.337*** [*t* = 4.619]	−1.355* [*t* = −1.818]	–
x^2	–	–	0.171*** [*t* = 3.059]	–
ln *x*	–	–	–	1.467*** [*t* = 3.612]
(*Intercept*)	−2.464* [*t* = −1.449]	−1.885*** [*t* = −3.507]	2.716 [*t* = 1.289]	−2.136*** [*t* = −2.896]
R^2	0.584	0.681	0.796	0.566
p(*F*)	0.001	0.000	0.000	0.002

Note. The square brackets indicate t-statistics. Parameter estimates that are significant at levels of 10, 5, and 1% are marked with *, **, and ***, respectively.

innovative development of the region in the period of 2018–2021, when it reached 12.1 % from nearly 0 %. This escalation was “taken into account” by the above-mentioned specifications to various degrees.

Resource concentration has stable (negative) dynamics only in the Yaroslavl Region (Fig. 3, models 14–18)

All models (Table 4) give pessimistic forecasts of varying degrees that do not differ significantly with the exception of the linear model, which “forecasts” negative values in the short-term period and cannot be used.

The technological concentration demonstrates a steady growth described by several functions in Saint Petersburg, the Yaroslavl, and Volgograd Regions. In the Kaliningrad Region it is only reliably characterised by the polynomial function and in the Murmansk Region none of the functions characterise it reliably.

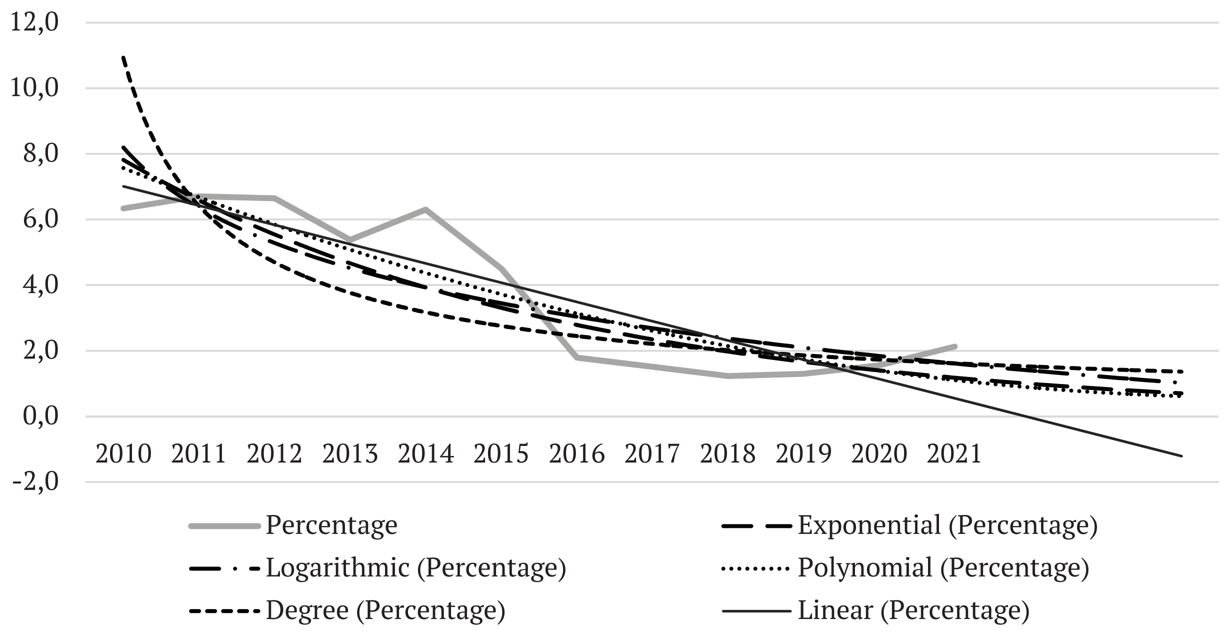

Fig. 3. The percentage of innovation costs in the total volume of shipped goods and performed jobs and services in the Yaroslavl Region, %
(calculated by the authors based on the materials of the Federal Service for National Statistics. URL: https://rosstat.gov.ru/statistics/science)

Table 4

Assessment results of trend models (Yaroslavl Region)

Independent variables	Model 14 (linear)	Model 15 (exponential)	Model 16 (logarithmic)	Model 17 (polynomial)	Model 18 (degree)
x	−0.587*** [t = −6.184]	−0.172*** [t = −5.4]	–	−0.981** [t = −2.356]	–
x^2	–	–	–	0.03 [t = 0.971]	–
ln x	–	–	−2.649*** [t = −4.936]	–	−0.769*** [t = −4.351]
(*Intercept*)	7.599*** [t = 10.874]	2.228*** [t = 9.513]	8.194*** [t = 8.408]	8.517*** [t = 7.237]	2.391*** [t = 7.455]
R^2	0.793	0.745	0.709	0.812	0.654
$p(F)$	0.000	0.000	0.000	0.000	0.000

Note. The square brackets indicate t-statistics. Parameter estimates that are significant at levels of 10, 5, and 1 % are marked with *, **, and ***, respectively.

Results and discussion

The proposed hypothesis of restrained innovative development of regions due to the spatial and functional disbalance of their innovation subsystems, including process, resource, and result blocks, was confirmed by the following results.

There is a wide variety of studies dedicated to functional and spatial differentiation of Russian regions.

For example, Letyagina, Perova, Yashin, and Borisov pointed out territorial differentiation of innovative development in regions in the context of global challenges (Letyagina, 2021). Firsova and Vygodchikova speak about a significant differentiation of Russian regions in terms of the level of innovative development, only seven of which the authors classify as developed (Firsova, 2016). We agree with the criterion chosen by the authors to assess the level of innovative development: percentage of innovative goods and services in their total volume. Our analysis showed that this component of innovative development of regions, regardless of its general level (of innovative development) is the "weakest link".

Indeed, only one group of the three groups of functions of innovative development, process function, can be described as having fairly stable positive dynamics. It is comprised of three innovation functions: functional diversification, technological diversification, and technological concentration. Functional diversification, which is quantitatively characterised by the level of innovation activity, i.e., the percentage of organisations engaged in any type of innovation (process block), is steadily growing only in the Murmansk Region. In other regions, regardless of the general state of their innovative development, we did not find any regularities for its dynamics.

Technological diversification expressed by the percentage of organisations engaged in technological innovation is steadily growing in all model regions.

Technological concentration, which is characterised by the number of used advanced technologies (process block) under various trends demonstrates a greater or lesser increase in the indicator values in all model regions.

We agree with I. A. Tronina, G. I. Tatenko, and I. V. Zlobina who believe that technological competencies are highly important for the innovative development of regions (Tronina et al., 2020). However, the analysis presented in this article showed that technological competencies and positive dynamics are not sufficient for obtaining the necessary result, the production of innovative goods, jobs, and services.

Production concentration (result block) has a fairly pronounced growth (from 0.8 to 12.1 %) only in the Murmansk Region. What is more, it happened between 2018 and 2021. In an earlier period, the values for this indicator fluctuated within fractions of a percent. In Saint Petersburg, production concentration as a function of innovative development fluctuates abruptly in short time ranges, but in general these fluctuations are within the range of 8.0 to 12.2 %, which should be considered insufficient for such a technologically and socio-economically developed region. In the Yaroslavl Region, which is characterised by unstable dynamics, there is a significant decrease in the percentage of innovative goods, jobs, and services, from 12.1 % in 2010 to 5.0 in 2021. In the Volgograd Region, the trend is unstable, but in general there was a decrease in values from 13.5 to 2.4 % over the same period. In the Kaliningrad Region, the trend was unstable within the range of extremely low indicator values, which did not exceed 1 %.

Resource concentration (resource block) has mainly unstable dynamics. In Saint Petersburg, the indicator value increased from 1.9 to 2.8 %; in the Yaroslavl Region it steadily decreased from 6.3 % in 2010 to 2.1 % in 2021. In the Volgograd Region, resource function fluctuated significantly during the analysed period (the indicator value reached 6.3 % in 2014), however it remained at a low level of development: 0.7 % in 2010 and 0.4 % in 2021.

Thus, the empirical analysis of the dynamics of the functions of innovative development in all model regions revealed a disbalance of the developing process block on the one hand and the resulting and resource block on the other. This allows us to determine areas for further research: the identification of factors that work against the extension of the results of the positive dynamics of innovation processes to the results and resource support for the innovative development of Russian regions.

Conclusions

The factual analysis conducted during the study showed that 12 years after the adoption of the strategy of innovative development of the country, the set goals have been fulfilled fragmentarily and the targeted results for the most important block of innovative development, the production of innovative goods, jobs, and services, have not been achieved. Hence, the proposed hypothesis of restrained innovative development of regions due to the spatial and functional disbalance of their innovation subsystems, including process, resource, and result blocks, was confirmed by the following results.

Theoretical works provide important provisions defining perspective vectors of the innovative development of the country, its spatial and functional subsystems. These provisions allow us to draw a conclusion about considerable innovative potential of the Russian enterprises, complexes, and educational organisations.

The researchers speak about a significant differentiation of Russian regions, municipal districts, and industries by various indicators which reflect the state of their innovative development. Researchers use dozens of different indicators, which allows characterising the essential details of innovative development, however, this makes it difficult to identify disbalances in its major subsystems.

Hence, this article proposes to use a limited set of indicators characterising the functions of innovative development, which we combined into three blocks: process block, result block, and resource block.

Cluster analysis of spatial features of the innovative development of regions used in the work had a supplementary role in this case, since they had been studied in great detail in works by various authors, including those presented in our publications. The main focus of the study was made on identifying functional disbalances in model regions representing the analysed virtual clusters.

Empirical analysis showed that over the 12 year period, since 2010, a year prior to the adoption of the strategy, process block indicators have improved in all model regions regardless of the overall level of innovative development. This allows us to forecast their further positive dynamics.

However, the result and resource functions are poorly developed and tend to be unstable. In the model regions, the indicators that characterise them are at a low level of development and in most cases are deteriorating.

In other words, in the model regions there is a disbalance between the developing process block on the one hand and the stagnating result and resource blocks on the other.

Since we are talking about a significant number of economic entities that contribute to the innovative status of the regions, the obtained results allow us to assume that their economic behaviour is dominated by a process approach that has system-related defects that do not allow using the growing potential for the production of innovative goods, jobs, and services, which, in fact, are their goal.

Conflict of Interest

The authors declare the absence of obvious and potential conflicts of interest related to the publication of this article.

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Эмпирический анализ и прогнозирование динамики инновационного развития регионов России

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Предмет. Инновационное развитие российских регионов. Динамика базовых параметров инновационной деятельности, характеризующих три блока инновационных функций: процессный, результирующий, ресурсный.
Цель. Исследование базовых параметров инновационной деятельности, установление сбалансированности/дисбаланса процессного, результирующего, ресурсного блоков инновационного развития регионов.
Методы исследования. Теоретической основой исследования является диалектический метод, позволивший сформулировать гипотезу исследования: низкий уровень инновационного развития регионов обусловлен пространственно-функциональной разбалансированностью их инновационных подсистем, включающих процессный, ресурсный и результирующий блоки. Для выявления состояния и динамики инновационного развития российских регионов проведен эмпирический анализ базовых параметров данного процесса, релевантно отражающих различные аспекты инновационного развития регионов страны: состояние инновационных процессов, результатов и используемых ресурсов. Выбор модельных регионов (регионов-представителей) осуществлен с использованием кластерного анализа. Динамика базовых параметров оценивалась на основе использования корреляционно-регрессионного метода за период 2010–2021 гг. Прогнозирование на период 2022–2024 гг. проведено на основе экстраполяции данных по функциям, описывающим фактическую динамику с достаточной степенью достоверности.
Результаты и обсуждение. Инновационные процессы предложено оценивать по пяти инновационным функциям, объединенным в три блока: процессный блок (функциональная диверсификация, технологическая диверсификация, технологическая концентрация); результирующий (производственная концентрация); ресурсный (ресурсная концентрация). Результаты анализа показали, что в их составе функциональная диверсификация развивается в большинстве модельных регионов нестабильно, что не позволяет достоверно прогнозировать ее дальнейшую динамику. Технологическая диверсификация и технологическая концентрация демонстрирует устойчивый, хотя и различный, рост во всех модельных регионах. Производственная концентрация (результирующий блок) и ресурсная концентрация (ресурсный блок) характеризуются нестабильностью трендов и зачастую общим ухудшением состояния в течение 2010–2021 гг.

Ключевые слова: инновация, регион, эмпирический анализ, инновационные функции, прогнозирование.

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