

Growth zones of the national innovation system of Russia

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Abstract. The article presents the original algorithmic model for identification of growth zones of the national innovation system that maximize the effect of government support. The model is based on numerical comparison of values of indicators of gross domestic product, the human development index and the integral value of the global innovation index, and also its subindicators characterizing government support of national innovation system in each of the countries under consideration. The model compares these indicators for about 180 countries aggregated from 2013 to 2019 and identifies sectors of the national innovation system, stimulation of which gives the highest contribution to growth of the integral indicator of the global innovation index. For the Russian Federation with the use of the model the spheres of potential economic growth in the national innovation system were determined and ranked according to the dynamics. The growth zones of the national innovation system of Russia identified by the model are generally consistent, on the one hand, with the internal policy pursued by the government, and on the other hand, with the peculiarities of the country's historical path.

Keywords: government support, algorithmic model, global innovation index, national economic, innovation

1 Introduction

The national innovation system (NIS) develops under the influence of national policy in the context of the action of specific state – formal and non-formal institutions of management [1], formed as a result of the historical path of each particular state. It is quite normal that the structure of the NIS is unique for each country, however, there are tools for assessing the effectiveness of the NIS. One of these tools is the Global Innovation Index [2] (Global Innovation Index – GII), compiled by Cornell University, INSEAD and the World Intellectual Property Organization.

The index is formed on both subjective and objective data obtained from sources such as the International Telecommunication Union, the World Bank and the World Economic Forum, etc. The index was introduced in 2007 by the French business school INSEAD and

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the British magazine World Business. The GII is commonly used by corporate executives and governments to compare countries in terms of their level of innovation activity [3].

The GII is calculated by averaging of the scores of indicators in two sub-indexes: characterizing the “Input conditions” conditions for innovation activity – “Potential of innovation” and “Output results” – “Results of innovation activity”. Sub-indexes consist of 5 and 2 groups of indicators, also combined from 2 to 5 elements – statistical and calculated data. The structure of the index indicators is shown in Fig. 1.

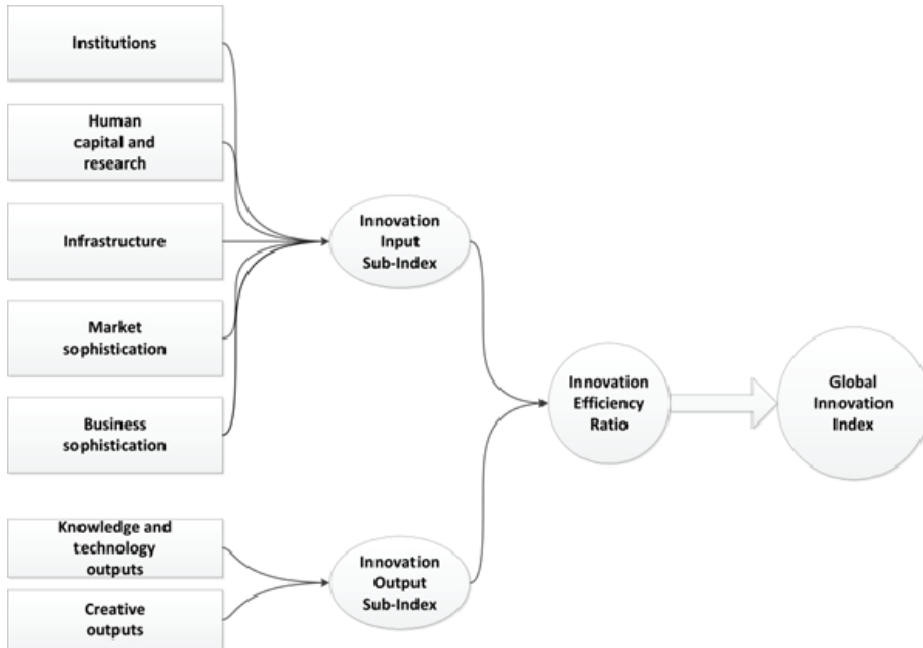


Fig. 1. Global Innovation Index structure.

A detailed description of the components of the index, as well as the GII calculation methodology, the authors of the index provide in the appendices to the annually published report containing the GII. A world ranking of countries, which is formed annually, on the value of the index, characterizes the level of their innovative activity.

2 Materials and methods

The growth of the country’s gross national income directly depends on the level of development of its NIS. Such researchers as Borisova E.Yu. [4], Nikonova Ya.I. [5], Kacprzyk A. [6] and others note a direct connection between such characteristics of the country’s economy as the value of Gross National Income (GNI), the level of competitiveness and economic security or the ability to develop sustainably with the state of its innovation system. The NIS is formed in the conditions of state institutions of management, in many countries programs have been developed to support the NIS to achieve the established national goals.

In the Russia, since 2011, program documents have been developed and implemented at all Government levels to support and develop the NIS and its elements [7]. Despite this, the score of Russia in the world innovation rating has a downward trend since 2015 (see Fig. 2).

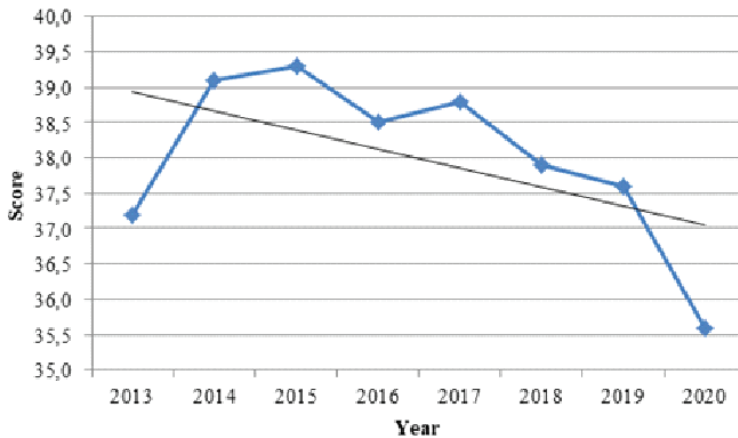


Fig. 2. Russia score, according to the GII.

The dynamics of the GII score cannot be explained only by external political and economic reasons (for example, the imposition of sanctions [8], currency fluctuations [9], etc.) or structural changes in the Russian economy [10, 11]. In our opinion, the current state support programs for NIS, aimed at developing its specific areas, as they are implemented, open up potential in other, related areas.

In other words, the specifics of state support for NIS in Russia lead to a disproportional increase in its elements and, as a consequence, to a general decrease in score. We believe that adjusting the directions of state support for NIS Russia may lead to stabilization of Russia’s place in the rating or even its growth.

The state of government support can be assessed through a set of components of the GII and the resulting economic effect – GNI. Based on this, the main hypothesis was formulated: it is possible to identify such components of the GII that characterize state support for NIS, the change in which significantly affects the country’s rank in the GII rating, as well as GNI.

For the purposes of this study, 2 groups of indicators were selected from the components of the GII (for 2013-2019), characterizing the state support of the NIS: Integral indicators for 2013-2019, included in the 1st group of sub-indexes (5 indicators): Political environment, Regulatory environment, Business environment, Credit, Innovation linkages.

Partial indicators – 37 indicators (group 2) for 2013-2019, are shown in table 1.

Table 1. List of 37 indicators.

No.	Indicator
1.	Cost of redundancy dismissal
2.	Domestic credit to private sector
3.	Ease of getting credit
4.	Ease of paying taxes
5.	Ease of protecting investors
6.	Ease of resolving insolvency
7.	Ease of starting a business
8.	Electricity output

9.	Environmental performance
10.	Expenditure on education
11.	Firms offering formal training
12.	Foreign direct investment net inflows
13.	Foreign direct investment net outflows
14.	GERD financed by abroad
15.	Government effectiveness
16.	Government expenditure on education per pupil, secondary
17.	Government's online service
18.	Graduates in science and engineering
19.	Gross expenditure on R&D – GERD
20.	Intensity of local competition
21.	Joint venture/strategic alliance deals
22.	Logistics performance
23.	Market access for non-agricultural exports
24.	Microfinance institutions' gross loan portfolio
25.	Patent cooperation treaty international applications by origin
26.	Patent families filed in at least two offices
27.	Political stability and absence of violence/terrorism
28.	Press freedom
29.	Pupil-teacher ratio, secondary
30.	Regulatory quality
31.	Researchers
32.	Royalties and license fees payments (% of service imports)
33.	Rule of law
34.	State of cluster development
35.	Tertiary enrolment
36.	University/industry research collaboration
37.	Venture capital deals

Additionally, the data set for the study was supplemented with the resulting GII and data on the GNI of the World Bank [12] for the same period (2013-2019) of the corresponding countries of the world.

2.1 Data description

The peculiarity of the database is its heterogeneity: the number of indicators of group 2 and the number of countries varies depending on the year. This is presumably caused by a

change in the names of countries, the deletion of some indicators (for example, “Press freedom”) by the authors-compilers of the index, as well as the merging of several indicators into one, which was a consequence of a change in the methodology for compiling the GII (Fig. 3).

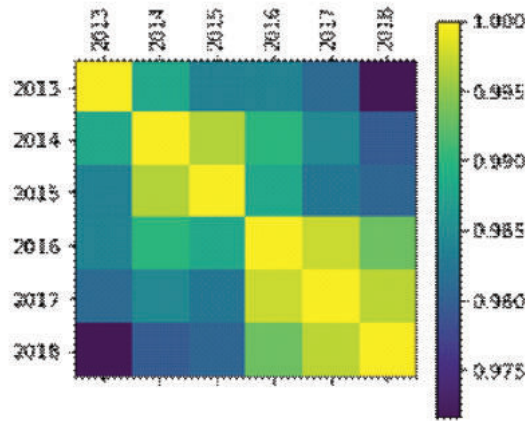


Fig. 3. GII correlogram from 2013 till 2019.

The change by the authors of the index in the number of countries and sub-indexes resulted in gaps in the GII samples in both groups. The gaps in the data were filled by linear regression. The final data set includes 125 to 204 countries, depending on the year, see Fig. 4.

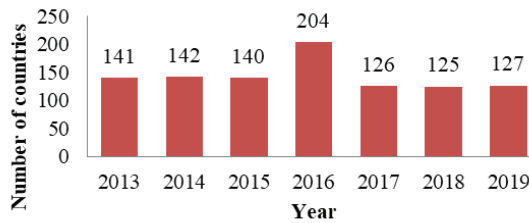


Fig. 4. Number of countries in the basic GNI.

As a supplement, the GNI indicator provided by the World Bank for 2013-2019 was selected in current US dollars. The number of countries also varied (Fig. 5).

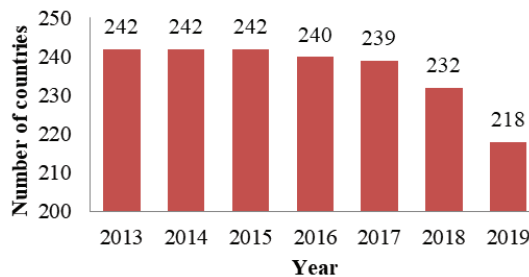


Fig. 5. The number of countries in the GNI.

After preprocessing the data, the number of countries was 180 in each year, the number of omissions was reduced to zero.

The calculations were carried out in the Jupiter notebook v.6.0.3 environment in the Python v.3.7.7.

2.2 Methodology

Countries are at different levels of socio-economic development, have their own system of formal and informal institutions; goals and priorities for the development of the national economy; own scientific production and technological base, etc. – all this influences the methods and instruments of state support of the NIS. Based on this, it is obvious that the search for the most influential indicators should be carried out within a group of countries that are similar in the period under consideration. For the purposes of this study, it is advisable to group countries based on the values of the available indicators in a particular year.

To identify indicators that have the greatest impact on improving the rating of countries, the following algorithmic mode is proposed. As a first, countries are divided into groups (clusters) with similar values of the studied indicators. Further, the countries are highlighted that during the study period improved their positions, moving from a lower to a higher cluster. Further, it is proposed to compare the values of the indicators for the countries that left the cluster with the indicators of the countries that remained in the cluster and highlight the differing indicators. We assume that the transition from cluster to cluster occurred due to differing indicators, that is, these differing indicators are the most influential indicators that determine the country's place in the ranking. To select the most influential indicators from the differing indicators by the Pareto method, it is proposed to select indicators, the sum of the values of which in the module was 80% of the sum of all indicators in the country. After that, the obtained indicators are proposed to be aggregated for all countries and clusters and to highlight the most common ones.

3 Results

3.1 Main findings

As can be seen (Fig. 6 and Fig. 7), the GII and GNI levels are falling until 2016, and the rate of decline (the slope of the graph) for GNI is lower, which can be explained by the damper effect of methods and instruments of state support, as well as the delayed result of the state's economic policy. The more intensive growth of GDP after 2016 compared to the growth of GII can be associated with the cumulative effect and the delayed effect of previously launched state support programs and the effect of the resonant growth of related sectors of the economy.

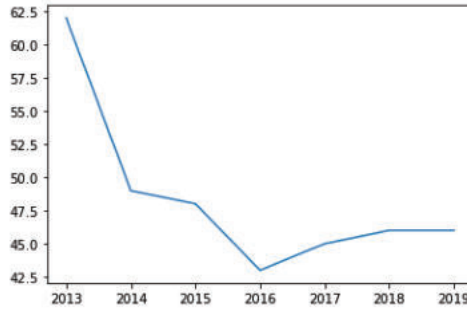


Fig. 6. GII in Russia index change.

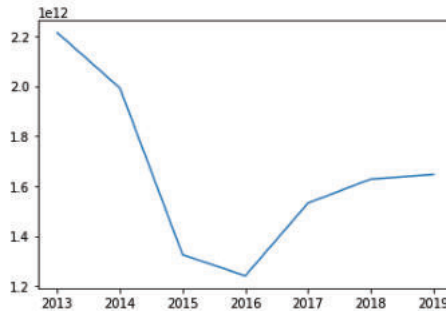


Fig. 7. GNI in Russia index change.

The change in the GII is closely related to the change in indicators characterizing government support and included in the corresponding sub-index. For the Russia, the indicators that have undergone the largest drop (in 2013-2016) are shown in Fig. 8 (the most significant are highlighted in color).

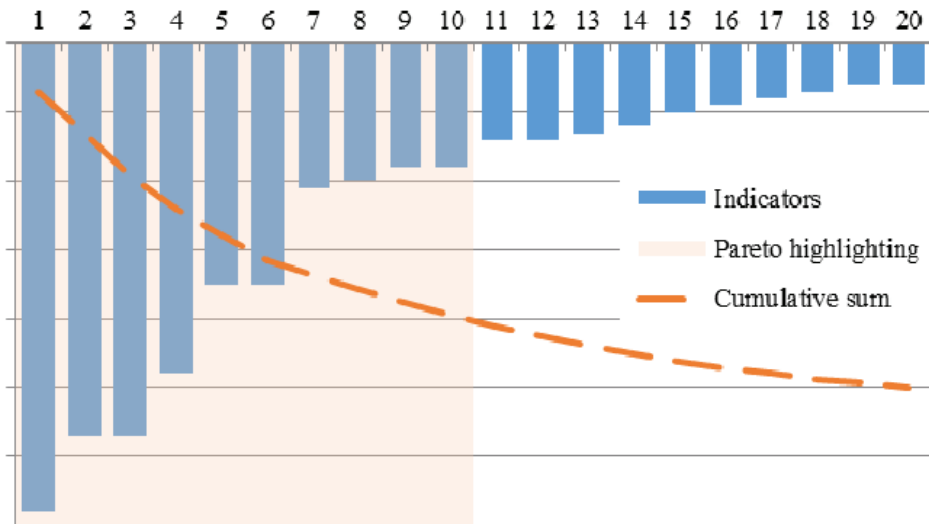


Fig. 8. Chart of the indicators characterizing government support in 2013-2016.

Note: the number of the indicator in Fig. 8 corresponds to the number of the indicator in Table 3.

As can be seen from Fig. 8, in 2013-2016, the largest drop in the values of the following 10 indicators of the Russia included in the GII was observed (see Table. 3).

Table 3. Indicators of the Russia included in the GII, which had the largest drop in 2013-2016.

No.	Indicators
1	Environmental performance
2	Government expenditure on education per pupil, secondary
3	Ease of getting credit
4	Logistics performance
5	Ease of starting a business
6	Ease of protecting investors
7	University/industry research collaboration
8	Foreign direct investment net inflows
9	Domestic credit to private sector
10	Foreign direct investment net outflows
11	Government effectiveness
12	Ease of resolving insolvency
13	State of cluster development
14	Patent families filed in at least two offices
15	Government's online service
16	Microfinance institutions' gross loan portfolio
17	Rule of law
18	Researchers
19	Cost of redundancy dismissal
20	Joint venture/strategic alliance deals

From 2016 to 2019, the GII and the GNI level grow and have the same character. During this period, as can be seen from the diagram in Fig. 9, other indicators shown in table 4 show the greatest growth.

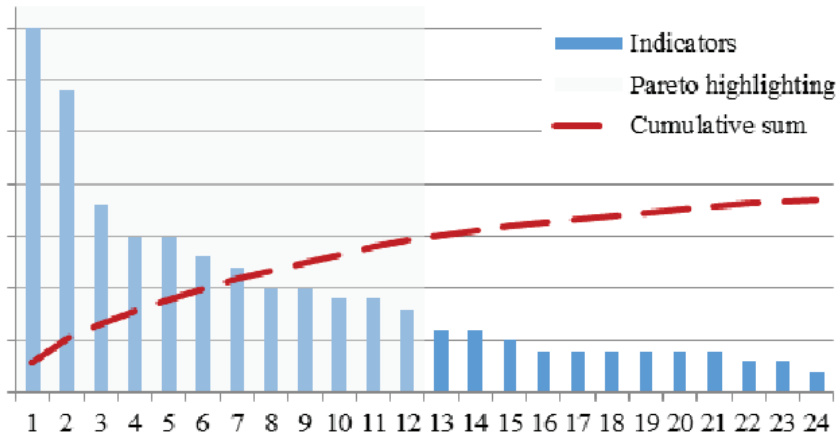


Fig. 9. Diagram of the significance of indicators characterizing the state of NIS support in 2016-2019.

Note: the indicator number in Fig. 9 corresponds to the number of the indicator in Table 4.

Table 4. Indicators in the GII of Russia, showing the most significant positive dynamics in 2016-2019.

No.	Indicators
1	Logistics performance
2	Venture capital deals
3	Joint venture/strategic alliance deals
4	Environmental performance
5	Microfinance institutions’ gross loan portfolio
6	Government effectiveness
7	Regulatory quality
8	Government’s online service
9	State of cluster development
10	Political stability and absence of violence/terrorism
11	Domestic credit to private sector
12	Foreign direct investment net outflows
13	Rule of law
14	Cost of redundancy dismissal
15	Researchers
16	Ease of starting a business

17	Expenditure on education
18	Tertiary enrolment
19	Ease of protecting investors
20	GERD financed by abroad
21	Patent families filed in at least two offices
22	Gross expenditure on R&D
23	Market access for non-agricultural exports
24	Ease of resolving insolvency

Subtracting the lists of Table 3 and table 4, it is easy to see that in Russia the most significant indicators, a change in which led to a fall or increase in the GII in 2013-2019:

- 1) Domestic credit to private sector;
- 2) Environmental performance;
- 3) Foreign direct investment net outflows;
- 4) Logistics performance.

It should be noted that, despite the formally positive trend, the "Environmental performance" indicator has a strongly negative forecast dynamics [13]. In 2019, the programs to support the development of these 4 indicators no longer give a tangible increase in the GII. This may be due to both the exhaustion of their growth potential in the current environment and an increase in the need to support other innovative drivers. Referring to the list of the most important indicators we can add the following indicators with negative dynamics the development of which can significantly accelerate the growth of the GII and, consequently, the level of Russia's GNI (see Table 5).

Table 5. Additional growth areas for the development of NIS Russia.

No.	Indicators
1.	GERD financed by abroad
2.	Cost of redundancy dismissal
3.	Ease of resolving insolvency
4.	Expenditure on education
5.	Graduates in science and engineering
6.	Gross expenditure on R&D
7.	Joint venture/strategic alliance deals

Due to the positive dynamics, as well as the possible growth as a result of the National Projects, the indicators with positive dynamics are not considered. However, monitoring indicators in this group is necessary to prevent their overflow into group with negative dynamics.

The indicators with negative dynamics are united, first of all, by the susceptibility to the influence of external factors, such as the growing pressure of sanctions and a series of global financial and economic crises. Obviously, direct government support is difficult,

nevertheless, stimulating the intensification of interaction with Asian countries hides the growth potential of both the direction and the entire NIS of Russia as a whole.

The indicators with positive dynamics group refer to internal factors, which are directly influenced by Federal Target Programs (or National Projects), the delayed effect of which has not yet manifested itself. Nevertheless, the accumulated long-term experience of FTP monitoring shows a lack of consideration of changes in the global and national economies, as well as the experience of other countries, which reduces their effectiveness [14].

In the context of increasing globalization and interpenetration of markets, the influence of external factors is of particular importance in the development of the NIS of Russia. National innovation system agents who do not have sufficient resources to effectively overcome the negative impact of the emerging restrictions, especially in need of government support. In turn, support for the development of international relations by the state will not only increase the rating of NIS Russia in the international index, but will also lead to an increase in its GNI.

3.2 Research progress statement

Countries can be divided into a finite number of groups (clusters) by the GINI and GINI value together in the same year. Thus, within the clusters there will be countries with a similar level of development of both NIS and NI, which indicates that they are implementing similar government support.

The change in GNI undoubtedly affects the change in the cluster country, however, since there is an unambiguous relationship between GII and GNI and there is a relationship between indicators of groups 1 and 2 with GII, there is also their relationship with GNI. To assess the impact of government support measures for NIS on GNI, it is necessary to carry out a two-factor clustering according to GII and GNI, which will reflect not only individual differences of NIS, but also its effectiveness.

Two-factor clustering was carried out in the following stages:

- 1) Reducing the data to the same scale. For this, the GNI values were logarithmized.
- 2) Using the DBScan() method, we searched for the optimal number of clusters.
- 3) Clustering of pre-processed by the K-means() method according to the number of clusters determined by the DBScan() method according to the GII and the GNI level.

The DBScan() method revealed a large scatter in the number of clusters, which depends on the value of the initial parameters for a particular data set, in particular, on the min samples parameter. The spread ranged from 22 in 2015 to 2 in 2014. To compensate for this spread, the number of clusters was averaged over the years and over the combination of the method parameters, and amounted to 10.

It should be noted that the effect of state support for NIS is stretched over time, while world economic crises, sanctions and changes in the global market can directly affect the country's economy. The impact of the combination of the above factors can lead to the change of the cluster by the country.

4 Discussion and conclusion

The developed model differs from the accepted econometric approach, as it uses integral characteristics of both national innovation system, and results of economic activity of the country. However, unlike the methods using natural indicators combined in panel data, the results of the model may look excessively generalized, which in turn requires further detailing.

In the context of increasing globalization and interpenetration of markets, the influence of external factors is of particular importance in the development of the NIS of Russia. National innovation system agents who do not have sufficient resources to effectively overcome the negative impact of the emerging restrictions, especially in need of government support. In turn, support for the development of international relations by the state will not only increase the score of NIS Russia in the international index, but will also lead to an increase in its GNI.

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