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Comprehensive evaluation of Russian regional innovation system performance using a two-stage econometric model

Evaluación integral del rendimiento del sistema regional de innovación de Rusia mediante un modelo econométrico de dos etapas

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Content

ABSTRACT:
In the presented article the authors analyzed contemporary models and performance evaluation criteria of regional innovation systems in the context of the entities of the Russian Federation, as well as existing methods of assessing innovation potential, and clarified in this connection the concept of innovation potential as a key element in performance evaluation of the regional innovation system. In consequence of the conducted analysis, the authors justified necessity to allocate two subsystems in the regional innovation system, namely, the knowledge creation subsystem and the knowledge commercialization subsystem. The authors proposed to develop an integrated approach to performance evaluation of the regional innovation systems. For this purpose, a mathematical simulation

RESUMEN:
En el presente artículo, los autores analizaron los modelos contemporáneos y los criterios de evaluación del desempeño de los sistemas regionales de innovación en el contexto de las entidades de la Federación de Rusia, así como los métodos existentes de evaluación del potencial de innovación, y aclarado a este respecto el concepto de potencial de innovación como elemento clave en la evaluación del desempeño del sistema regional de innovación. Como consecuencia del análisis realizado, los autores justificaron la necesidad de asignar dos subsistemas en el sistema regional de innovación, a saber, el subsistema de creación de conocimientos y el subsistema de comercialización del conocimiento. Los autores propusieron desarrollar un enfoque integrado para la evaluación del desempeño de

was carried out using a two-stage Data Envelopment Analysis (DEA) to assess the Russia's regional innovation system performance for the period from 2011 to 2015. The proposed comprehensive approach to the performance evaluation of regional innovation systems allowed identifying inconsistencies between the existing system of the innovation performance ratings in the regions of the Russian Federation and the proposed model, as well as revealing the advantages and disadvantages of various approaches.
Keywords: regional innovative system, two-stage Data Envelopment Analysis, innovation potential, innovation process, effectiveness.

los sistemas regionales de innovación. Con este fin, se realizó una simulación matemática utilizando un análisis de envolvente de datos de dos etapas (DEA) para evaluar el rendimiento del sistema regional de innovación de Rusia para el período de 2011 a 2015. El enfoque global propuesto para la evaluación del desempeño de los sistemas regionales de innovación permitió identificar las incoherencias entre el sistema existente de las calificaciones de rendimiento de la innovación en las regiones de la Federación de Rusia y la propuesta modelo, así como revelar las ventajas y desventajas de diversos enfoques.
Palabras clave: sistema innovador regional, análisis de envolvente de datos en dos etapas, potencial de innovación, proceso de innovación, efectividad.

1. Introduction

To date, domestic and foreign authors have sufficient number of available methods and tools to build an adequate technique for performance evaluation of regional innovation systems.

However, despite considerable number of research and publications on this subject, contemporary literature lacks common understanding of the regional innovation system’s (RIS) essence, as well as performance evaluation system. We can only note the significant variety, which is inherent in the approaches to performance evaluation of innovation system.

In previous studies, the authors noted the relationship between innovativeness and innovation potential of the region (The draft strategy of innovative development of the Russian Federation for the period till 2020), therefore it is logical to begin exploring these approaches with an assessment of the regional innovation potential.

2. Literature review

The issue concerning the innovation potential assessment of Russian regions was studied by different authors. Thus, regional innovation potential was studied in (Untura 2011; Amosenok and Bazhanov 2008). The authors of the project on innovative development strategy "Innovative Russia – 2020" (The draft strategy of innovative development of the Russian Federation for the period till 2020) also highlight successful innovation-active entities of the Russian Federation (the regions), such as the St. Petersburg, Novosibirsk Region, Tomsk Region, as well as the Republics of Mordovia and Tatarstan (The best practices of formation of innovative growth areas: achievements and mistakes, 2011).

Study (Zhits 2000) gives the definition of innovation potential as a resource provision of the system’s operation at the world level or above it. The innovation potential conditionally consists of four interrelated segments.

1. Scientific and technical potential to ensure the availability of innovations designed for productive use in macrosystems.

2. Educational potential, characterizing the macrosystem’s capabilities in the creation and use of scientific and technological innovations.

3. Investment potential, characterizing the capabilities of the macrosystem to implement scientific and technological innovations into economic utilization and their dissemination throughout the entire macrosystem.

4. The potential of the consumer sector, i.e. all individuals and legal entities, which are, on the one hand, consumers of the innovations proposed for practical application, and on the other hand, initiate follow-up activity of other segments through the formation of new needs.

Technological capability occupies a central position in innovation potential, encompassing all four of the listed elements in the particular area, which is associated with the creation, development, and dissemination of advanced technologies.

The innovation potential includes the following main elements:

> 1. *The personnel element:* the number and qualification of technical and scientific specialists, their level of education, creativity, experience, erudition, knowledge of advanced technologies, commitment to training, willingness to develop and implement novelty, and receptivity to innovations.
>
> 2. *The institutional element:* the number of organizations supplying professionals and key technologies, their status, affiliation, size structure, etc. The same data apply to the organizations, which are the key users of technology.
>
> 3. *Finance and investment element:* the investment in the creation of new technologies during the concerned period, the volume and structure of financial resources for investment in technologies, availability level of equipment, materials, instruments, office automation and computer equipment, etc.
>
> 4. *Organizational and managerial element:* technology development and transfer mechanisms, as well as intellectual property protection.
>
> 5. *Generalizing indicators:* involvement of the region in the technological exchange, the share of innovative products in the gross regional product (GRP), etc.

It should be noted that different regions have certain peculiarities that inevitably affects the level of innovation potential and its structure. The literature on regional innovation activity presents discussions on different approaches suggesting the ways how to take into account the regional characteristics, when assessing the regional innovation potential.

> 1. Typically, innovation-active enterprises and research institutes are concentrated in large agglomerations (Feldman and Audretsch 1999).
>
> 2. Industrial and industrial-innovation clusters contribute to the dissemination of knowledge and new technologies; often they can be far enough away from the major regional centers (Botazzi and Peri 2003).
>
> 3. Generally, the regions located on the outskirts of the country, are less active in terms of implementing innovations than those that are close to the largest scientific and financial centers (Rudskaya, Rodionov and Guzikova 2014).

In foreign practice there are several systems to measure the regional innovation potential. The EU Regional Innovation Scoreboard (RIS) (Regional Innovation Scoreboard 2012) became the most famous methodology in Europe. The value of this index lies in regular information collection, whereby it can be used for benchmarking of regional innovative development. The methodology to determine the innovation index of the EU regions is presented in (Regional Innovation Scoreboard 2012). It is close to the European Innovation Scoreboard methodology. The index includes three dimensions of innovative development: innovative development factors; activities carried out by companies; and the results of innovative activities.

The American index of regional innovative development, namely Portfolio Innovation Index (PII) (Crossing the next regional frontier: Information and analytics linking regional competitiveness to investment in a knowledge-driven economy) is based on the assessment of four groups of indicators. Each of these groups is assigned a specific weight: the development level of human capital (30%); level of economic dynamics (30%); productivity and employment (30%), and economic well-being of the region (10%). It is noteworthy that the American rating lacks specific groups of innovation indicators, though each group contains indicators characterizing innovative development.

The innovative development index is calculated by the formula:

$$PII_j = \sum_{s=1}^{4} A_s X_{sj},$$

where PII_j – is the innovative development index for the j region (county), A_s – is the s component's weight in the innovative development index, X_{sj} – is the index value with respect to component s for region j.

The structure of the RIS and PII indices is such that they combine both the innovation activity resources and results. As a rule, the leading regions are characterized by high scores with regard to both resource and result components of the indices. However, in some cases, this condition is not met.

Finally, we should mention one more technique, which has become to a certain extent the basis for our study. This is knowledge-based regional competitiveness index (World Knowledge Competitiveness Index, WKCI), developed by Robert Huggins and coauthors (Huggins, Izuschi, Davies and Shougui 2008). The authors pursued the task to measure the contribution of the knowledge-driven economy in the region's competitiveness. The authors have built a rating based on consideration of 145 regions of the world.

This methodology is based on the comparison of the region's performance results with resources (capital) involved in the region. That is, essentially we are talking about efficiency of knowledge-driven economy in a particular region.

The regional production function of the knowledge-driven economy consists in transformation of four types of capital into the knowledge-based economic performance. Further we measure the contribution of this economy to the overall results of the region's performance over a certain period of time. An important element of the concept is the formation of a sustainable relationship between the results of the previous period and resources of the subsequent period. If part of the achieved results is reinvested in resources, especially in intangible ones (human capital and knowledge capital), in the future, the existence of these relations means the welfare of the region at the expense of the knowledge-driven economy (Khalimova 2015).

The attempts to build a single aggregate index of regional innovativeness have been undertaken in Russia as well. The most widely known is the Rating of Innovative Regions of Russia (RIRR), developed by the Association of Innovative Regions (Semenova 2016), which includes three subratings.

From the authors' standpoint, the weak point of the AIRR rating is that it is based solely on statistical indicators. Thus, it allows obtaining quantitative data characterizing the results of innovative activities rather than conditions, i.e. the rating does not allow explaining the reasons for the obtained results (Rudskaya 2014).

Finally, we should mention the Russian Regional Innovation Index (RRII), which is being published by the Institute of Statistics and Knowledge-based Economy of the National Research University "Higher School of Economics" since 2012 (Gokhberg 2012; Gokhberg 2016). The rating is based on the methodology used by the EU, though has specific features relevant to the realities of innovative activities in Russia. It involves 4 groups of indicators. Each of these groups includes the upper and lower level indices.

The above and other approaches to rankings of regional innovative development, as noted, are based on the ratio of costs and results. It is natural to assume that the regions with vast resources and those investing more in innovation, achieve better results. But the question arises, how effective are these investments?

The conducted analysis of various techniques to assess regional innovation activities allows us to develop common approaches and identify weaknesses inherent in each of considered method.

1. Attempt to rank regions on the basis of aggregated index, which is based on the weighted average of the indicators. Weights are specified initially that, firstly, is a

subjective estimate, and secondly, does not allow taking into account the individual characteristics of the regions, which, while striving in general to improve the performance efficiency of innovation, do so in different ways;

2. Indices do not allow comprehend clearly how essentially the regions are lagging behind the leaders of innovative development, and in which direction they should put in the effort (as reflected in the regional innovation policy) towards raising innovative performance.

Thus, we can conclude that there is need for a comprehensive approach to performance evaluation of the regional innovation system.

In literature it is accepted to distinguish two basic types of efficiency, namely technical and allocative (pricing) efficiency.

In this paper the authors examine, first of all, the technical effectiveness of the regional innovation activity, because with regard to the regional innovation system we can assume that a region is technically effective if it is able to produce the best possible result of innovation activity per the unit of innovation resources (Fritsch and Slavchev, 2006), that is, to maximize its innovation potential. Thus, the technical effectiveness reflects the region's ability to convert investment into innovation resources in consequence of innovation activity (Chen and Guan 2012). In fact, this is production function, where the key role is played by knowledge.

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3. Methods

Key approaches to assessing technical effectiveness of economic systems are based on the theory of production curves and the specification of production function. Their construction can be conducted with the use of two groups of techniques – parametric and nonparametric methods (Table 1).

Table 1

Approaches and assessment methods of technical effectiveness

Parametric methods	Nonparametric methods
Stochastic Frontier Approach (SFA) Distribution-Free Approach (DFA) Thick Frontier Approach (TFA)	Data Envelopment Analysis (DEA); Free Disposal Hull (FDH) (special case of DEA)

Source: Coell, Rao, O’Donell and Battese, 2005

In this work, we used nonparametric approach, namely DEA. This method is used quite often in the analysis of national innovation systems (an overview of the conducted research is presented in the article (Kotsemir 2013)), however it has been almost never used to the Russian regional innovation systems. Among various methods for a comprehensive assessment of the Russian regional innovation system, DEA-based approach is used in the article of S.P. Zemtsova and V.L. Baburin (2017). However the authors have used a small number of input and output parameters and have not taken into account the time lag, that is, the approach cannot be employed independently as policy-making indicator.

The nonparametric approach used in DEA, implies that each economic unit is in the process of transformation of available resources into performance results. This approach involves the ideology of benchmarking, because the group of effective economic units is considered as samples (benchmarks) for other units having the same priorities and development goals, though using less effectively the resources available to them.

The model aims at maximizing the ratio of "results" to "resources." A detailed formal description of the model and its limitations is given by W. Cooper (Cooper, Seiford and Tone 2007).

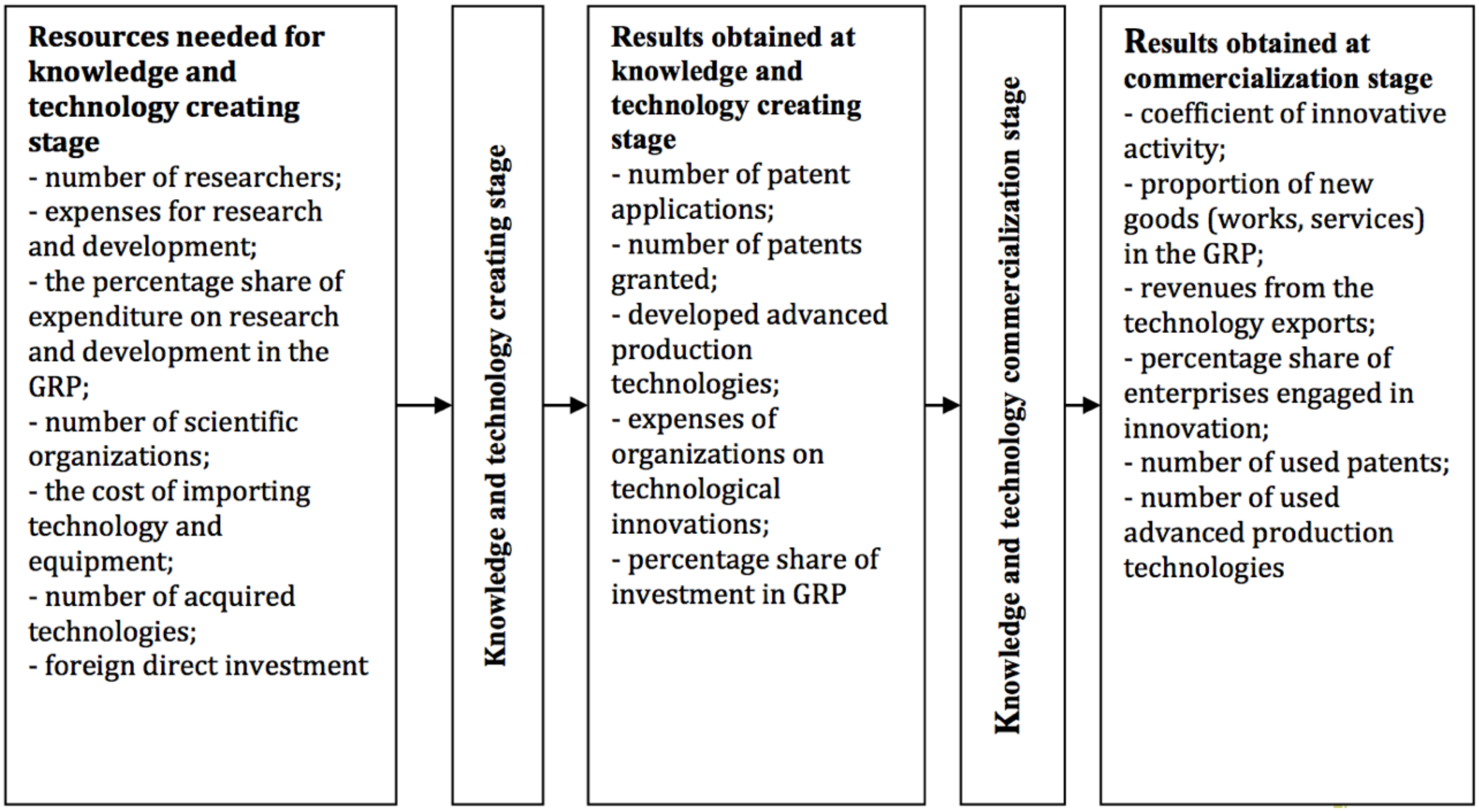
For the regional innovation efficiency analysis, one of DEA advantages is its ability to assess the overall performance, as a result of the impact of many factors on costs and results. Thus, this approach differs from the usually adopted approach associated with the formation of the index based on the weighted indicators, characterizing separately the cost-based and resultant components of innovation.

Further research needs highlighting two subsystems in the regional innovation system: a subsystem for creating knowledge, and knowledge commercialization subsystem. These two subsystems are closely interrelated and operate simultaneously, though they can be considered as successive stages of the innovation process: the commercialization is only possible if the knowledge creating subsystem has produced new knowledge and technology that can generate valuable commercial results. Such results of the knowledge production subsystem can include, for example, advanced manufacturing technologies developed in the region, or registered patents.

Consequently, it is appropriate to modify the model for assessing the effectiveness of the regional innovation system based on these two stages, because classical DEA model provides the opportunity to assess the effectiveness of just one specific stage. In our case we have two stages: at the first stage we assess the knowledge production subsystem (the effectiveness of scientific activities), while at the second stage we assess knowledge and technology commercialization subsystem, that is, the effectiveness of innovation performance (Fig. 1).

Because there is a time lag between the creation and commercialization of knowledge and technology, this should be taken into account in our model. The authors, exploring innovation performance, recognize the presence of this lag, though stipulate the fact that its numerical value is not fixed and depends on the development of infrastructure as well as research areas prevailing in the region’s structure (Bonaccorsi and Daraio 2004). Like a significant number of authors (Shakina, Barajas, Parshakov and Chadov 2017), we chose the two-year time lag between development and commercialization stages.

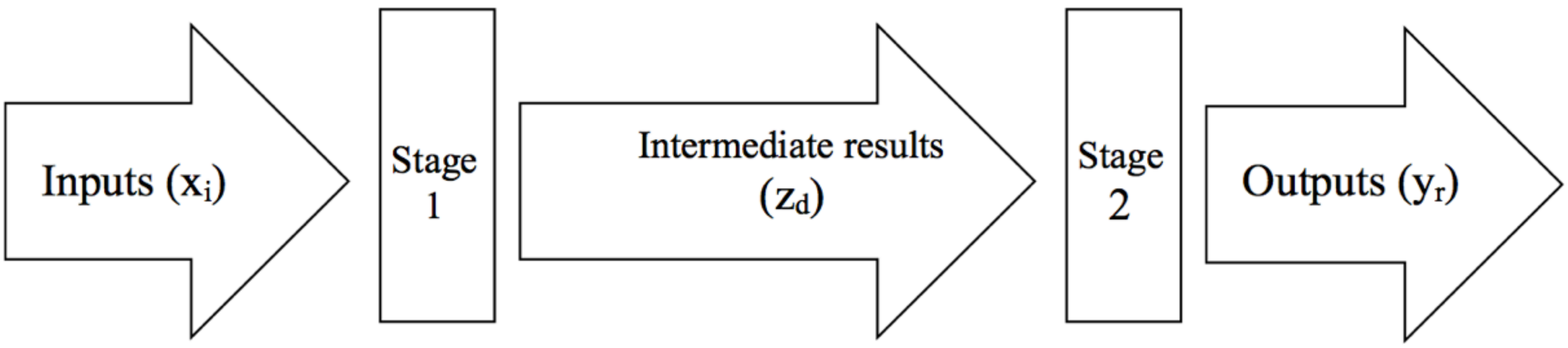
Figure 1
The logical model to assess the regional innovation system performance



Data for calculations were taken from official statistics provided on the website of the Federal State Statistics Service. Since the latest complete data refer to 2015, we have considered two-year intervals 2011 – 2013 – 2015.

A two-stage model was used for simulation (Chen and Guan 2012). It is based on the fact that the results of the first stage serve input recourses for the next stage, and are used in the model as intermediate indicators (z_d). Figure 2 presents the general two-stage model process, where at the stage 1 we use the inputs x_i ($i = 1, ..., m$) to obtain the outputs z_d ($d = 1, ..., D$), and then obtained z_d are used as inputs at the stage 2 to obtain the outputs y_r ($r = 1, ..., s$). We can see that z_d (intermediate results) are outputs of the stage 1 and inputs for the stage 2.

Figure 2
The overall process of the two-stage model (Chen and Guan 2012.)



That is, an effective model minimizes the resources of the intermediate stage, while in turn, the results of the intermediate stage in the effective model are achieved at the minimum resources investment at the initial stage. The model looks as follows:

$$\min_{\alpha,\beta,\lambda_j,\mu_j\tilde{z}} w_1\alpha - w_2\beta$$

subject to

(stage 1)

$$\sum_{j=1}^{n}\lambda_j x_{ij} \le \alpha x_{ij_0} \qquad i = 1,\dots,m$$

$$\sum_{j=1}^{n}\lambda_j z_{dj} \ge \tilde{z}_{dj_0} \qquad d = 1,\dots,D$$

$$\sum_{j=1}^{n}\lambda_j = 1$$

$$\lambda_j \ge 0, \quad j = 1,\dots,n$$

$$\alpha \le 1$$

(stage 2)

$$\sum_{j=1}^{n}\mu_j z_{dj} \le \tilde{z}_{dj_0} \qquad d = 1,\dots,D$$

$$\sum_{j=1}^{n}\mu_j y_{rj} \ge \beta y_{rj_0} \qquad r = 1,\dots,s$$

$$\sum_{j=1}^{n}\mu_j = 1$$

$$\mu_j \ge 0, \quad j = 1,\dots,n$$

$$\beta \ge 1$$

where w_1 and w_2 – are the weights reflecting the preference of parameters for both stages of the model, while the sign "~" means that the parameters at the initial stage are not defined.

If $\alpha^*=\beta^*=1$, this means that total economic efficiency has been achieved at both process stages and in the model in general. If $\alpha^*=1$ while $\beta^*>1$ (or $\alpha^*<1$ while $\beta^*=1$), the model shows that with the given input and output parameters the efficiency can be achieved just at one stage.

Economic unit is effective on both stages subject to the achievement of optimum weights at each stage.

4. Results

Based on the results obtained, we can conclude that the majority of regions are not technically effective in terms of evaluating successive creation and commercialization of new knowledge and technology.

A graphical representation of the results obtained is shown in Fig. 3. This chart provides the opportunity to clearly comprehend that for the regions, which are ineffective at least at one stage of analysis, the blue line, which corresponds to the overall efficiency, will be always below the red and green lines corresponding to the effectiveness at the first and second stages. So, a certain region, for example, may be ineffective at the first stage, i.e. in the production of new knowledge and technologies, though effective at the second commercialization stage, and vice versa. This means that at one of the stages the region's effectiveness will not be equal to one. However, according to the methodology used in this article, the region is recognized brand effective only in case if its effectiveness is equal to unity at both stages. In this case the concluding effectiveness will be equal to one as well.

Table 2 presents technically effective regions based on their assessment with the use of two-stage model employing DEA. Also, for a more illustrative analysis the table was supplemented by the ranking results of these regions according to two existing techniques, namely Association of Innovative Regions and Russian Regional Innovation Index.

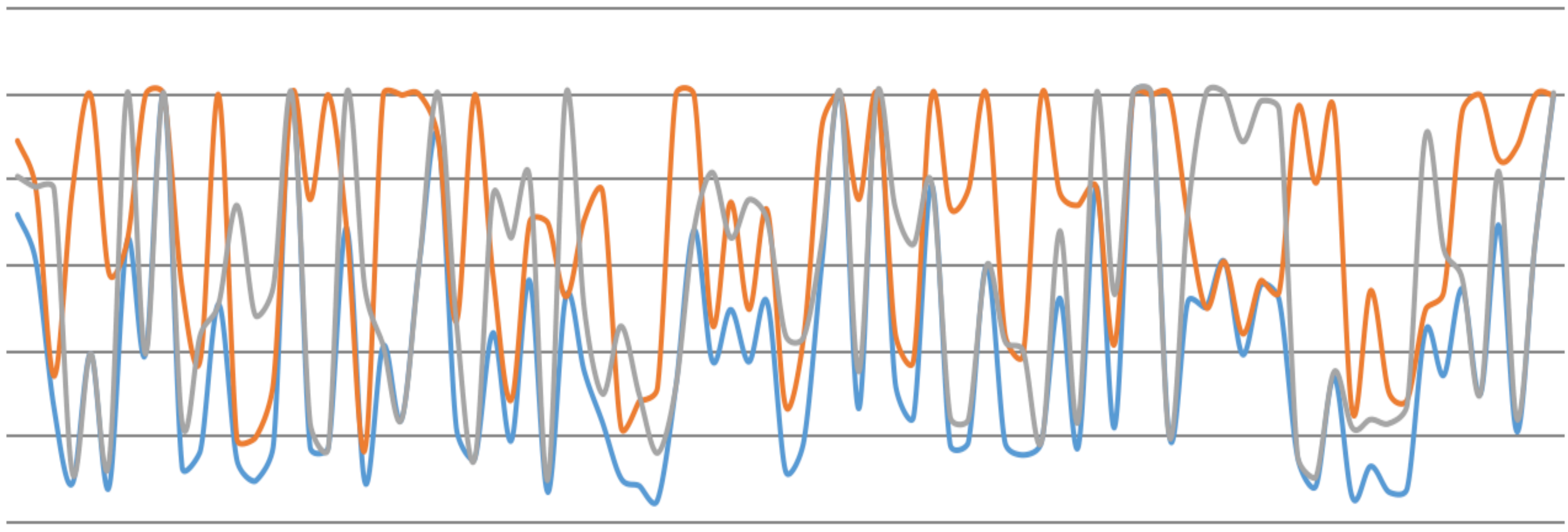
The simulation results show that over a long period of time (considering two-stage assessment process of the regional innovation system’s performance) effective are not the leaders of ratings (whose effectiveness at each stage could be higher), but the regions belonging to the "followers" (second and third group, medium-strong and medium innovators). This means that all leading regions have reserves to enhance innovation performance without significant increase in investments that requires new innovative process management mechanisms, primarily, the improvement of the interaction between the participants of innovation performance. "Weak" Chukotka Autonomous Region is the exception among the effective regions. This can be interpreted by the fact that any increase in the resource component of the innovation process, while keeping the existing approaches to the management of innovation, can lead to increase in effectiveness of the regional innovation system performance in general.

Table 2
Technically effective regional innovation systems according to the assessment by the two-stage model

No	Region	RRII-based group	AIRR-based group
1	The Lipetsk Region	II (14)	Moderate innovators (31)
2	The Tula Region	III (42)	Moderately-strong innovators (18)
3	The Republic of Mordovia	II (4)	Moderately-strong innovators (20)
4	The Udmurtian Republic	III (61)	Moderately-strong innovators (29)
5	The Yamalo-Nenets Autonomous District	II (26)	Moderately -weak innovators (74)
6	The Tyumen Region	II (21)	Moderately -strong innovators (21)
7	The Chukotka Autonomous Region	IV (73)	Moderately -weak innovators (73)

Figure 3
The effectiveness frontier in the two-stage model. The blue line indicates the overall

effectiveness, red line corresponds to the effectiveness of the first stage, green line corresponds to the effectiveness of the second stage.



5. Conclusion

In consequence of the conducted study, we can draw the following conclusions: firstly, we have confirmed the results obtained by other researchers. The regions with the highest investments in innovation do not always use their potential effectively (Zabala-Iturriagagoitia, Voigt, Gutiérrez-Gracia and Jiménez-Sáez 2007); secondly, we have confirmed regional innovative development ratings obtained using other methods (Gokhberg, 2016; Semenova 2016; Untura 2011).

Thus, in consequence of the assessment of regional innovation systems' performance we

have revealed the variety of approaches to assessment;

and identified the advantages and disadvantages of different approaches.

Besides, we also revealed that even the regions with leading rating of innovative development face challenges associated with the fact that the resources targeted to these purposes do not always give the expected results. This discrepancy is even strengthening when assessing within a long period of time that requires more thorough predicting the prospects of innovative development in the long term.

6. Discussion

Since the proposed approach has proved its applicability for enhancing comprehension of the innovation performance drivers in Russian regions, it provides the opportunities for further research development in this area. However, this requires, firstly, defining the effectiveness frontier within categories of regions defined by other researchers. This will allow defining more clearly the factors influencing the innovation performance. Secondly, we need to expand the periodization of the study and analyze the obtained performance indicators over time.

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