Modeling of the Innovation Activity of Russia's Regions

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Abstract: - Stable development of industries and regions of Russia is impossible without the development of an innovative economy. The paper shows that the introduction of innovations, according to global trends, is one of the key factors for increasing competitiveness. Some conceptual provisions of modern regional economic science on the problems of innovative development have been considered. An assessment of innovation activity in the regions of Russia has been carried out, and factors affecting innovation activity have been identified. The paper has developed a factor econometric model of innovations. The dynamics of such indicators as the output of innovative products and the costs of technological innovations have been analyzed. As a result of the study, the influence of expenditures on technological innovations on product output with regard to various time lags has been identified.

Key-Words: - innovation activity, modeling, regression analysis, regional development.

1 Introduction

In the conditions of the formation of a post-industrial economy, sustainable socio-economic development of society is impossible without technical innovations. Development and introduction of new ideas, their commercialization, and implementation in the form of technologies used in the real sector of the economy becomes the main driver of production growth, an increase in employment, an increase in real investment in the economy, improvement of the quality of products and the public standard of living [1]. Improvement of organizational processes at industrial enterprises, reduction of production costs in modern conditions is impossible without the introduction of technological and organizational innovations into the activities of companies. Technological innovations are usually understood as the introduction of technologically new processes into enterprises (or a significant improvement of existing ones), making it possible to significantly improve production methods.

International statistics confirm the importance of innovation processes for the development of the national economy. In the most developed countries of the world, there is a stable opinion that innovation activity is the main driver of economic modernization. According to global ratings calculated by the methodology of the International Business School INSEAD (France) [2, 3], the top

ten in terms of competitiveness include developed countries: the EU, the USA, and South Korea, actively developing innovations, which allowed these countries to take the position of leaders in terms of competitiveness.

Currently, Russia occupies a rather low place in the indexes of global competitiveness – 43rd out of 137 countries, and in 2017 it ranked 38th. The level of innovation activity in Russia has a positive trend (change from the 62nd to the 45th position). This fact indicates the need to increase innovation activity both at the national level and at the level of regions. Innovation activity in the real sector of the economy is understood as the realization of ideas, the results of scientific research and development, the introduction of scientific and technological achievements in technological processes, products or services, as well as the modification and improvement of existing technological processes or production methods. To introduce innovations, a number of scientific, technological, organizational, financial, and commercial actions are needed.

The aim of this study is to assess the innovation activity of the regions of Russia, the selection and identification of factors affecting innovation activity, as well as to build an econometric model of the influence of these factors, taking into account the heterogeneity of regional development. Based on the review of theories in the field of innovation, the authors put forward the following hypotheses. Successful innovation requires the joint efforts of business, the state and society; advanced technologies occupy a leading role in shaping the innovation activity of a territory; the role of basic research is implicit, but influencing the innovation activity of a region.

2 Literature review

Many publications by leading economists are devoted to the issues of innovative development [4, 5]. The role of innovative development in the formation of a post-industrial society and its impact on economic development are widely sanctified in the work by Ivanov [6]. With the formation of a post-industrial society, more and more attention is paid to improving the quality of human life. Changing technologies and new types of products directly affect the standard of living of people and their role in the new emerging socio-economic space.

The methodological foundations of modern innovation emerged in the theory of economic development of Schumpeter [7] back in the early 20th century. According to this theory, the main driver of economic development is the emergence of new products, materials, technologies, and markets. Science in this approach does not play a leading role in economic development, but only contributes to the emergence of innovations. As most of the complex notions, innovation currently does not have a generally accepted definition. The most complete, in the authors' opinion, is the definition of innovation as a process, as reflected in the OECD Guidelines for Collecting and Analyzing Data on Innovation. In these recommendations, innovation activity is defined as "...all scientific, technological, organizational, financial and commercial activities that actually lead to the implementation of innovation or are conceived for this purpose. Some activities are innovative *per se*, others do not have this property, but are also necessary for implementing innovation. Innovation activities also include research and development not directly related to the preparation of any particular innovation" [8]. According to this approach, conducting basic research can be attributed to innovation, as indirectly leading to the implementation of innovation.

To confirm the studies of Schumpeter, Quatraro analyzed the changes in the effectiveness of the development of Italian regions for the period of 1981-2003. The results of the analysis of 20 Italian regions indicate a direct link between socio-economic development and the transition of the regions to the intellectual economy. In this case, the researcher identified the following pattern. The early industrial territories are most fully oriented to the movement towards the knowledge economy; in the late industrial regions, due to the slow expansion of production, efficiency increases and active innovation is observed within industrial sectors [9]. Modern theories in the field of regional innovation development agree on the leading role of technology (Solow [10], Barro [11], Romer [12], Aghion and Howitt [13], Limba *et al*. [14]). Studies in the field of innovative development of regions are developing in three directions: the study of innovative activity and those economically employed in the regions; the study of regional innovation clusters; identifying the role of geographical concentration of innovations (agglomerations) in regional socio-economic development [15].

For analyzing the concentration of spending on technological innovation, indicators such as the Herfindahl-Hirschman index, as well as the indices of Gini and Rosenbluth (Hall & Tideman), are often used [16]. The peculiarities of using these indicators include the fact that the Herfindahl-Hirschman index reflects mainly the concentration level of

innovations in the leading regions, the Rosenbluth index characterizes the relative size of the volume indicators of innovation development in the outsider regions, and the Gini index – the uniform distribution of regions by the values of innovation indicators.

3 Materials and Methods

At the first stage of the study, a statistical analysis of the innovative activity of Russia's regions was carried out, on the basis of such indicators as the volume of innovative goods, works, and services in the region. As a result, a typology of regions was formed, according to the aforementioned criterion – the regions where the output of innovative goods and services had the minimum and maximum values were excluded from the sample, because they are uncharacteristic of the Russian economy. Basically, these regions have special preferences or conditions and may distort further modeling of innovative activity. Also at this stage, an analysis was conducted in terms of comparing the costs of technological innovation with the output of innovative products of the region. Regions, where this ratio was more than 50%, were removed from the sample.

The selection of factors for the construction of an econometric model is based on the results of previous researchers in the field of innovative modeling, according to the Hannan-Quinn Information Criteria (HQC) and the Bayesian Information Criterion (BIC). The factors were selected for such groups as: human development, conditions for the development of competition, investment activity, the degree of involvement in international activities, the level of infrastructure development, and the use of scientific and technological potential. The final selection of factors was carried out at the stage of building and testing the model, using indicators of significance of the variables. At the next stage, as a major factor affecting the innovative activity of a region, such an indicator as the cost of technological innovation was analyzed. The analysis was conducted on the structure and dynamics, in the territorial context for 2012, 2014 and 2017.

Further, the study built a pair of models of innovative activity, taking into account the time lag. The model takes into account the impact of expenditures on technological innovation on the volume of innovative goods and services in the region. Models are linear and are represented by the following equation:

$$Y_t = \propto + \beta x_{t-k} \quad (1)$$

Where Y – volume of innovative goods, works, and services produced in the region in a period of time t; α – free term of the equation; x – costs of technological innovation in the region; b – parameters of the equation regression coefficients; k – period of time lag.

In order to assess other factors affecting the innovative activity of a region, a multifactorial correlation and regression analysis was carried out. As a base of the study, the authors used the data of the Federal Statistics Service for the 48 regions of Russia. The selection of regions for sampling is connected, as mentioned above, with the level of innovative products in the region, as well as the ratio of the costs of technological innovations and the output of innovative products.

The volume of innovative goods, works of services is chosen as the result indicator (V). The following factors were selected as explanatory variables: the degree of depreciation of fixed assets by economic activity, % (X1); the revenues of consolidated budgets of Russian regions, million rubles (X2); the expenses of the consolidated budgets of Russia's regions on the national economy, million rubles (X3); the inflow of foreign direct investment, million USD (X4), the withdrawal of direct investment abroad, million USD (X5); the investment in fixed assets of Russian enterprises, manufacturing, million rubles (X6); the total ICT costs, million rubles (X7); the number of personnel engaged in research and development, by category, persons: researchers (X8); technicians (X9); the domestic expenditures on research and development, million rubles (X10); the domestic current expenses on research and development by type of work (million rubles) – fundamental (X11), applied (X12); developments (X13), used advanced technology, pcs. (X14). When building this model, the time lag is one year.

At the initial stage of building the model, the functional specification of the model was determined. To assess the influence of factors on the innovation activity of the regions, the authors used the power regression model:

$$Y_t = \propto \prod_{i=1}^{m} x_{i,t-1}^{\beta_j} \quad (2)$$

where Y_t – volume of innovative goods, works, and services produced in the region in a period of time t; α – free term of the equation; xi – factors included in the regression model; bi – parameters of the equation of regression coefficients; i – the sequence number of the factor.

To build a generalized econometric model, a modified Cobb-Douglas type "knowledge generation function" was applied [17]. For the further building of the model, a linearization procedure was carried out, that is, the transformation of the initial data to a linear form. Logarithms were taken of both parts of the regression equation using the *ln* natural logarithm. At the next stage, a multicollinearity test was performed. When analyzing the constructed matrix of pairwise correlations, a strong correlation of the factors among themselves was revealed, that is, the private correlation coefficient between the factors exceeded the threshold value of 0.7. To eliminate multicollinearity, the method of eliminating variables by the calculated Beta coefficient for each indicator was applied. After the removal of insignificant factors, the authors constructed a multiplicative model and estimated its significance by the required parameters of regression significance.

4 Results and Discussion

4.1 Statistical analysis and typology of Russia's regions

An analysis of innovation activity in 82 regions of Russia in 2017 showed that the volume of innovative goods, works and services in Russia as a whole amounted to 4.16 billion rubles, which is 7.2% of the total output of goods and services in Russia, in 2016 – 4.36 billion rubles (8.5% of the total output), which indicates a decrease in the total national innovation activity. It is important to note that the distribution of the national innovative output is extremely uneven – from 22.8 million rubles (Republic of Ingushetia) to 435,557.7 million rubles (Republic of Tatarstan). On average, the volume of innovative products in Russia amounted to 50,817.05 million rubles. More than 21% of all regions of Russia (17 regions) have a volume of innovative products below 1,000 million rubles. About 10% (8 regions) occupy a leading position with the output volume of these goods more than 0.2 billion rubles a year. The typology of the regions by the level of innovative activity is shown in Table 1.

Table 1. Distribution of Russia's regions by the level of innovative activity in 2017

Volume of innovative goods, works, services in the region, million rubles	Number	% of total	Russia's regions
under 1000	17	21%	Chukotka Autonomous Area; Republic of Khakassia; Sevastopol; Astrakhan Region; Chechen Republic; Republic of Karelia; Magadan Region; Kabardino-Balkarian Republic; Jewish Autonomous Region; Ivanovo region; Republic of Dagestan; Altai Republic; Republic of Kalmykia; Karachayevo-Circassian Republic; Republic of Tuva; Republic of North Ossetia – Alania; Republic of Ingushetia
from 1,000 to 10,000	17	21%	Irkutsk Region; Republic of Sakha (Yakutia); Novgorod Region; Kurgan Region; Republic of Adygea; Murmansk Region; Republic of Buryatia; Pskov Region; Trans-Baikal Territory; Komi Republic; Amur Region; Primorye Territory; Orel Region; Republic of Crimea; Sakhalin Region; Kamchatka Territory; Kaliningrad Region
from 10,000 to 20,000	13	16%	Ryazan Region; Tomsk Region; Vologda Region; Kaluga Region; Republic of Mari El; Kostroma Region; Altai Territory; Kirov Region; Tambov Region; Bryansk Region; Saratov Region; Smolensk Region; Tver Region
from 20,000 to 30,000	7	9%	Kemerovo Region; Omsk Region; Volgograd Region; Orenburg Region; Chuvash Republic; Leningrad Region; Penza Region
from 30,000 to 50,000	7	9%	Yaroslavl Region; Novosibirsk Region; Ulyanovsk Region; Vladimir Region; Stavropol Region; Voronezh Region; Kursk Region
from 50,000 to 100,000	7	9%	Arkhangelsk Region; Tula Region; Khabarovsk Territory; Krasnoyarsk Region; Lipetsk Region; Udmurtian Republic; Republic of Mordovia
from 100,000 to 200,000	6	7%	Sverdlovsk Region; Krasnodar Region; Republic of Bashkortostan; Rostov Region; Chelyabinsk Region; Belgorod Region
over 200,000	8	10%	Republic of Tatarstan; Moscow Region; St. Petersburg; Moscow; Perm Region; Nizhny Novgorod Region; Samara Region; Tyumen Region

The main factor affecting the innovation activity of a region was analyzed by such an indicator as the cost of technological innovation for 2012, 2014 and 2017 (Table 2). It is important that in general the cost of technological innovation in Russia in 2017 compared with 2012 increased by 55%, from 0.9 billion rubles in 2012 to 1.4 billion in 2017. The largest share of growth accounted for the period up to 2014 (33%); for the period of 2014-2017, the increase was only 16%.

The cost structure for technological innovation over the study period has also changed significantly. In 2012, the main share of this indicator (42.08%) accounted for the acquisition of machinery and equipment related to technological innovation. In 2017, the largest share of costs (42.33%) accounted for the research and development of new products, services, and methods for their production, as well as the improvement and creation of new production processes. Among those items that significantly changed the amount of expenses, one can mention an increase in engineering costs (171% by 2012), an increase in the number of acquired patents/licenses for the use of inventions, industrial designs and models by 171%; such an item as "software purchase" has almost doubled.

Table 2. Structure and dynamics of the cost of technological innovation in Russia

Cost items	Growth rate in 2017 by 2012	Growth rate in 2017 by 2014
Research and development of new products, production processes	83%	13%
Design (activities to change the form, appearance or usability of products or services)	-53%	-77%
Acquisition of machinery and equipment related to technological innovation	26%	15%
Acquisition of new technologies	-2%	-26%
Software purchase	98%	121%
Engineering	171%	62%
Innovation education and training of staff	-58%	29%
Marketing research	71%	299%
Other costs	65%	68%
Total in Russia	55%	16%

The reduction in the cost of technological innovation occurred in the following items: design (activities to change the form and appearance of products and services) – by 53% by 2012; innovation education and training of staff – 58%, acquisition of new technologies – 2%.

In the context of the federal districts of Russia, the Central and Volga Federal Districts occupy the largest share in the total share of innovative costs in the total volume. An analysis of the growth rates of these indicators suggests that the highest rates were achieved until 2014, when investment, and hence innovation activity, was not opposed by the sanctions pressure. In Russia as a whole, the growth rate from 2012 to 2010 was 126%; in 2014 compared to 2012, only 34%, and in 2017 compared to 2014, only 16%. The situation is similar in some particular federal districts. For example, in the Central Federal District in 2012, the growth rate of expenditures on technological innovations compared to 2010 was 193%. The same indicator in 2014 compared to 2012 was only 24%, in 2017 compared to 2014 – even lower than 21%. Similar dynamics are also characteristic of the North-Western Federal District and the Southern Federal District.

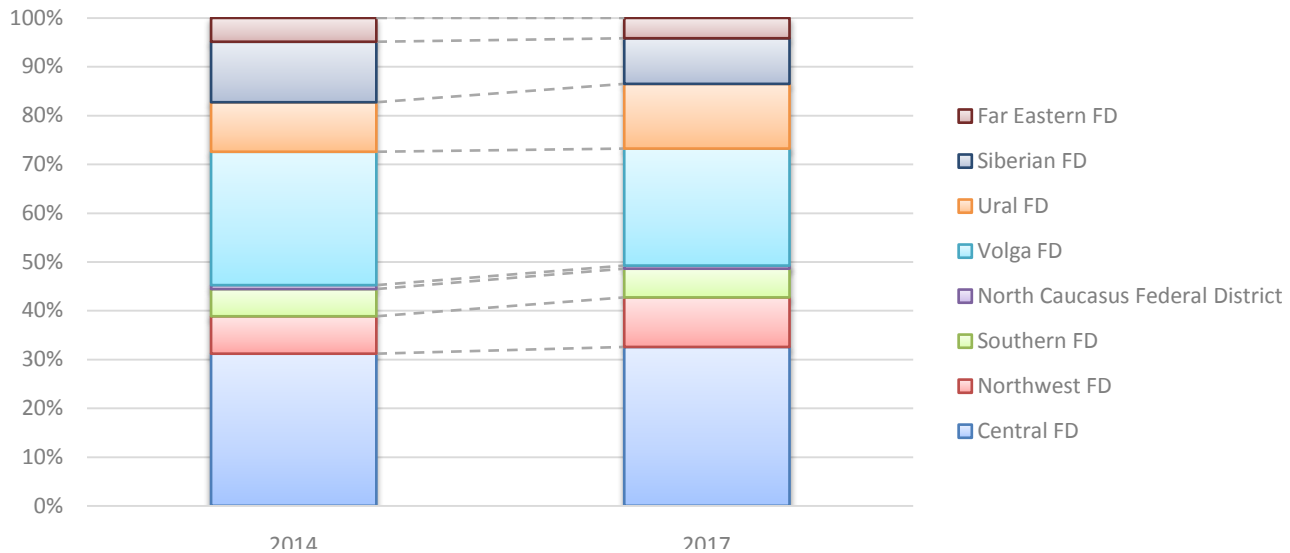

Figure 1. Expenditures on technological innovation by the federal districts of Russia, thousand rubles

In the Urals Federal District, on the contrary, there is an increase in the cost of technological innovation, and for the last analyzed period (2017 by 2014) the increase was 52%. It should be noted that the Sverdlovsk and Chelyabinsk Regions are among the leaders in innovative goods and services produced.

From the point of view of the sectoral structure of the economy, most of the costs of technological innovations in Russia account for the production sector (0.8 billion rubles), including more than 0.6 billion rubles in manufacturing industries. The distribution of costs by major sectors of the economy is also extremely uneven. The largest share (27% and 20%) falls on the most capital-intensive sectors of the domestic economy – production of coke and petroleum products and metallurgical production. This cost distribution structure is characteristic for all the periods considered. For the period of 2012-2014, there are no expenditures on technological innovations in such sectors as the woodworking industry, textile, and clothing production, the share of innovative costs in the food industry being extremely small. According to the leading economists, the balanced structure of the economy is one of the main conditions for its successful development. In Russia, according to some authors, Lin [18, 19], Simachev [20] and others, there is a structural inconsistency in the development of sectors; in particular, there is a lag of the consumer sector of the economy from the export-oriented, defense-industrial and raw materials sectors [21]. Unbalanced development of sectors can lead to structural crises.

An analysis of the cost of technological innovations in the context of the regions of Russia also revealed an uneven distribution. The coefficient of variation is many times greater than the threshold value, which does not allow the study to rely on the average value of this indicator. The maximum figure for 2017 was recorded in the city of Moscow – 194,204.99 million rubles, the minimum in the Republic of Ingushetia – 0.683 million rubles. At the same time, 50% of regions spend on technological innovations less than 4.2 billion a year. Only in three regions of Russia, the level of these costs exceeds 100 billion rubles – the Moscow and Tyumen Regions and the city of Moscow.

4.2 Results of regression-correlation analysis

In assessing the impact of expenditures on technological innovations on the volume of output of innovative goods and services, the following regression equation was obtained for a linear type model (3).

$$V_{\text{in prod}} = 11,003.34 + 3.62 \cdot C_{\text{in prod}} \quad (3)$$

where $V_{\text{in prod}}$ – volume of innovative goods, works, services, 2017, million rubles; $C_{\text{in prod}}$ – expenditures on technological innovations, 2017, million rubles.

The regression is significant for all the main parameters, R-squared is 0.82, which indicates the closeness of the relationship of factors (Appendix A). In this model, the coefficient at the cost indicator shows that with an increase in the amount of costs for technological innovation by 1 ruble, the volume of innovative goods and services will increase by 3.62 rubles. In this equation, the time lag is not taken into account, i.e. the coefficient k = 0 (formula 1). Data was used for one year (2017). At the next stage, two-time lags were set for 3 and 5

years, and accordingly, models were built according to 2014 and 2012 data (Table 3).

Table 3. Comparison of the models of innovative activity of regions

Time lag (k)	Calculation period, years	Constant	Costs influence
0	2017/2017	11,003.34	+3.62
3	2014/2017	12,141.74	+4.34
5	2012/2017	15,696.74	+3.87

From the data in the table, it is clear that the greatest increase in the volume of innovative products, under the influence of the same factor – the expenditures on technical innovation, occurs with a time lag of 3 years – 4.34 rubles on 1 ruble of costs, which indicates the feasibility of investing in medium-term projects. The assessment of the significance of these models is given in Appendix A.

At the next stage, a multi-factor model of a region's innovative activity is built. At the initial stage of building the model, the functional specification of the model is found. The found dependence has a nonlinear form, since the magnitude of the accuracy of approximation (R^2), with a power trend line, was 0.96 – this is the largest value of R^2 of all other types of functions.

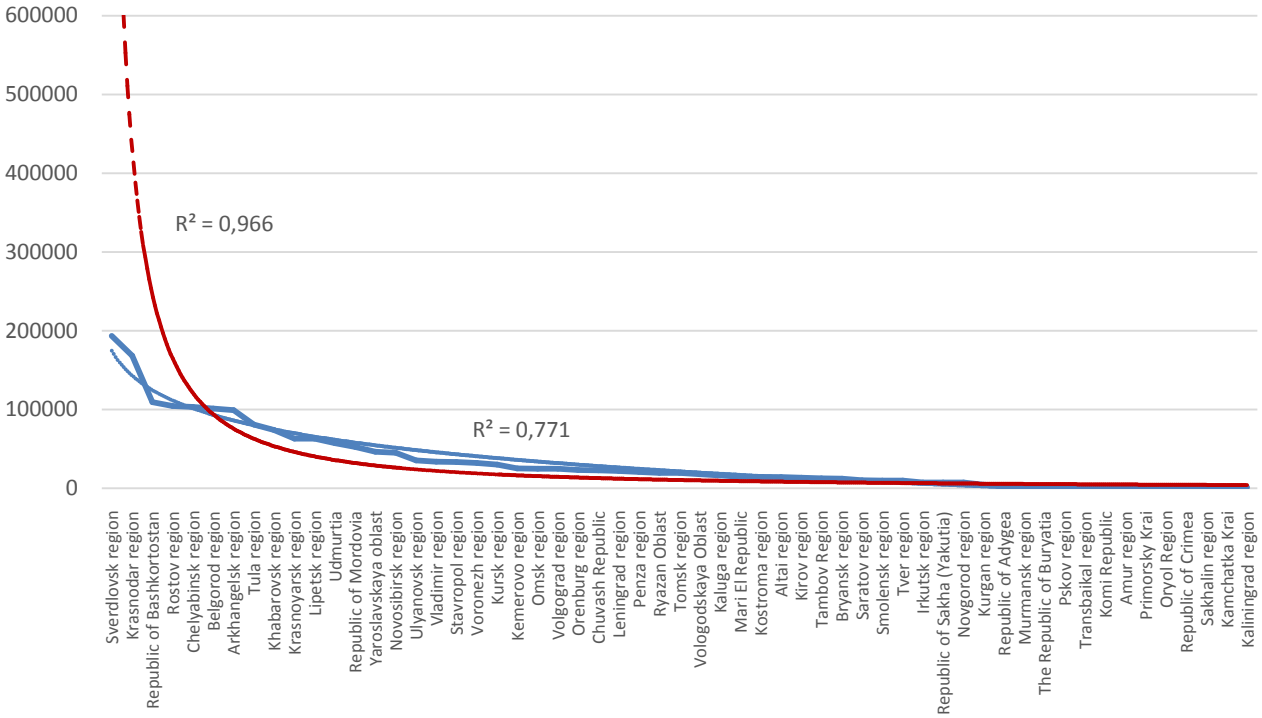

Figure 2. Specification of the model

In the course of the correlation-regression analysis, factors affecting the volume of innovative goods and services turned out to be 3 of the 14 above factors. The following factors turned out to be significant factors according to Student's criterion: the expenses of the consolidated budgets of Russia's regions on the national economy (X3), investments in fixed assets of manufacturing industries (X6) and the number of advanced technologies used in a region's enterprises (X14). Non-relevant factors determined by Student's t-test (t-statistics) were removed from the model. Also, the constant was not a significant factor. According to the results of the correlation analysis, the following equation was obtained (4):

$$Y=X3^{0.3999}\ X6^{0.3953}\ X14^{0.3510} \quad (4)$$

where Y – volume of innovative goods, works, services, 2017, million rubles; X3 – expenses of consolidated budgets of Russia's regions on the national economy, 2016, million rubles; X6 – investments in fixed assets of manufacturing industries (Russia), million rubles; X14 – advanced technologies used, pcs., 2016.

These factors have a positive effect on the volume of innovative products. The coefficients of the regression equation obtained show that with an increase in the expenses of the Russian regions on the national economy by 1%, the volume of innovative products will increase by 0.399%. With an increase in investment in the manufacturing sector of the regional economy by 1%, the volume of innovative products will increase by 0.395%. An increase in the number of advanced technologies used by 1% will result in an increase by 0.351%. The values of these coefficients indicate a certain equivalence of the influence of factors. The sum of the coefficients is 1.145, which allows concluding on the positive effect of scale and under-investment of this segment of the economy.

The multiple regression coefficient is 0.996, which indicates the presence of a high relationship between the factors under consideration and the impact of these indicators on the level of production of innovative goods and services. The revealed positive relationship allows concluding about the importance of investment in the manufacturing sector of the regional economy, the need to increase enterprises' access to advanced production and organizational technologies, as well as the importance of such an item of the regional budget as the "national economy". Graphic display of the built regression model is shown in Figure 3. In general, the modeled value corresponds to the real trend, and some gaps between real and modeled values indicate the heterogeneity of the development of Russian regions and the need for an individual approach to the design of their development.

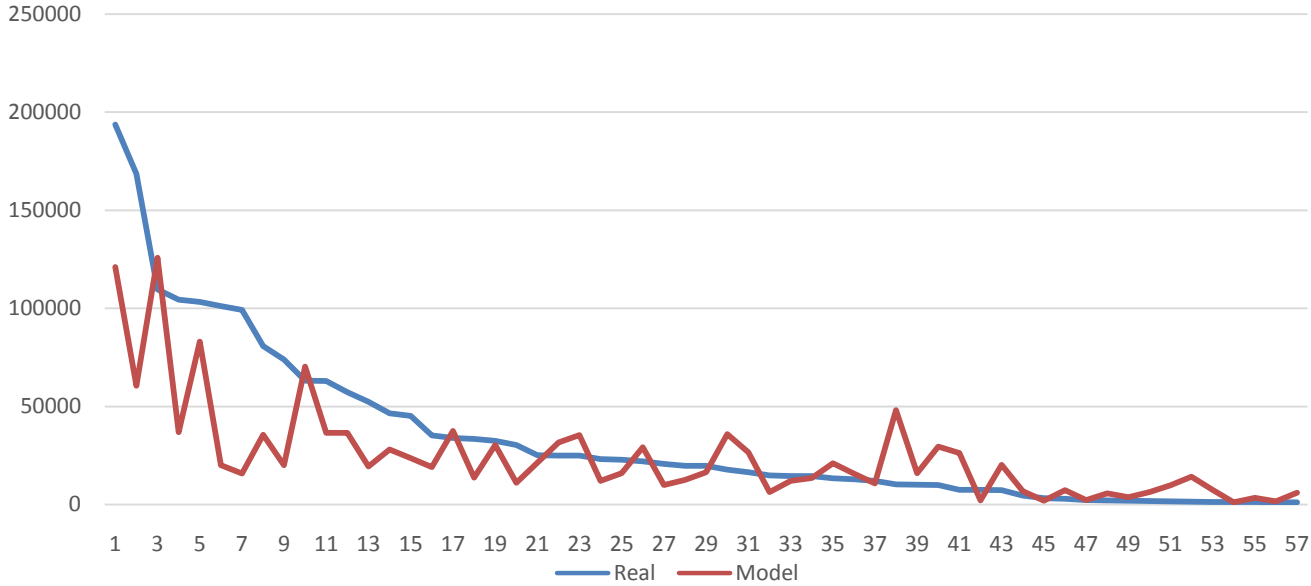

Figure 3. Real and modeled values of the volume of innovative products

The proposed model does not take into account all factors affecting the innovative activity of a territory; there is a probability of inaccuracy due to incorrect statistics. There is also a large share of uncertainty in forecasting innovation development on the parameters of this model, since the development of regions is extremely uneven [22]. A special economic status and geographical location of a region play a very significant role. Nevertheless, the results obtained allow forming the directions for increasing the innovation activity of the territories.

The results of the study suggest the importance of using advanced technologies, as well as government support, to increase the innovative activity of the territories. A significant factor is also the implementation of investments in fixed capital of the real sector of the economy, namely, manufacturing industries. For developing countries, an investment strategy is very important [23]. Currently, the complex geopolitical situation and the introduction of sanctions for Russian business have led to an increase in interest rates on loans and credits and have prevented the development of long-term investment projects. Since 2014, there has been a decrease in the volume of investments in fixed assets in Russia as a whole. In 2012, the index of the physical volume of investments in Russia as a whole was 106.8%, and by 2016 it decreased to 99.1% [24]. Under these conditions, state support for investments becomes particularly relevant. An effective form of implementation of that is the industrial policy.

The industrial policy is an effective mechanism for encouraging investments in the form of loans, subsidies, tax incentives, government orders, and procurement systems. The transition of the Russian economy from a mineral wealth export model of development to an innovative one is the goal of the industrial policy. In view of this, the formation of the industrial policy that takes into account the specifics of regional development is of particular importance in these conditions.

5 Conclusions

The results of the empirical analysis allow concluding that for the successful development of any region and the maintenance of its innovative activity, an influx of investments into the economy of the real sector is a must. It is also important to maintain the availability and quality of advanced technologies, the introduction of the best available technologies at enterprises. Budget expenses on the national economy have a direct impact on the level of innovative activity in a region. For the development of the regional economy on an innovative basis, joint efforts of business, government and science are required, which confirms the hypothesis the authors have outlined. The hypothesis about the leading role of technologies in the formation of innovative activity of a territory has been confirmed. The industrial development funds are aimed at increasing the innovation activity of regions and have a direct effect on all three factors of the model the authors proposed: the expenses of the regional budgets on the national economy, investments in fixed assets of the manufacturing industries and the introduction of advanced technologies at enterprises.

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Appendix A.

Assessment of the significance of regression models

Model	Model parameters	Regression statistics
Paired model no time lag (k=0) $V_{in\ prod} = 11,003.34 + 3.62 \cdot C_{in\ prod}$	$V_{in\ prod}$ – volume of innovative goods, works, services, million rubles; $C_{in\ prod}$ – expenditures on technological innovations, million rubles	R=0.9095788 R^2=0.8273336 F=177.28 N=39 p_y= 0.009 p_x = 0.000 Reliability level 95%
Paired model time lag 3 years (k=3) $V_{in\ prod} = 12,141.74 + 4.34 \cdot C_{in\ prod}$		R=0.7249568 R^2=0.5255623 F=48.738 N=46 p_y= 0.04584 p_x = 0.00000 Reliability level 95%
Paired model time lag 5 years (k=5) $V_{in\ prod} = 15,696.74 + 3.87 \cdot C_{in\ prod}$		R=0.7149568 R^2=0.5155623 F=45.21273 N=45 p_y= 0.01000 p_x = 0.00000 Reliability level 95%
Power model time lag 1 year (k=1) $Y=X3^{0.3999}\ X6^{0.3953}\ X14^{0.3510}$	Y – volume of innovative goods, works, services, 2017, million rubles X3 – expenses of consolidated budgets of Russia's regions on the national economy, 2016, million rubles	R=0.998335 R^2=0.996672 F=4492.823 N=48 p_{x3}= 0.02500

	X6 – investments in fixed assets of manufacturing industries (Russia), million rubles X14 – advanced technologies used, pcs., 2016	p_{x6} = 0.0890 p_{x13}= 0.0495 Reliability level 95%