National Open Innovation Systems: an Evaluation Methodology

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Abstract

The focus of the article is the problem concerning rapid acceleration of the existing economic and institutional change that challenges economic entities to search for new approaches and solutions that will accelerate further innovation and modernization. The purpose of the article is to develop an evaluation methodology for national open innovation systems. The leading approach is a simulation method that allows to evaluate the level of national innovation systems openness by means of qualitative and quantitative indicators. The article reveals the essence of open innovation, national open innovation systems, explains the systematization of innovation strategies, submits the evaluation methods for national open innovation system to perform their positioning, segmentation and rating. The article submissions are theoretically and practically significant for the development of the open innovation management models and a strategy of the state innovation policy.

Keywords: national innovation system (NIS), open innovation, global competitiveness index, the global innovation index

1. Introduction

1.1 The Relevance of the Issue

The world and Russian practice of recent decades has shown that various strategies of fragmentary reforming of the economy do not produce the desired effect and gradually fade out. The successfully implemented reforms and modernization of the economic systems structurally coordinate and balance the efforts to establish a system of markets and institutions that would ensure progressive changes of the primary macroeconomic indicators. It requires deep abstract conception of managing economic and innovative changes.

The theory and methodology of open innovation was studied by: G. Chesbrough (2007), M. Vanhaverbeke, M. Torkkeli & A. Trifilova (2010), J. West & S. Gallagher (2006), K. Kristensen & E. Skott (2008), M. Torkkeli, K. Kok & I. Savickaya (2009), DS Medovnikov & S.D. Rozmirovich (2011) and others.

The theory of open innovation is based on the following fundamental principles:
- using external knowledge along with the internal ideas and developments;
- diversification of channels to introduce a new product on market through own network and external partners distribution system;
- designing a model of a "trainee organization";
- formation of the crowdsourcing system;
- considering innovation as a factor of achieving competitive advantage of the national and regional economies and separate economic entities;
- providing innovative development on the basis of networking and collaboration;
- achieving a high innovation activity of the economic systems;
- predominance of the integrated systems of technological development («global-linked»).
In recent years open innovation models have become an integral part of innovative strategies of some countries and company business models. Open innovations provide a wider platform for new ideas and technologies and become a strategic tool to explore new opportunities for growth, provide greater flexibility, self-organization and sensitivity to market changes.

2. Methodological Framework

2.1 Research Methods

The study is based on the following methods: the analysis, synthesis, operations analysis, systematization, simulation, positioning, segmentation, correlation analysis, factor analysis, comparison method, descriptions, analogies.

2.2 Theoretic Background

The theoretical framework of the study is based on fundamental and applied works of foreign and national scientists exploring the innovative development of economic systems, institutionalization of innovation processes, open innovations; who are engaged in developing management tools for the economy innovation and modernization.

2.3 The Stages of the Study

The study was performed in three phases:

- at the first stage - the preparatory one - we have analyzed the current state of the investigated problem in theory and practice of open innovation management; developed a program of research methodology;
- at the second stage - the main one - we have arranged positioning of the national innovation systems on the basis of Shell / DPM model, systematized the innovative strategies of national innovation systems, calculated the integral indicator of the national innovation systems openness (NIS) according to the submitted methodology;
- The third stage - the final one - we have arranged systematization, interpretation and synthesis of the research results; made theoretical conclusions; processed and registered the results of the study.

3. Results

3.1 The World Indices of Innovative Development: A Review

Nowadays to evaluate the innovative activity of economic entities the international community applies to a variety of indicators: the European Innovation scoreboard, the Global Innovation index, the Global Competitiveness Index, ranking innovation economies ITIF, the Networked Readiness Index, the Knowledge Economy Index and others. However, it seems appropriate to use a spatial set of innovative indices in conjunction with the models of strategic analysis and planning while developing the models of innovative development of national innovation systems (NIS). As a tool for the innovation activities analysis we offer to apply a Shell / DPM model. The Shell / DPM model was designed in 1975 by the British-Dutch Shell chemical company and was named "The Directional Policy Matrix » (Hichens & Robinson, 1978; Tompson & Strriklend, 2007).

In the process of research it is offered to apply the Global Competitiveness Index (Global Competitiveness Report) as NIS competitiveness and the Global Innovation Index as a perspective for development.

The Global Competitiveness Index includes 113 variables that thoroughly describe the competitiveness of the countries at different levels of economic development. The set of variables by two-thirds consists of the results of a global survey of business executives (to cover a wide range of factors affecting the business climate in the countries studied), and by one-third - of public sources (statistics and the research results performed on a regular basis by international organizations). All the variables are grouped into 12 benchmarks that determine national competitiveness:

- The institutions quality;
- The infrastructure;
- Macroeconomic stability;
- The health and primary education;
- Higher education and professional training;
- The market efficiency;
- The labor market efficiency;
- Financial market development;
- The level of technological development;
- The domestic market size;
- The companies competitiveness;
- The innovation potential.

Designing the Index the experts take into account that the national economies are at different stages of their development. The importance of certain growth factors of the country’s competitiveness is connected either with the initial conditions or with institutional and structural characteristics that allow to position the state to other countries in the light of development.

At the end of 2014 according to the Global Competitiveness Index the leading positions were taken by Switzerland (5.7), Singapore (5.6) and the United States (5.54). Russia ranked 53 with an index of 4.4 which is similar to the index of Italy, Kazakhstan, Costa Rica, the Philippines, Bulgaria and South Africa. At the same time over the past year Russia advanced in the ranking - from 67th in 2012, 64th in 2013 to 53-d rating position in 2014. In total, 144 countries were involved in ranking (The Global Competitiveness Index) (Table 1).

Table 1. The rating of countries according to the Global Competitiveness Index

| Rating | Country        | Index |
|--------|----------------|-------|
| 1      | Switzerland    | 5,7   |
| 2      | Singapore      | 5,6   |
| 3      | The USA        | 5,5   |
| 4      | Finland        | 5,5   |
| 5      | Germany        | 5,5   |
| 6      | Japan          | 5,5   |
| 7      | Hong Kong      | 5,5   |
| 8      | The Netherlands| 5,5   |
| 9      | The UK         | 5,4   |
| 10     | Sweden         | 5,4   |
| 51     | Costa Rica     | 4,4   |
| 52     | Philippines    | 4,4   |
| 53     | Russia         | 4,4   |
| 54     | Bulgaria       | 4,4   |
| 59     | Romania        | 4,3   |
| 71     | India          | 4,2   |
| 77     | Croatia        | 4,1   |
| 144    | Guinea         | 2,8   |

The Global Innovation Index is composed of 80 different variables that give the detailed description of the countries’ innovative development at various levels of economic development. The authors of the study (International Business School INSEAD, Cornell University and the World Intellectual Property Organization (WIPO) believe that the economy success is connected with the innovation potential and conditions for its implementation. Therefore, the index is calculated as a weighted total of the evaluations of the two groups of indicators:

- the available resources and facilities for innovation (Innovation Input);
- the achieved practical results of innovation (Innovation Output).

Therefore, the resulting Index is the cost-effectiveness balance allowing to objectively evaluate the effectiveness of efforts for developing innovations in one or another country.

In 2014 the survey covered 143 countries which together produce 99.5% of world GDP and where 95% of the world population live.

According to the Innovation Index the top three countries included (Table 2), Switzerland (64.8), the UK (62.4)
and Sweden (62.3). Russia in the overall ranking took 49th rating position (39.1) between Thailand (48th position, 39.3) and Greece (50th position, 38.9), rising by 13 positions compared to 2013. Among the BRICS countries Russia ranks second after China (29th position while China's rating is now comparable with the rating of many high-income nations ahead of South Africa (57), Brazil (61) and India (76).

Table 2. The Global Innovation Index Ranking

| Rating | Country     | Index |
|--------|-------------|-------|
| 1      | Switzerland | 64.8  |
| 2      | The UK      | 62.4  |
| 3      | Sweden      | 62.3  |
| 4      | Finland     | 60.7  |
| 5      | The Netherlands | 60.6 |
| 6      | The USA     | 60.1  |
| 7      | Singapore   | 59.2  |
| 8      | Denmark     | 57.5  |
| 9      | Luxemburg   | 56.9  |
| 10     | Hong Kong   | 56.8  |
| 29     | China       | 46.6  |
| 47     | Qatar       | 40.3  |
| 48     | Thailand    | 39.3  |
| 49     | Russia      | 39.1  |
| 50     | Greece      | 38.9  |
| 54     | Turkey      | 38.2  |
| 128    | Uzbekistan  | 25.2  |
| 143    | Sudan       | 12.7  |

According to the report, Russia’s advantages are related to the quality of human capital (30th place), business and information technology development (43 and 34, respectively). The infrastructure indicators remain at an average level (51st position). The innovation activity is interfered with imperfect institutions (88th position), low results of creative activity (72) and domestic market development (111) (The Global Innovation Index).

3.2 The Shell / DPM Model and Innovative Strategies for National Open Innovation Systems

To develop a model of managing innovation activity we offer to use the Shell / DPM matrix in terms of the following indicators: competitiveness - "the Global Competitiveness Index" and the development perspectives - the "the Global Innovation Index" (using the example of the European Union and Russia). The NIS positioning in the Shell / DPM model is represented within nine quadrants.

The first quadrant is represented by ten countries (Serbia, Slovakia, Croatia, Russia, and others.). These states have weak positions on the innovations market applying mainly a strategy of technological borrowing and product and process simulation.

The second quadrant includes three states - Poland, Lithuania and Turkey. The NIS of these countries occupy a middle position, but the prospects of NIS development are assessed low. The innovation system advantages and opportunities for innovation are used inefficiently. The possible innovative strategies for the countries of the second quadrant include: following the market of innovation, a strategy of parallel development, licensing strategy, the stage-skipping catch-up strategy.

The fourth quadrant includes Cyprus, Slovenia, Hungary, Czech Republic. The NIS of these countries keep weak positions with moderate prospect for innovation. The key innovative strategies implemented by the countries of this quadrant include: support for innovative product line, licensing strategy, the strategy of parallel development, technological relatedness strategy.

France, Italy, Estonia, Spain, Malta represent the fifth quadrant which occupies a middle position in the global innovation market with an average perspective for development. The possible strategies for the countries of the fifth quadrant include: investment diversification, a stageskipping catch-up strategy, a lifecycle strategy.

The sixth quadrant includes the two states - Austria and Belgium. The prospects of NIS are estimated as
moderate, but the NIS of these countries hold strong competitive positions. Most economic entities of these countries are in the middle of the innovation business lifecycle. The basic innovative strategies implemented by NIS countries of the sixth quadrant include: the strategy of advanced R&D, the staeskipping catch-up strategy, the lifecycle strategy.

The eighth quadrant is occupied by Ireland and Iceland. These NIS countries occupy an intermediate competitive position with high prospects for innovative activity development. To enter one quadrant with the innovative development leading countries these countries’ NIS should introduce the strategies of advanced R & D, of radical innovation and of close follower.

The ninth quadrant joined the leaders of innovative development - 9 countries (Switzerland, Sweden, Finland, Germany, etc.). The innovation perspective is rated high, and the NIS of these countries has a steady competitive position being the leaders; the potential market is large, and neither NIS weaknesses nor visible threats from competitors are observed.

The possible strategies for the ninth NIS quadrant: a strategy of a research leader, a strategy of maintaining technological advantage, the strategy of radical innovation.

In the third quadrant (high competitiveness with low prospect for further innovative development) and seventh quadrant (low competitiveness with a strong prospect for innovative development) the NIS of European countries are not represented.

The grouping of NIS innovative strategies in the Shell / DPM model is represented in Table 3.

Table 3. The NIS innovative strategies for the Shell / DPM model

| GLOBAL INNOVATION INDEX | 7 section | 8 section | 9 section |
|-------------------------|-----------|-----------|-----------|
|                         | Advanced R&D strategy, radical innovation and close follower strategies | Research leader strategy, strategy of maintaining technological advantage, the strategy of radical innovation |
|                         | support for innovative product line, licensing strategy, the strategy of parallel development, technology transfer strategy | investment diversification, investment diversification strategy, a stageskipping catch-up strategy, a lifecycle strategy |
|                         | a strategy of technological borrowing and product and process simulation | following the innovative market, a strategy of parallel development, licensing strategy, the strategy of technological relatedness |
|                         | World Competitiveness Index | |

The theoretical and applied research has allowed us to conclude that at present time a transition to an open model of innovation has a great potential for national economies. Open Innovation is a paradigm of doing business dominant in the knowledge-driven economy providing a more flexible policy in case of R & D and intellectual property. The term "open innovation" was promoted by the executive director of the Center for Open Innovation, University of California, Professor H. Chesbrough "Open Innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation. With wide knowledge extension the companies cannot fully rely on their own research, but must acquire inventions and intellectual property of other companies, as it allows to improve the business model" (Chesbrough, 2006).

3.3 The Submitted Integral Evaluation Indicator of the Level of National Innovation System Openness

Whereas this stage does not allow to estimate the level of the NIS openness we offer to apply the integral indicator consisting of the following indices:

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 amount of scientific publications in the country;
3. The proportion of non-native doctoral students in total number of doctoral students in the country;
4. The medium and high-tech export as a percentage of total export;
5. The export of high technology services as a percentage of services total export;
6. "New to market" and "new to the firm" products (sales) as a percentage of total turnover;
7. The revenues from licenses and patents from abroad as a percentage of GDP;
8. The index of institutional regime;
9. The characteristics of the NIS organizational culture according to G. Hofstede (2008).

The components of the integral indicator of NIS openness are the global indices indicators of innovative development which, in our opinion, characterize the level of innovation system openness mostly quantitatively and qualitatively. Thus, the integral indicator of NIS openness includes the figures of the European innovation scoreboard (p. 1-7), the Knowledge Economy Index (p.8) and the characteristics of the organizational culture according to G. Hofstede (p.9). The description of the European innovation scoreboard procedures and calculation of the Knowledge Economy Index as well as their results are discussed in the authors’ studies (A. Shinkevich, S. Kudryavtseva & M. Shinkevich, 2012, 2014). In our opinion, the Integral Indicator of NIS openness should include the national cultural characteristics as the quality levels of organizational and national culture can be regarded informal institutions that influence innovation.

The Hofstede’s research published in 2010 offers the data for 93 countries. The proposed model of organizational culture includes the following parameters: power distance, individualism, masculinity, uncertainty avoidance, dynamism and indulgence versus restraint (Hofstede, 1978, 1983, 2008). However, among the submitted characteristics of national culture the level of NIS openness includes: power distance, uncertainty avoidance, dynamism and indulgence versus restraint.

3.4 The Component and Factor Analysis of Integral Indicator of National Innovation Systems Openness

Within the first stage of analysis basing on the component and factor analysis we calculated the weight numbers for the indices and indicators included in the integral indicator of NIS openness (Table 4 and 5).

### Table 4. The results of the selected principal components for the Integral Indicator of NIS openness

| №  | Eigenvalue | Percent of Total variance | Cumulative Eigenvalue | Cumulative Percent of 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 5. The results of the factor analysis using principal components method for the Integral Indicator of NIS openness

| The number of international scientific publications per 1 million people | Factor 1 | Factor 2 | Factor 3 | weight |
|-----------------------------------------------------------------------|----------|----------|----------|--------|
| 0.9164                                                                | -0.1504  | -0.0630  | 3        |
| The share of scientific publications of the highest international level in the total amount of scientific publications in the country; | 0.8672  | -0.1785  | -0.1066  | 3        |
| The proportion of non-native doctoral students in total number of doctoral students in the country; | 0.7326  | -0.2456  | 0.1309   | 3        |
Medium and high-tech export as a percentage of total export; -0.1159 -0.7128 0.4259 2
Export of high technology services as a percentage of services total export; 0.6754 0.3841 0.2352 3
"New to market" and "new to the firm" products (sales), as a percentage of total turnover; -0.2792 -0.7918 -0.3193 2
Revenues from licenses and patents from abroad, as a percentage of GDP 0.7694 -0.3933 0.0877 3
The index 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 versus restraint 0.7763 -0.3235 -0.2521 3
Total variance 5.6106 1.8372 1.2578
Total variance share 0.4676 0.1531 0.1048

Therefore, the 12 initial indices appear to be distributed in 3 integrated factors that allow to assign a weight to every parameter while calculating the Integral Indicator of NIS openness. The greatest weight -3 has been assigned for the parameters forming the first group of factors that explain 46.8% of the variance of characteristic change, the weight - 2 has been assigned for the second group of factors explaining 15.3% of the variance of characteristic changes and the weight 1 - to the third group of factors explaining 10.5 % of the variance of the characteristic change.

To calculate the integral indicator of NIS openness we have used the weighted arithmetic mean. The integral indicator of NIS openness (NIS OII) i = ΣHi / 32, where

Xi - an indicator of the local index for the i-th NIS.

4. Discussions

The leading position in terms of the integral indicator of NIS openness belongs to Switzerland that is provided with the high figures of all the reviewed indicators compared to the average European level with the exception of high-tech services exports as a percentage of services total exports - 31% versus 48.1% of the EU countries. The number of international scientific publications per 1 million people has exceeded the European average by 7.7 times; the revenue from licenses and patents from abroad as a percentage of GDP - by 3.4 times; the proportion of non-native doctoral students of the European Union in the total number of doctoral students in the country - by 2.4 times. In addition, there is a low value of power distance - 34 points out of 100 and a high dynamic development - 74 points.

Iceland has ranked second provided, first of all, with such indicators as "number of international scientific publications per 1 million people" - it exceeds the European average by 7.7 times; "The revenue from licenses and patents from abroad, as a percentage of GDP" - by 2.3 times; low power distance - 30 points out of 100.

Denmark rounds out the top three leaders in terms of the NIS openness. A significant contribution to the integral indicator of the NIS openness has been made by: "The number of international scientific publications per 1 million people" - the excess over the European average is 5.1 times; "The export of high-tech services as a percentage of services total exports" - 1.3 times; low power distance - 18 points out of 100 and uncertainty avoidance - 23 points.

Russia in this rating ranks penultimate 34th position leaving Turkey behind. The most significant impact on the integral indicator reduction of the NIS openness has been shown by "The export of high-tech services as a percentage of services total exports", making 15% of the European average; "New to market" and "new to the firm" products (sales), as a percentage to total turnover " - 19%; "The share of scientific publications of the highest international level in the total amount of scientific publications in the country" - 23%, a low index of institutional regime - 2.23 against 6.95 in Europe; high power distance - 93 points out of 100 and uncertainty avoidance - 97 points.

The descriptive statistics for the Global Innovation Index, the Global Competitiveness Index and the Integral Indicator of NIS openness is presented in Table 6.
Table 6. The descriptive statistics of the Global Innovation Index, Global Competitiveness Index and the Integral Indicator of NIS openness

|                          | Global Innovation Index | Global Competitiveness Index | Integral Indicator of NIS openness |
|--------------------------|-------------------------|------------------------------|-----------------------------------|
| N value                  | 35                      | 35                           | 35                                |
| Average value            | 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                               |
| Range                    | 30.7                    | 1.9                          | 224                               |
| Variance                 | 69.5                    | 0.3                          | 3315.7                            |
| Standard deviation       | 8.3                     | 0.5                          | 57.6                              |
| Coefficient of variation | 16.9                    | 11.3                         | 60.9                              |
| Skewness                 | 0.1                     | 0.4                          | 1.0                               |
| Kurtosis                 | -1                      | -1.1                         | 0.7                               |

The results of the descriptive analysis showed that the distribution of the indices is close to the normal distribution law (the mean converges towards the median, and skewness and kurtosis are mild). The variation series is characterized by a small left-sided asymmetry.

Thus, our analysis suggests the interdependence of the Global Innovation Index, the Global Competitiveness Index and the Integral Indicator of NIS openness (Table 7).

Table 7. Correlation matrix

|                           | Global Innovation Index | the Global Competitiveness Index | Integral Indicator of NIS openness |
|--------------------------|-------------------------|---------------------------------|-----------------------------------|
| Global Innovation Index  | 1.000000                | 0.889495*                      | 0.848332*                        |
| the Global Competitiveness Index | 0.889495*            | 1.000000                       | 0.721796*                        |
| Integral Indicator of NIS openness | 0.848332*          | 0.721796*                      | 1.000000                        |

* statistically significant at the level of 5%.

The high level of NIS openness allows business entities to create innovations both inside and outside the company as well as to embody them commercially in different ways. Using targeted inflows and outflows of knowledge to accelerate internal innovation and expand the opportunities for their external use requires the development of innovative strategies, funding policies and entrepreneurial culture within which experimentation, creativity and intelligence are highly valued.

The companies innovation activity becomes international assuming "open" character through collaboration with external partners, suppliers, customers or research centers giving access to new goods and services on the market ahead of the competitors. At the same time innovations also take the "open" form for consumers and businesses that are becoming increasingly involved in the innovation process.

Open innovation models are becoming an integral part of the innovative strategies of some countries and company business models that in a globalized economy can improve the efficiency of individual companies, economy sectors and NIS as a whole, and this is reflected in the world ratings of innovative development.

Therefore, the development of national open innovation systems is possible on the basis of a balanced innovation policy, when implementing multi-functional measures aimed at building open innovation models and taking into account the world economy globalization and national interests should become an important growth area.

The previous research on the problem was made by J. West & S. Gallagher (2006), G. Chesbrough (2007), K. Kristensen & E. Skott (2008), M. Torkkeli, K. Kok & I. Savickaya (2009), M. Vanhaverbeke, M. Torkkeli & A. Trifilova (2010), DS Medovnikov & S.D. Rozmirovich (2011).

However, the analysis of scientific papers on the issue of evaluating technique for assessing the level of NIS openness has not been structured and is only debatable.
5. Conclusion

It was found that the components of the Integral indicator of the national innovation systems openness are the indicators of the global innovative development indices which mostly characterize the level of openness of the innovation system quantitatively and qualitatively. Thus, the integral indicator of NIS openness presents the figures of the European innovation scoreboard, the Knowledge Economy Index and the characteristics of the organizational culture according to G. Hofstede. Proceeding from economic and mathematical modeling we have rated the national innovation systems according to the level of openness, submitted the positioning matrix and innovative strategies of national innovation systems according to the Shell / DPM model.

The proposed evaluation methodology of national open innovation systems allows to perform their positioning, segmentation, rating.

The article submissions have theoretical and practical significance for the development of open innovation management models as well as for working out a strategy of the state innovation policy.

Following the results of this study we can identify a number of scientific issues and directions for further consideration: elaboration of certain provisions related to the evaluation of the national open innovation systems development level and working out the innovation strategies and business models on their basis.

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