National Innovation System: Experience of Formation, Revealing Patterns of Development, Regulation

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Abstract

In the context of the accelerated pace of globalization, the global trends of the modern economy are defined by innovative development which is a priority to strengthen the position of the national economy. Generation of new knowledge and formation of innovative intellectual environment of the public good become a part of the market mechanism in competitive tools for the country's leadership in the field of high technology. In addition, activation of the scientific potential and strengthening the innovation component of the economy determine high rates of economic growth and, consequently, the social economy in the long term. Under present conditions special attention is paid to the study of national innovation system formation, since the global improvement in the quality of life is only possible through development and strengthening the role of innovation in economic development. The aim of the study is to identify and study formation and development regularities of the national innovation system based on the use of new methodological approaches and based on fundamental provisions of the system analysis using the original methods of mathematical, computer and GIS modeling to improve its functional and spatial structure. Objectives of the study: - To analyze the theoretical and methodological study of different types of provisions in national innovation systems based on experience of their formation in developed and developing countries; - To identify the methods of their regulation and laws of development, to develop and justify the interdisciplinary scientific approach to the study of the national innovation system in Russia; - To use the modern tools of Mathematics and Statistics (cluster, dispersion, spectral, correlation and regression) modeling and forecasting, allowing not only identifying the most important factors affecting innovation and analyzing the current trends of their development, but also quantifying their mutual influence. The theoretical and methodological basis of the research is a systematic-structural and systematic-functional approach to the study of relationships between socio-economic systems and their major components. The solution of the main objectives of the study requires the use of various methods of the scientific analysis: comparative, historical, statistical, mapping, GIS technologies, mathematical, geographical information and computer modeling. Obtained results can be the basis to develop a strategy of government of the state focused on long-term sustainable development; socio-economic development and innovation at the national level and directly at the level of regions and areas.

Keywords: *national innovation system, innovation, typology, integral index, innovation potential.*

1. Introduction

1.1 Introduction of the problem

Formation of the national innovation system in the country, and the study of factors, prerequisites for development of the economy based on innovation contribute to sustainable economic development in line with modern trends in macroeconomic development, and improve the quality aspects of life of the population. The problem of innovative development in the Russian economy with a predominant share of primary GDP sector is particularly acute, which has a diversified economic structure and a territorial system of many subjects and that determines development of innovative

multi-level systems with formation of regional and branch innovative production systems, interacting with large corporate entities and the state. The problem of formation and development of the national innovation system is comprehensive and multidisciplinary in nature, requiring a systematic study, using a variety of techniques and methods. The analysis involves the study of the past, present and forecast the future development of the national innovation system, which requires the various systems of modeling techniques at every stage.

The theoretical and methodological basis of the research is a systematic-structural and systematic-functional approach to the study of relationships between socio-economic systems and their main components that require the use of various methods of scientific analysis: comparative, historical, statistical, GIS technology, mathematical, and geoinformation computer modeling as well as the typology and zoning. With the financial support of RFBR grants (project №11-06-00177 «Mathematical and computer modeling of economic cycles in agriculture", 2011-2012 and the project № 13-06-00200-a "Mathematical modeling and GIS innovative development of agriculture", 2013-2014) and RHF (RHF project № 14-12-13006 «Development of the innovative model in the agri-territorial system of the region (using an example of the Republic of Mordovia)", 2014-2015.) there have been developed and tested various approaches and modeling methods of social and economic facilities, which can be used in this study. In this case, the authors use mathematical modeling techniques to identify factors in formation and development of the national innovation system, and implement the original mathematical tool, which is a method of modernization and structural parametric identification of the mathematical model. This mathematical tool is used in the computer simulation modeling (RFP "Simulation statistical modeling Simwek 1.0.» which has been developed by Department of “Statistics, Econometrics and Information Technology in Management”, Ogarev Mordovia State University (Certificate of the Federal Service for Intellectual Property, Patents and Trademarks on official registration №2005612656, which is registered in the Register of Computer Programs)) to identify the factors that have the greatest impact on functioning of the national innovation system, which allows the authors varying quantitative parameters, assessing their extent and impact on individual components of the national innovation system. Complex mathematical calculations with development of mathematical models have been carried out using RFP Statistica and MATLAB according to official statistics of Rosstat.

1.2 Explore Importance of the Problem

It involves the following analysis phases:

1. Analysis of theoretical and methodological approaches to the problem of formation and development of national innovation systems and the use of modeling techniques.
2. Development of the complex interdisciplinary scientific approach to functioning and development modeling of the national innovation system in Russia.
3. Identification and evaluation of socio-economic, organizational, industrial and institutional factors contributing to development of the national innovation system in Russia.
4. Analysis of innovation diffusion as a factor in formation of the national innovation system in Russia. 5. Development of the computer modeling system on functioning and development of the national innovation system. Its logical organization presents three interrelated components: 1) preparation unit and converting raw data; 2) simulation unit; 3) the graphic representation block of the obtained results. Interpretation of the results. Identification and synthesis of the basic laws.

1.3 Background / Literature review

Many researchers are interested in transformation of the economy, the role and place of the state in fostering innovation, despite the fact that the theory of national innovation systems arose only in 80-90 years of the twentieth century and, therefore, is one of the youngest in modern economics. The term "national innovation system" was firstly used by K. Freeman as a kind of institutional structure network in public and private sectors, which activity and interaction initiate, create, modify, and contribute to diffusion of new technologies (Freeman, 1987). B. A. Lundvell defined the national innovation system as a system of innovation, formed from the elements and relationships which interact in production, distribution and use of new and economically useful knowledge ... within the boundaries of the nation-state (Lundvall, 1985). The basis of these authors' methodological principles is based on Schumpeter's ideas about innovation, or "new combinations", and on entrepreneurs, whose main economic function is to implement innovations; consider the institutional aspect of innovation as a factor directly influencing its content and structure (Schumpeter, 1911). In its turn, assumptions of Schumpeter's innovation theory are based on Kondratiev's works, who linked the wave of invention and innovation with transition to a new cycle (N. D. Kondratiev, 1922).

Kondratiev's research and conclusions were based on statistical analysis of time series of economic indicators in various countries, when the author illustrated a large wave of radical innovation at the beginning of the growth cycle, profound changes in technology and production technology based on radical inventions and discoveries, substantial transformation in determining the conditions of the economic life of society. This technology improvement is under control of a cyclical process with a large period.

Among foreign scientists, whose works are of greatest interest for NIS development, we should note such scholars as: R. Daniels (Daniels et al., 1996), B. A. Lundvall (Lundvall, 1992), R. Nelson (Nelson, 1993), D. North (North et al., 1989), M. Porter (Porter, 1990), P. Romer (Romer, 1986), P. Samuelson (Samuelson, 1952), B. Santo (Santo, 2005), K. Freeman (Freeman, 1987), S. Huntington (Huntington, 1993), G. Chesbrough (Chesbrough, 2005), I. Schumpeter (Schumpeter, 1911), J. Andrew (Andrew et al., 2007) and others.

As for domestic researches in the field of national innovation system development we should note such authors as: A. E. Varshavsky (Varshavsky, 1999), M. V. Volynkina (Volynkina, 2005), O. G. Golichenko (Golichenko et al., 2013), L. M. Gokhberg (Gokhberg et al., 2013), A. A. Dagaev (Dagaev, 2013), A. A. Dinkin (Dinkin et al., 2004), V. V. Ivanov (Ivanov. 2002), N. I. Ivanova (Ivanova, 2002), G. B. Kleiner (Kleiner, 2004), T. E. Kuznetsova (Kuznetsova, 2013), V. M. Polterovich Polterovich (1990) and others.

Despite numerous studies on national innovation systems, we do not have generally accepted definition of this concept yet. Thus, according to K. Freeman, the national innovation system is a network of institutions in public and private sectors, which activities and interactions have the following result: new technologies are imported, modified and distributed (Freeman, 1987). The innovation system is formed from elements and relationships which interact in production, distribution and use of new and economically useful knowledge ... the national system includes elements and relationships located within the boundaries of the nation-state (Lundvall, 1992). R. Nelson examines the national innovation system as a set of institutions whose interactions dictate innovation national firms. National institutions, their incentive systems and competencies determine the degree and direction of technological learning (or activity, generating changes) within the country (Patel & Pavitt, 1994). According to N. N. Ivanova, the national innovation system - a complex of related entities (agencies) involved in production and commercialization of science and technology within national borders (small and large companies, universities, laboratories, technology parks and incubators) (Smith, 2002). At the same time, the national innovation system is a complex of institutions, legal, financial and social issues, providing innovative processes and having strong national roots, traditions, political and cultural characteristics.

Generalizing numerous definitions of the national innovation system, we can define it as a subsystem of the national economic system, including business entities (innovative companies, universities, research institutes, industrial parks, manufacturing facilities, funds, small and medium-sized businesses, consumers) and institutions (legal, legislative, financial social), jointly involved in the process of generation, diffusion and implementation of competitive knowledge and technologies to support the implementation of innovative activities in order to achieve the strategic goals of sustainable development of the economic system and help improve the country's competitiveness at international level.

The most important structural feature of the national innovation system - the ratio of public and private business R & D funding, the objective function of innovative system development is to increase innovation demand from private and public enterprises as the basis for scientific orientation in commercialization and development of mutually beneficial cooperation between scientific and educational, industrial and infrastructure organizations.

A key role in many domestic researches is the question of the state's role in innovation coordination and management. It is noted that the priority areas of the state innovation policy are:

1. Increase of scientific and high technology priority;
2. Development of innovative tasks within the major programs of economic and social development;
3. Formation of innovation clusters;
4. Development of information infrastructure and formation of professional innovation management;
5. Implementation of procurement mechanisms of technically advanced and high-tech products to meet the challenges of economic and social development (health, energy saving and environmental protection, and others.);
6. Development of coordinated measures of tax, credit, depreciation, customs, regional and fiscal policy to stimulate innovation supply and demand;
7. Development of mechanisms to consolidate the financial resources of public and private business sectors for priority scientific and technical problems, optimization of the partnership between the private sector and state;
8. Improvement of public innovation program assessment, disseminating of its results to business and expert community;
9. Improvement of the investment climate, stabilization of property rights, including intellectual property,

development of the stock market and banking system, as well as the system of financial intermediaries, increased competition, including at the regional level are necessary conditions to get an innovative type of economic growth;

10. Promotion of international scientific and technical cooperation, fostering of international and regional technological strategic alliances.

In 2011 the government adopted "The strategy of innovative development of the Russian Federation for the period up to 2020", which shows three possible options for innovative development:

- Inertia (based on imports) of technical development;
- Catch-up development and local technological competitiveness is based on modernization of the economy at the expense of imported equipment and technologies, as well as selective stimulation of domestic R&D development;
- Achieving leadership in leading scientific and technical sectors and basic researches (2011).

Obviously, the third embodiment is more preferable, but it is more expensive and has a limited application. In Russia this option can be implemented only in those sectors where the country claims to be a leader in the world. These is MIC production (military-industrial complex), aerospace, composite materials, development and application of nanotechnology, biomedical technology life support and protection of human and animal, software, as well as nuclear and hydrogen energy, certain areas of nature conservation and ecology and a number of other activities. Therefore, implementing innovative strategies all the options will be used with the dominance of the catch-up development version at the first stage. In general, as it is noted by many researchers, "Strategy - 2020" is intractable by many positions, and according to some - impossible.

Much attention in studies of the national innovation system is given to consideration of its basic elements. Special place in the study is taken by assessing the level of development in national innovation systems. To rank the European Union 25 indicators have been used characterizing the innovative development of the countries.

The integral indicator of this assessment is Summary Innovation Index (SII), calculating which the following groups of data are used:

- Enablers (resources of innovative development, assessment: the educational level of the population, the level of science, science funding and innovation development);
- Firm activities (activities of enterprises; assessment: private investment in R & D and innovation, entrepreneurship and communication, intellectual assets);
- Outputs (results; dimensions: organization-innovators, economic effects).
- Depending on reducing the amount of SII, each of the EU countries fall into one of four types: innovation leaders – "leaders of innovation"; innovation followers – "followers of innovation"; moderate innovators – "moderate innovators"; modest innovators – "modest innovators."

To assess the innovative development level of the countries the authors use widely the global index of innovative development (The Global Innovation Index), developed by the international business school INSEAD (France), Cornell University (Cornell University) and the World Intellectual Property Organization (World Intellectual Property Organization, WIPO). It is cost-effective, that allows evaluating the effectiveness of efforts objectively to promote innovation in a particular country. The index is calculated as a weighted sum of two scored groups of indicators: Innovation Input - has resources and conditions for innovation (institutions, human capital and research, infrastructure, business development, and others.) and Innovation Output - achieved practical results of innovative implementation (technology development and economy knowledge and the results of creative activity).

The technique level of innovative development in the World Bank (Knowledge for Development - K4D) allows evaluating the level of economic development compared with neighboring countries, competitors and others.

The Integral Innovation Index of the World Bank consists of 76 indicators grouped into four blocks:

a) The economic and institutional environment, its effectiveness using existing and development of new knowledge and production;
b) The level of human development;
c) Information infrastructure;
d) Effectiveness of innovative firms, research centers, consulting and other organizations creating technology.

The Innovation Capacity Index, presented in «The Innovation for Development Report», was developed under Augusto Lopez-Claros and Yasmin N. Mata's leadership. It includes 60 indicators in five areas: human development, institutional climate, the quality of legislation, and the use of information and communication technologies, conditions for R & D.

Innovation diffusion on the territory takes place through their diffusion. E. Rogers believed that diffusion is a

process in which innovation is passed through certain channels over time among the members of the social system (Rogers, 2010). The propagation velocity of innovation in society according to E. Rogers depends on five main factors: relative advantages (relative advantage); compatibility (compatibility); complexity (complexity); ease of testing (trialability) and communication (communicability) innovation (Rogers, 2010).

In studies of the national innovation system we can see that the questions of their tool study and their individual components are the least developed. The conceptual models are more developed in the structure of the national innovation system, reflecting the key components of the system and relationships between them. There are also four types of the world's national innovation systems "Euro-Atlantic" (the model of the full innovation cycle); "East Asian" (in the innovation cycle there is no stage in formation of the fundamental ideas); "Alternative" (emphasis on the training of highly qualified personnel with a weak development of the block of fundamental and applied science and high-tech component) and "triple helix". The latest model works in the following way: two out of three helices form the boundary conditions of the interval situation in relation to the third one, and the third one - environment "between", and each of the selected variables can perform these frame functions pairwise (Andryushkevich, 2013).

The modern literature also presents evolution of innovative models in firm behavior (Golichenko et al., 2013). The starting point for evolution of innovative models was linear models of technological shock (technologypush model) in 60-ies of XX century. Then was the type of innovative linear models based on the gravitation market. Innovative models of the next generation (mid-70s until the mid 80-ies) combined both types of models of previous generations (technological push and thrust of the market). Since the early 80's to mid 90-ies of XX century the model of innovation processes became dominant. The fifth generation, according to R. Rothwell, is a system-integration and network model (Rothwell, 1992). It is a model of continuous innovation, has great flexibility and a high speed of innovative development.

Overall, the analysis of studies of the national innovation system does not fully reveal the essence of the integration process in the innovation sphere, the structure and mechanism of a coherent national innovation system, the definition of the role and functions of the system subjects, the place of innovation policy in national policy and others.

1.4 State Hypotheses and Their Correspondence to Research Structure

With the financial support of the RFBR grant (project №11-06-00177 «Mathematical and computer modeling of economic cycles in agriculture", 2011-2012 and the project № 13-06-00200-a "Mathematical modeling and GIS innovative development in agriculture", 2013-2014) and the RHF grant (RHF project № 14-12-13006 «Development of an innovative model of the agriterritorial system in the region (using an example of the Republic of Mordovia)", 2014-2015.) were considered some aspects of the problem under investigation. The authors developed the methodological and methodical aspects of interdisciplinary research related primarily to the study of innovation development in agriculture.

In particular, there was a historical and economic analysis of evolution and functioning in agriculture based on space-time agricultural performance and developed electronic database of more than 100-year period. Using a spectral analysis, the authors substantiated cyclical development of innovative processes in agriculture and a mathematical model for predicting (Ivanova, 2013).

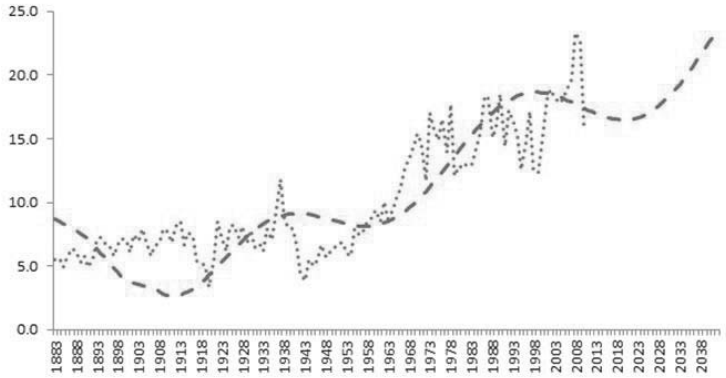

Figure 1 - Prediction of innovation processes in agriculture in Russia until 2042, taking into account the increasing trend of Fourier's polynomial and cyclic model.

However, the research has shown a need for a deductive approach, that is, to understand innovative development of individual sectors in the economy, we have to analyze the national innovation system as a whole. However, in previous works there were various methods of mathematical modeling applied to solve the problems of innovative development.

Thus, studying research and innovation activities in the Russian Federation as a whole and its individual regions, for management decisions on regulation and improvement of its efficiency, it is suggested to use modern tools of mathematical and statistical modeling and forecasting, allowing not only identifying the most important factors, influencing innovation, and analyzing the current trends of its development, but also quantifying their mutual (Ivanova, 2014).

2. Methods

Multivariate Analysis Methods - the most effective quantitative research tool of innovative processes described by a large number of characteristics. They include clustering, factorial, correlation and regression analysis techniques. The cluster analysis more clearly reflects the features of the multivariate analysis in classification (Sazhin et al., 2014). The cluster analysis is a multivariate statistical procedure, which collects data, containing information about the sample objects, and then organizes objects into relatively homogeneous groups. A great advantage of the cluster analysis is that it allows you to divide objects not on one parameter, and on a set of features. In addition, the cluster analysis, unlike most mathematical and statistical methods, does not impose any restrictions on the form of the objects, and allows you to consider a variety of input data of arbitrary nature. This is important, for example, to predict the situation when indicators are diversified and it makes difficult to use traditional econometric approaches.

Cluster analysis methods can perform the following tasks:

- Classification of objects based on features that reflect the essence, the nature of the objects in order to improve knowledge in the population of classified objects;
- Testing of hypotheses on presence of a certain structure in the population of the studied objects;
- Clustering of poorly studied phenomena in order to establish the links within the population (Sazhin et al., 2014).

The decision of the cluster analysis is a partition satisfying some criterion of optimality. This criterion may be functional (objective function), expressing the desirability levels of different groups and partitions.

To conduct the qualitative analysis of regional differences in regions' innovative activity of the Russian Federation the authors carried out their typology based on the cluster analysis. To simulate the main indicators that have a direct impact on effectiveness of regions' innovative activity of the Russian Federation, it was used spatial statistical data of Rosstat on 76 of its subjects.

As the main factors that characterize effectiveness of Russian regions' innovative activity the authors identified the following innovative indicators:

- X_1- Innovative activity of organizations,%;
- X_2- The share of organizations implementing technological innovation in the reporting year, the total number of surveyed organizations,%;
- X_3- Expenditure on technological innovation in the total volume of shipped goods, works, services,%
- X_4- Used advanced production technology, U .;
- X_5- Expenditure on technological innovation, ths. rub .;
- X_6- Economically active population, on average per year, thous. people .;
- X_7- The number of personnel engaged in research and development, people .;
- X_8- The number of researchers with a degree, people .;
- X_9- The share of organizations that use a personal computer in the total number of surveyed organizations of the relevant subject in the Russian Federation,%;
- X_{10}- Average annual population, thous. people .;
- X_{11}- GRP, mln. rub .;
- X_{12}- PPS per capita, rub .;
- X_{13}- The number of computers with the Internet access per 100 workers;
- X_{14}- The share of organizations that use ATP for research in the total number of surveyed organizations,%;
- X_{15}- The share of expenditure on technological innovation in the total GRP,%;
- X_{16}- The number of personnel engaged in research and development per 1000 people of economically active population;
- X_{17}- The number of researchers with a degree per 100 people;
- X_{18}- Created (developed) advanced production technology per 10000 advanced manufacturing technologies, U .;

For clustering the authors applied agglomerative hierarchical and non-hierarchical classification methods, the most obvious of which is Ward's method (Ward's method). Using k-means method and Ward's method using PPP Statistica, the authors classified Russian regions with different levels of innovation activity, which allowed to apply a differentiated approach to development and management decisions in order to regulate and improve effectiveness of individual clusters' innovative activity of subjects in the Russian Federation (Ivanova, 2014).

As an econometric model which shows the way how indicators of Russian regions' innovative activity depend on main factors, it was used a recursive system of linear regression equations (Sazhin et al., 2014):

$$\begin{cases} Y_1 = a_{11}X_1 + a_{12}X_2 + \ldots + a_{1m}X_m + \varepsilon_1; \\ Y_2 = b_{21}Y_1 + a_{21}X_1 + a_{22}X_2 + \ldots + a_{2m}X_m + \varepsilon_2; \\ Y_3 = b_{31}Y_1 + b_{32}Y_2 + a_{31}X_1 + a_{32}X_2 + \ldots + a_{3m}X_m + \varepsilon_3. \end{cases} \quad (1)$$

The recursive system of regression equations was constructed being based on causality of endogenous Y_i (i = 1,2,3) and exogenous variables X_j(j = 1, ..., 18). The number of granted patents (Y_1) includes conducting of fundamental and applied research and development, and determines development and creation of new advanced technologies that enhance product competitiveness and stimulate innovation. There are new constructive ideas that give impetus to new products and process innovations, essentially forming creation of new advanced technologies (Y_2). The use of new technologies, product and process innovation, in turn, leads to an increase in production and sales of innovative products (Y_3). Furthermore, many factors affect each endogenous component individually X_j (j = 1, ..., 18). Using a step joining method it is possible to construct multiple equations of regression correspondence Y_1, Y_2, Y_3 on assumed factors avoiding from the model some factors which are responsible for multicollinearity, as well as factors which are statistically insignificant by Student's test. The system of recursive equations of regression correspondence indicators in innovation potential of the regions in the Russian Federation on presented factors (Smith, 2014) has the following form:

$$\begin{cases} Y_1 = -268,74 + 4,06X_9 + 0,29X_{18} + \varepsilon_1; \\ Y_2 = 70,71 + 0,07Y_1 + 0,64X_6 + 2,29X_{15} + 1,82X_{16} + \varepsilon_2; \\ Y_3 = -1,19 + 0,001Y_1 + 0,05Y_2 + 1,61X_1 + 1,73X_2 + 0,00002X_{12} + 2,62X_{15} + \varepsilon_3. \end{cases} \quad (2)$$

The actual values of Student's t test (t - statistics) for each equation of the constructed system (2) exceed the corresponding critical values:

$$\begin{gathered} t_{a_{19}} = 1,91;\ t_{a_{118}} = 4,24;\ t_{кр_1}(0,1;73) = 1,667; \\ t_{b_{21}} = 4,68;\ t_{a_{25}} = 2,06;\ t_{a_{215}} = 2,63;\ t_{a_{216}} = 5,88;\ t_{кр_2}(0,1;71) = 1,667; \\ t_{b_{31}} = 1,91;\ t_{b_{32}} = 1,97;\ t_{a_{31}} = 1,69;\ t_{a_{32}} = 1,68;\ t_{a_{312}} = 4,11;\ t_{a_{315}} = 4,75; \\ t_{кр_3}(0,1;69) = 1,667. \end{gathered} \quad (3)$$

The observed values of Fisher's criterion (F - statistics) exceed the critical value:

$$\begin{gathered} F_1 = 10,55;\ F_{кр_1}(0,05;2;73) = 3,12; \\ F_2 = 30,61;\ F_{кр_2}(0,05;4;71) = 2,50; \\ F_3 = 8,77;\ F_{кр_3}(0,05;6;69) = 2,23; \end{gathered} \quad (4)$$

Thus, regression equations of the system and their parameters are statistically significant by Fisher's test and Student's criteria at significance level α = 0,1 (0,05) and hence can be used for the study and prediction.

Formation and development of innovative potential of Russia involves consideration and analysis of specific innovative development in some regions. Regional innovation systems, combined by a single goal (competitiveness, sustainable development), operating under a single state economic policy and law, provide innovative potential of the country as a whole. It is clear that we have to develop its innovative environment in each region, taking into account its specific conditions of development, based on availability of material, information, financial, labor and production resources and infrastructure.

One method of integral evaluation of innovative activity in the region can be a converted polygon or radar of competitiveness (Smith, 2014). This polygon was built as a graphic image of Russian regions' position on the most significant criteria of innovative activity.

Innovation Capability Index is calculated by the formula:

$$I_i = \frac{S_i}{S} \quad (5)$$

where S_i - area of the polygon innovative potential of the i-th PPO region,

S - total area of feature space (polygon "standard" in the region, for which grades are equal to the maximum possible value).

3. Results

The authors studied different types of national innovation systems theoretically and methodologically; built an econometric dependability model of innovative activity in the regions of the Russian Federation on the main factors; held clustering of Russian regions in terms of development of the national innovation system as a whole and its individual components using methods of multidimensional mathematical statistics, developed a methodological approach to construct integrated estimation of innovative potential of the region in the Russian Federation and to inform management decisions for improving it in order to develop a strategy to improve the subject competitiveness in the Russian Federation.

4. Discussion

The study tested different modeling methods of innovative objects. In future it is supposed to use the original mathematical apparatus purposefully, which is a method of modernization and structural parametric identification of the mathematical model. Structural identification includes procedure of its aggregation taking into account the essential properties of systems that determine their effectiveness. In the process of structural identification the authors determined the population of the model components and relationships between them, as well as the minimum necessary population of selected parameters. The purpose of parametric identification is to quantify the aggregate model parameters based on comparison of experimental data with observed characteristics of innovation systems in their various states. The procedure for parametric identification of the mathematical model is currently developed insufficiently in terms of methodology, so the authors proposed a method of conceptual modeling, based on a combination of comparison procedures of simulation and source databases. This mathematical tool will be used in computer simulation to identify the factors that have the greatest impact on functioning of the national innovation system. On the basis of parametric and structural identification methods the authors will also develop integrated performance indicators of its operation.

Fredholm-Voltaire's integro-differential equations, spline-functions, which are not enough applied in economic and mathematical studies, will be used to study the dynamics of the national innovation system.

For the diffusion analysis of innovations as a basis for formation of the national innovation system will be used various modifications of Monte Carlo's method and Bass's innovation-simulation model, GIS technology and GIS modeling, using which it is possible to describe the complex processes more accurately taking into account a variety of natural and socio-economic factors of their functioning. This will allow implementing the computer simulation system of the national innovation system in Russia.

5. Conclusions

The proposed study allows developing recommendations to assess the level of innovative activity in the region, to develop a national innovation strategy, and to improve the competitiveness of the state as a whole and its regions, focused on long-term sustainable development, taking into account global trends, ensuring balanced economic, social and environmental development of society.

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