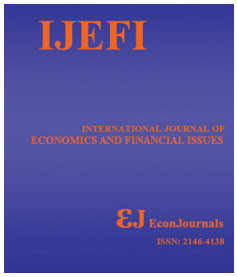

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Econometric Methods for Evaluating of Open National Innovative Systems

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ABSTRACT

The urgency of the problem stated in the paper is reasoned by the fact that the rapid acceleration of the changes of the existing economic and institutional conditions raises the need to develop new theoretical-methodological and practical approaches to the problems' solving in order to achieve sustainable growth of innovation growth. The purpose of the paper is developing of a methodology to assess the open national innovation systems through the use of econometric models. The leading approach to the study of this problem is the method of economic-mathematical modeling, allowing evaluating of the level of national innovation systems' openness using quantitative indicators and building of innovative development's forecasts. The article reveals the essence of open innovations, open national innovation systems, on the basis of production functions the forecast of the share of service sector's value added in gross domestic product is built using additive and multiplicative models. Paper Submissions are of theoretical and practical significance for open innovation management models' development, as well as for the development of the state innovation policy's strategy.

Keywords: National Innovation System, Evaluation Methods, Econometric Modeling, Production Function, Additive Model, Multiplicative Model
JEL Classifications: B23, F41, O31

1. INTRODUCTION

1.1. The Relevance of Research

World and Russian experience of the last decades shows that a variety of strategies of fragmental reform of the economy do not give the desired effect and are gradually fading. The success of the reforms and modernization of economic systems provide structurally coherent and balanced efforts to establish a system of markets and institutions, which would ensure the progressive changes in the major macroeconomic indicators. This requires in-depth theoretical concepts in the management of economic and innovative changes.

To the questions on the theory and methodology of open innovations are devoted works of: Chesbrough (2007), Vanhaverbeke et al. (2010), West and Gallagher (2006), Kristensen and Skott (2008), Torkkeli et al. (2009), Medovnikov and Rozmirovich (2011), Kudryavtseva et al. (2016) and others.

The theory of open innovations is based on the following fundamental principles:

- Use along with the inner ideas of external developments and knowledge
- Diversification of the output channels of new products to the market through their own network, as well as by external partners sales system
- Projecting of "learning organization" model
- Formation of the system of crowd sourcing
- Consideration of innovation as a factor of competitive advantage of national and regional economic systems, as well

as individual business entities
- Provision of innovative development on the basis of a network cooperation and collaboration
- Achieving of a high innovation activity of economic systems
- Prevalence of integrated systems of technological development ("global-linked").

In recent years, the open innovation models have become an integral part of innovative strategies in a number of countries, and the companies' business models. Open innovations provide a broader base for new ideas and technologies, become a strategic tool to explore new growth opportunities, provide greater flexibility, self-organization and sensitivity to market changes.

2. METHODOLOGICAL FRAMEWORK

2.1. Methods of Research

In the course of the research the following methods were used: Analysis, synthesis, system analysis, systematization and generalization of facts, simulation, comparison method, descriptions, analogies, prediction.

2.2. The Theoretical Base of Research

The theoretical basis of the study are formed by basic and applied works of foreign and domestic scientists, exploring the innovative development of economic systems, open innovations; concerned with regularities' modeling of economic systems' development at the micro, mezzo and macro levels, the development of managerial tools of innovation and modernization development of the economy.

2.3. Stages of Research

The study was conducted in three phases:
- At the first stage - the preparatory stage - the current state of the research problem in the theory and practice of open innovations' management was analyzed; a program of research methodology was developed.
- At the second stage - the main one - calculation of integral indicator of the national innovation systems' openness was made according to the method proposed by the author, production functions were calculated for different types of national innovation systems, forecasts of innovative development of the Russian national economy was made.
- At the third stage - the final stage - systematization, interpretation and synthesis of the research results were carried out; theoretical conclusions were refined; processing and presentation of the obtained research results were carried out.

3. RESULTS

3.1. Integral Indicator to Assess the Level of National Innovation Systems' Openness

Currently, the question of assessing of the level of national innovation systems' openness remains debatable in the world economy. At this stage, there is no single universal method. In this context, it is suggested to use the integral indicator of national innovation systems' openness, consisting of the following parameters:

1. The number of international scientific publications per 1 million people
2. The share of scientific publications of the highest international level in the total volume of scientific publications in the country
3. The proportion of doctoral students who are not natives of the country in the total number of doctoral students in the country
4. Medium- and high-tech exports in % of total exports
5. Exports of high-tech services in % of total exports of services
6. "New for the Market" and "new for the firm" products (sales), in % of total turnover
7. Revenues from licenses and patents from abroad, in % of gross domestic product (GDP)
8. The parameter of institutional regime
9. Characteristics of NIS organizational culture by Hofstede (2008).

The components of the integrated indicator of NIS openness are parameters of the global indices of innovative development, which, in our opinion, to a greater extent from the quantitative and qualitative points of view characterize the level of innovation systems' openness. Thus, in the integral indicator of NIS openness index of the European innovation scoreboard (p. 1-7), the Index of Knowledge Economy (p. 8) and characteristics of the organizational culture by Hofstede (2008. p. 9) are presented. Description of the procedures of The European innovation scoreboard and calculation of the index of knowledge economy, as well as their results are discussed in the author's works (Shinkevich and Kudryavtseva, 2014). In our opinion, the calculation of the integral indicator of NIS openness should include the cultural characteristics of the states, as quality levels of organizational and national culture can be considered as informal institutions that have an impact on innovation activities.

In the work by Hofstede (2008), published in 2010, data for 93 countries are presented. The proposed model of organizational culture includes the following dimensions: Power distance, individualism, masculinity, uncertainty avoidance, dynamism and indulgence against restraint.

However, among the presented characteristics of national culture, to the level of NIS openness are referred: Power distance, uncertainty avoidance, dynamism and indulgence against the restraint.

3.2. Component and Factor Analysis of Parameters of Integral Indicator of National Innovation Systems' Openness

In the first stage, based on the component analysis and factor analysis the weights coefficients for indices and parameters included in an integrated indicator of NIS openness were calculated (Tables 1 and 2).

Thus, the 12 initial parameters are distributed in 3 integral factors, allowing assign weight to each indicator in the calculation of the integral indicator of NIS openness. The greatest weight - 3, is

Table 1: Results of the selected principal components for the integral indicator of NIS openness

Number of factors	The eigenvalues	The percentage of the total variance	Accumulated eigenvalues	The accumulated percentage of the total variance
1	5.610625	46.75520	5.61062	46.7552
2	1.837219	15.31016	7.44784	62.0654
3	1.257834	10.48195	8.70568	72.5473
4	0.826890	6.89075	9.53257	79.4381
5	0.757371	6.31143	10.28994	85.7495
6	0.572106	4.76755	10.86205	90.5170
7	0.326355	2.71963	11.18840	93.2367
8	0.259565	2.16304	11.44797	95.3997
9	0.215127	1.79273	11.66309	97.1924
10	0.173687	1.44739	11.83678	98.6398
11	0.122416	1.02013	11.95920	99.6600
12	0.040804	0.34004	12.00000	100.0000

Table 2: Results of factor analysis with principal component method's using for the integral indicator of NIS openness

Indicators	Factor 1	Factor 2	Factor 3	Weight
The number of international scientific publications per 1 million people	0.9164	−0.1504	−0.0630	3
The share of scientific publications of the highest international level in the total volume of scientific publications in the country	0.8672	−0.1785	−0.1066	3
The proportion of doctoral students who are not natives of the country in the total number of doctoral students in the country	0.7326	−0.2456	0.1309	3
Medium- and high-tech exports in % of total exports	−0.1159	−0.7128	0.4259	2
Exports of high-tech services in % of total exports of services	0.6754	0.3841	0.2352	3
"New for the Market" and "new for the firm" products (sales), in % of total turnover	−0.2792	−0.7918	−0.3193	2
Revenues from licenses and patents from abroad, in % of GDP	0.7694	−0.3933	0.0877	3
The parameter of institutional regime	0.8225	0.0490	0.2956	3
Power distance	−0.6665	−0.1887	0.2398	3
Uncertainty avoidance	−0.7182	−0.3423	−0.2153	3
Dynamism	−0.3215	−0.1594	0.7901	1
Indulgence against restraint	0.7763	−0.3235	−0.2521	3
The total variance	5.6106	1.8372	1.2578	
The proportion of the total variance	0.4676	0.1531	0.1048	

GDP: Gross domestic product

assigned to parameters, forming the first group of factors explaining 46.8% of the variance of feature's changes, weight 2 - The second group of factors explaining 15.3% of the variance of feature's changes and weight 1 - The third group of factors explaining 10.5% of the variance of feature's changes.

To calculate the integral indicator of NIS openness the formula of weighted arithmetic average is used.

Integral indicator of NIS openness (IIN NIS)$_i = \frac{\Sigma X_i}{32}$, where, X_i - Local index's parameter for i NIS.

3.3. Interpretation of Integral Indicator of National Innovation Systems' Openness

Leading positions on a combined indicator of NIS openness belong to Switzerland, which is provided by high values of all indicators under review compared with the European average level, with the exception of exports of high-tech services in % of total exports of services - 31% against 48.1% for the EU countries. The number of international scientific publications per 1 million people has exceeded the European average level 7.7 times; revenue from licenses and patents from abroad, in % of GDP - 3.4 times; the proportion of doctoral students, not originating from the European Union in the total number of doctoral students in the country - 2.4 times. In addition, there is a low value of power distance - 34 points out of 100 and a high dynamism of development - 74 points.

In the second place in the ranking is Iceland, which is provided primarily by such parameters as "number of international scientific publications per 1 million people" - Exceeding of the European average level 7.7 times; "Revenues from licenses and patents from abroad, in% of GDP" - The excess 2.3 times; low power distance - 30 points out of 100.

Three leaders in the level of NIS openness NIS is closed by Denmark. A significant contribution to the formation of an integral indicator of the NIS openness is made by: "The number of international scientific publications per 1 million people" - Exceeding of the European average value 5.1 times; "Export of knowledge-intensive services, in % of total export of services" - 1.3 times; low power distance - 18 points out of 100, and the desire to avoid uncertainty - 23 points. Russia in this rating is located on the penultimate 34th place, leaving behind itself Turkey. The most significant impact on the reduction of the integral indicator of NIS openness was made by "knowledge-intensive services' exports, in % of total export of services," accounting 15% of the European average parameter; "New for the market" and "new for the firm" products (sales), in % of total turnover, - 19%; "The share of scientific publications of the highest

international level in the total volume of scientific publications in the country" - 23%, a low value of institutional mode index - 2.23 against 6.95 for Europe countries; high power distance - 93 points out of 100, and the desire to avoid uncertainty - 97 points.

Descriptive statistics for the innovations' global index, the global competitiveness index and the integral indicator NIS openness are presented in Table 3.

The results of the descriptive analysis shows that the distribution of the indices is close to the law of values' normal distribution (average value is approximated with the median, symmetry and excess are expressed slightly). The rows of distribution are characterized by a slight left-sided asymmetry.

Thus, the conducted analysis leads to the conclusion about the interdependence of innovations' global index, the global competitiveness index and the integral indicator NIS openness (Table 4).

The high level of NIS openness allows business entities to create innovations both inside and outside the company, as well as to carry out their commercial embodiment in different ways. The use of targeted incoming and outgoing flows of knowledge to accelerate internal innovations and expand the opportunities for their external use requires the formation of an innovation strategy, financing policy and entrepreneurial culture within which the experimentation, creativity and intellectual capacity are evaluated.

Table 3: Descriptive statistics for the innovations' global index, the global competitiveness index and the integral indicator NIS openness

Descriptive statistics	Innovations' global index	Global competitiveness index	Integral indicator NIS openness
Value N	35	35	35
Average level	49.2	4.7	94.5
geometric mean	48.6	4.6	78.9
harmonic mean	47.9	4.6	65.8
Median	49.3	4.5	81.5
Mode	-	4.25	-
Minimum	36	3.8	23
Maximum	66.7	5.7	247
Scope	30.7	1.9	224
Dispersion	69.5	0.3	3315.7
Standard deviation	8.3	0.5	57.6
The coefficient of variation	16.9	11.3	60.9
Asymmetry	0.1	0.4	1.0
Excess	−1	−1.1	0.7

Innovation activities of companies become international, assuming the character of an "open" one thanks to the cooperation with external partners, suppliers, customers and research centers, which allows accessing to new goods and services on the market before competitors. At the same time, innovations also acquire the form of "open" ones as for goods' and services' consumer, so for businesses that are increasingly involved directly in the innovation process.

Open innovation models become an integral part of the innovation strategies of a number of countries, and the business models of companies that in a globalized economy conditions, can improve the efficiency of the activities of individual companies, sectors and NIS as a whole and this is reflected in the world rankings of innovation development.

Thus, the development of open national innovation systems is possible on the basis of a balanced innovation policy of states, an important area of which should be the implementation of the multi-functional measures aimed at building of open innovation models and taking into account the trends of globalization of the world economy and national interests.

3.4. Econometric Modeling of Development of National Innovation Systems Based on Production Functions

Weak institutional support for innovation activities in many ways is an obstacle for implementation of open innovations' models in the Russian national innovation system, slows the transition to a new technological structure and doesn't allow making effective use of the technological window of opportunities to accelerate innovation development.

Thus, the development of open national innovation systems is possible on the basis of a balanced state innovation policy, an important area of which should be the implementation of the multi-functional measures aimed at building of open innovation models, backed by institutional support, and taking into account the trends of globalization of the world economy and national interests.

One of the most important indicators of the innovation economy is the achieving of a sustained growth. Modeling of the regularities of economic systems' development at the micro, mezzo and macro levels successfully is implemented by constructing of production functions.

Enhancing of effects of crises situations in the economies of the world countries made it necessary to focus on the study of the theoretical foundations and regularities of economic growth. As

Table 4: Matrix of correlation coefficients

	The correlation coefficients		
Indicators	**Innovations' global index**	**Global competitiveness index**	**Index and the integral indicator NIS openness**
Innovations' Global Index	1.000000	0.889495*	0.848332*
Global Competitiveness Index	0.889495*	1.000000	0.721796*
Index and the Integral indicator NIS openness	0.848332*	0.721796*	1.000000

*Statistically significant at the 5% level

a classical model of economic development is considered a model of Romer (1992), who attached great importance to technological changes, being in the most general form the efficiencies' increase of the available natural resources' use. In other words, in the economy with a high level of technological development and institutional environment the return from investment will be higher, and the investment will be carried out more rapidly. Thus, the exogenous concept of economic growth is supplemented by endogenous model that takes into account the impact of new technologies on the development of economic systems.

Classical production function defines the relationship of Y products' output with factors of production (capital K and labor L). The equation of the production function of Cobb-Douglas is an economic-mathematical model of mutual influence of production factors K (productive capital) and L (humane capital) by the amount of net profit of sector. It is noted that there are the production function of increasing ($\alpha + \beta > 1$), constant ($\alpha + \beta = 1$) and diminishing returns ($\alpha + \beta < 1$).

$Y = A \times K^a \times L^b$ (Romer, 1992).

For the purposes of the study as production function's factors were used:

Y - The share of value-added of service sector in percentage to GDP

K - Expenditure on research and development in percentage to GDP

L - The number of researchers per 1 million people.

The input data for the simulation was the information on the countries with a high level of NIS openness and strong institutional support for innovation (Sweden); middle-NIS openness and strong institutional support of innovations (Germany) and with a low level of NIS openness and weak institutional support for innovations (Russia). Dynamic range includes indicators from 1996-2013, as the analysis tool software product Statistica was used.

The resulting production functions and coefficients of elasticity are shown in Table 5.

Thus, the obtained production functions allow us to conclude that in the Russian economy more likely the formation of added value is affected by the factor "capital," as a share of expenditure on research and development in GDP (the value of the coefficient of elasticity is the greatest among the considered groups of countries), on the basis of which it is possible to assert that in the Russian NIS there is a tendency to enhance innovation capacity with a view of its subsequent use for the development of opening technological windows of opportunities. However, the negative trend of the number of researchers can be considered as a negative factor in the innovation economy, as it is evidenced by the corresponding value of the coefficient of elasticity of the production function (−0.000104).

4. DISCUSSIONS

These production functions can be used to construct the forecast of innovative development, where as a result variable acts share of value added of the service sector in GDP. Based on the analysis carried out in previous studies on the institutional and infrastructural support of open innovations' model in the Russian economy, it can be assumed that strengthening of the institutional and infrastructural support in innovation activities will have a positive multiplier effect, whereupon, it is proposed to consider the predictive model of innovative development of Russia as a multiplicative one, and for countries with sustainable innovative development, a high level of NIS openness and strong institutional support - as an additive one.

On the basis of exponential smoothing models in the first stage a forecast of exogenous (independent) variables was constructed: K - Expenditure on research and development in percentage of GDP and of L - The number of researchers per 1 million of population. Then in the second stage of analysis, using production functions, the medium-term outlook for the endogenous (dependent) variable Y is presented - The proportion of the value added of the service sector in percentage of GDP.

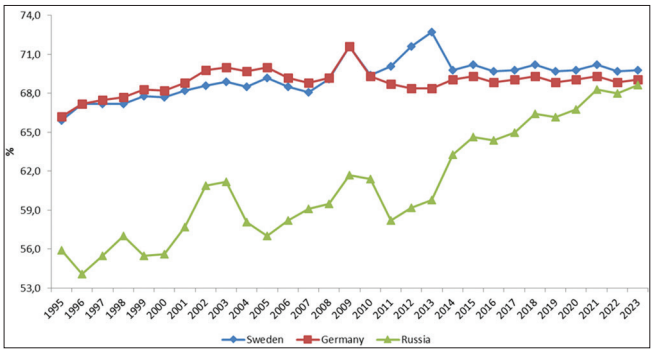
Thus, the strengthening of institutional support for the model of open innovations in the Russian NIS will reduce the lag in Russian share of service sector's value added in GDP with Sweden in 5 years to 5.2% points (at the end of 2013 the gap was 12.9% points), with Germany - up to 4.4% points (at the end of 2013, the gap was 8.6% points), in a 10-year period with Sweden - to 3.7% points, with Germany - to 2.9% points (Figure 1).

These projections have a mean absolute relative error of 0.44-0.62%, which is a good indicator of the quality of the forecast. The previous researches, which were made by West and Gallagher (2006), Chesbrough (2007), Kristensen and Skott (2008), Torkkeli et al. (2009), Vanhaverbeke et al. (2010),

Table 5: Equations of production functions

Country	The equation of the production function	The value of the degree α at variable "K"	The value of the degree β at variable "L"
Sweden (a high level of NIS openness and strong institutional support for innovation)	$4.28 \times K^{0.04} \times L^{0.000021}$	0.04	0.000021
Germany (middle-NIS openness and institutional support of innovations)	$4.28 \times K^{0.101} \times L^{-0.00003}$	0.101	−0.00003
Russia (low level of NIS openness and weak institutional support for innovations)	$4.28 \times K^{0.25} \times L^{-0.000104}$	0.25	−0.000104

Figure 1: Forecast of the share of added value of the service sector in percentage of gross domestic product



Medovnikov and Rozmirovich (2011) are devoted to modeling of innovative systems.

However, analysis of scientific papers on the issue of methodology for assessing of the level of national innovation systems' openness and the construction of innovative development forecasts are not structured and has a controversial nature.

5. CONCLUSION

It is found that the components of the integral indicator of national innovation systems' openness are parameters of global indices of innovative development, which to a greater extent from the quantitative and qualitative points of view characterize the openness level of the innovation system. Thus, in the integral indicator of NIS openness parameters of the European innovation scoreboard, the Index of Knowledge Economy and the characteristic of the organizational culture by Hofstede (2008) are presented. On the basis of economic and mathematical modeling a rating of national innovation systems on the level of openness is created. The proposed assessment methodology of open national innovation systems allows their positioning, segmentation, rating conducting. For each type of innovative systems based on econometric analysis production functions are revealed. A forecast of innovative development of the Russian national innovation system is built.

Paper submissions are of theoretical and practical significance for the development of open innovations' management models, as well as in the development of the state innovation policy strategy. Taking into account the obtained results of this study a number of scientific problems and promising areas for further consideration can be identified: The deepening and extension of certain provisions contained in the paper related to evaluation of the level of development of open national innovation systems and the development of their predictive models on innovative development.

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