Practical implementation of Data Envelopment Analysis technology to assess the innovative sustainability of resource-type regions

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Abstract. The article is devoted to the modification of the Data Envelopment Analysis (DEA) method to conduct a comparative assessment of the innovative sustainability of resource-type regions. The theoretical basis for the study was the results of the analysis of accumulated foreign experience and current Russian practice on the assessment of sustainable innovative development at the federal and regional levels. Based on the approaches studied, taking into account the identified advantages and disadvantages, the authors proposed a modification of the DEA method, which allows to evaluate the effectiveness of innovative development of regions from a position of sustainability, with subsequent interpretation of the assessment results and identification of factors that have a negative impact. The results of the study can be used by regional and federal government bodies to monitor risks and threats in the innovation sphere of the regions of the Russian Federation, as well as to adjust existing regulatory, strategic documents and improve mechanisms to stimulate innovation in resource-type regions.

1. Introduction

Innovative sustainability can be considered as one of the characteristics of successful innovative development of a socio-economic system at any level (national, regional, local). By the innovative sustainability of the regional socio-economic system, we should understand the ability of the system to generate the creation of intellectual property for a certain period of time with their subsequent commercialization in the production sector of the region with the aim of significantly changing the structure of industry and developing the production of a new technological structure [1].

The scientific understanding of innovative sustainability and the study of its significance for successful innovative development at the federal and regional levels make it possible to identify the factors of containment, formation and development of an innovative economy. In this regard, the issue of assessing the innovative sustainability of the socio-economic system is becoming particularly relevant.

In order to determine the appropriate system of indicators and methods for quantifying the innovative stability of the region, it is advisable to rely on the methodology for assessing the effectiveness of innovative activities at the federal and subfederal levels.

In the aspect of international practice, the experience of the countries of the European Union and the United States of America is interesting, which is presented in sufficient detail in a number of studies by domestic and foreign authors [2-6]. As a rule, the assessment results are reduced to the formation of a comprehensive indicator, including a number of sub-indicators, which, in turn, are differentiated into groups according to a certain classification criterion. The system of quantitative assessment of the level of innovative development of territories in the United States of America has its own characteristic

differences. As a rule, in current assessment systems, the element-wise structure of an integral indicator is characterized by a combination of both resource parameters of innovative activity and the results of its effectiveness.

According to I.M. Bortnik [6], the methodological foundations of the American and European assessment systems can be projected as the basic component in building a system for assessing the level of innovative development of the Russian Federation in a regional context.

In determining the level of innovative sustainability of the region, according to the authors, useful information can be obtained by comparing the regions among themselves. In this regard, it is proposed to use the Data Envelopment Analysis (DEA) method to perform such a comparison, having previously implemented its modification taking into account some assumptions.

2. Methods

The Data Envelopment Analysis method is based on linear programming. The Data Envelopment Analysis method was proposed in 1978 by American scientists A. Charnes, W. W. Cooper, E. Rhodes [7], which were based on the ideas of M. J. Farrell [8]. This method is successfully used in the West to assess the effectiveness of the functioning of homogeneous objects in various socio-economic systems. Such objects can be corporate structures, financial and credit institutions, social institutions, governing bodies, regions, etc. [9].

The essence of the DEA method on the example of the economic system is widely considered in the works of Russian and foreign scientists [9-13]. The DEA methodology uses the term “operational efficiency”, which reflects the efficiency with which the objects under study convert inputs to outputs. In the framework of this study, efficiency should be understood as the level of innovative sustainability of the region.

The main advantages of using Data Envelopment Analysis are [10]:

- the ability to calculate a complex indicator for each subject of the assessment based on the use of input parameters in order to obtain the desired output values;
- the ability to simultaneously process multiple input and output parameters of different proportionality;
- the ability to take into account external environmental factors;
- the possibility of using variables that do not require the mandatory use of weighting factors;
- the possibility of using the functional form of the relationship between inputs and outputs, which does not require the formation of any restrictions;
- the implementation of the necessary procedure for the quantitative assessment of desirable changes in both input and output parameters, which would make it possible to bring inefficient business systems to the appropriate level of effectiveness;
- the presence of many points corresponding to effective Pareto optimal systems;
- focusing on identifying best practices, while eliminating averaged trends.

Due to the fact that in the Data Envelopment Analysis method the problem statement is carried out in terms of inputs and outputs, therefore, a prerequisite when using it to assess the level of innovative sustainability is the need to classify one component of the system of indicators characterizing the situation in the region as inputs and another component of the totality of indicators - to the outputs.

Considering the system of criteria and indicators that are used to assess innovative development, we come to the conclusion that the separation of indicators into input and output is problematic.

One of the approaches to solving the problem of dividing indicators into input and output for assessing the innovative sustainability of a region can be the following [9]: input indicators can conditionally include those for which lower values are considered more preferable, and indicators focused on increase. As a result, after a series of computational operations using the DEA method, we will receive recommendations for “inefficient” regions on reducing input values and increasing output indicators.

Other approaches to solving the problem of dividing indicators into input and output are also possible. It should be borne in mind that in the methodology the input parameters are simplistically represented as system resources, and the output as the results of the system.

To select and justify the parameters for assessing the level of innovative sustainability of the region, the authors propose to adapt the indicators of innovative development at the regional level to the requirements of the DEA method as follows. It is proposed to use indicators reflecting conditions conducive to the development of the region's innovative economy as input parameters, and indicators characterizing the results of innovative activity of the subject as output parameters.

According to the basic principle of the DEA method, a safe state of the system is achieved either by striving to minimize the values of input parameters or striving to maximize the output parameters. Accordingly, from the position of ensuring a given level of innovative sustainability, all input parameters should be oriented towards a decrease, and output parameters should be oriented towards an increase in their values.

However, the system of indicators used as input parameters can be characterized by their multidirectionality (in the case when their values tend to either increase or decrease). The use as indicators for assessing the innovative stability of the region of indicators oriented from the perspective of innovative development to increase will be contrary to the requirements of the Data Envelopment Analysis method (the desire of all input parameters to minimize). Therefore, in order to adapt the selected indicators to the mandatory conditions for the application of the DEA method, it is necessary to distinguish between those selected as input indicators in the "direction": from a position of stability, oriented towards reduction (group 1); from a position of sustainability, focused on increasing (2nd group).

As a result, when using the Data Envelopment Analysis method, the information base for the first group of indicators will take their actual values. For the second group of indicators, according to the authors, a prerequisite will be the determination of reference parameters, the deviation of the actual values from which tends to a minimum to achieve a stable state. In this regard, for the indicators of the second group, it is advisable to take into account the deviation, which is defined as the difference between the actual value of the indicator and the established threshold, as initial data. Therefore, in this case, the assertion that the smaller the deviation, the more innovative the region is, will not be violated. Using this method, you can get a comparative section in the regions of Russia in terms of innovation sustainability.

As a result of using the Data Envelopment Analysis method, one integral indicator will be obtained for each of the subjects of the Russian Federation studied in the sample, based on the value of which ranking can be carried out and, as a result, the construction of a special rating system for the subjects of the Russian Federation according to the level of their innovative sustainability. In addition, specific assessments are made of the desired changes in inputs/outputs that would allow bringing inefficient regions to the so-called efficiency margin (the term "inefficient", as noted above, in this case will mean innovatively unstable, in a less favorable situation with point of view of sustainable innovative development).

3. Results

To study the analytical capabilities of the proposed modification of the Data Envelopment Analysis method for assessing innovative sustainability at the regional level, we consider the sequence of its application on the example of the constituent entities of the Russian Federation of a resource type. The selection of regions was carried out on the basis of two criteria: 1) the share of mining in the gross value added of the subject; 2) the volume of investment in fixed assets in the industry "Mining". As a result, 18 regions were selected for practical implementation: Khanty-Mansi Autonomous Okrug, Yamalo-Nenets Autonomous Okrug, Sakhalin Oblast, Republic of Sakha (Yakutia), Kemerovo Oblast, Komi Republic, Orenburg Oblast, Krasnoyarsk Territory, Tomsk Oblast, Irkutsk Oblast, Republic of Tatarstan, Astrakhan Oblast, Perm Territory, Udmurt Republic, Samara Oblast, Magadan Oblast, Murmansk Oblast, Belgorod Oblast (Nenets Autonomous Okrug and Chukotka Autonomous Okrug are

excluded from the list of raw material regions as part of the current study due to the lack of Ia a complete set of necessary indicators for further calculations).

We used 2010 and 2016 as calculation periods. To assess innovation sustainability, we used the following system of indicators and threshold values, presented in accordance with table 1. For input indicators, the deviation, which is defined as the difference, is taken into account as input data in accordance with the modification of the method between the actual value of the indicator and the established threshold. To establish threshold values, the authors relied on the work of domestic researchers [14-17].

Table 1. Scorecard for assessing the innovative sustainability of a region based on DEA technology (compiled by the authors).

Input Oriented Metrics		
Indicator	Threshold value	Comments
The share of internal research and development costs in the volume of GRP, %	Not less than 3	DEA Specific Threshold Adjustment
The number of personnel engaged in research and development in the total number of employees in the region, %	Not fewer than 5	-
The share of organizations implementing technological innovations in the total number of regional organizations surveyed, %	Not fewer than 35	DEA Specific Threshold Adjustment
Output Oriented metrics		
The volume of innovative products, works, services in the total share of goods shipped in the region, %	Not less than 15	-

Based on the system of indicators proposed in table 1 and the use of DEA technology, the corresponding calculations were made. As a result, the regions of the resource type were ranked by the level of innovative sustainability in 2010 and in 2016 (table 2).

Table 2. Assessment of the level of innovative sustainability of resource type regions based on DEA technology, output model (calculated by the authors according to Russian statistics).

Region	2010		2016	
	Value	Rank	Value	Rank
Hanty-Mansijskij_AO	0.0578261	13	0.020408	15
Yamalo-Neneckij_AO	0.0870736	11	0.005102	17
Sahalinskaya_oblast	6.41E-10	18	5.10E-10	18
Respublika Saha (Yakutiya)	0.067944	12	0.193878	10
Kemerovskaya_oblast	0.035467	14	0.107143	12
Respublika_Komi	0.205357	7	0.117347	11
Orenburgskaya_oblast	0.169944	9	0.204082	9
Krasnoyarskij_kraj	0.0348007	15	0.232943	8
Tomskaya_oblast	0.254381	6	1	3
Irkutskaya_oblast	0.0344998	16	0.066327	14
Respublika_Tatarstan	1	1	1	1
Astrahanskaya_oblast	0.201259	8	0.295918	7
Permskij_kraj	0.963365	4	1	1
Udmurtskaya_Respublika	0.256024	5	0.831633	5
Samarskaya_oblast	1	3	0.994891	4
Magadanskaya_oblast	1	1	0.015648	16
Murmanskaya_oblast	0.0303486	17	0.076531	13
Belgorodskaya_oblast	0.166737	10	0.372449	6

Based on the calculation results presented in accordance with table 2, we can conclude that the effectiveness of innovative development (in this case, innovative sustainability) demonstrates only one region - the Republic of Tatarstan. In this regard, this region serves as a benchmark for other regions both in 2010 and in 2016. In general, this is due to the high value of the indicator of the share of innovative products in the total volume of goods (works, services) in comparison with other entities. So, for example, the Sakhalin region demonstrates the almost absence of this indicator. Consequently, it can be assumed that there are significant structural differences between regions.

For the period from 2010 to 2016, a significant increase in positions in the ranking was demonstrated by Krasnoyarsk Territory (+7 points), Belgorod and Murmansk Regions (+4 points), Tomsk Region (+3 points), Perm Territory (+3 points) . The Republic of Udmurtia draws attention, which, with constant rating positions, demonstrates the maximum growth in terms of the value of the efficiency indicator. The regions showing a significant decrease in efficiency include the Yamalo-Nenets Autonomous Okrug (-6 points), the Komi Republic (-4 points). The bipolar evaluation results for the subject of Magadan Oblast are caused by incorrectly presented information in official statistical sources.

In general, we can say that innovative development in resource-type regions is at an average level, while there is a high structural heterogeneity among subjects. As an advantage of using DEA technology, it is worth noting the possibility of making managerial decisions based on the calculation results in terms of achieving certain values of indicators for inefficient (in this case, innovatively unstable) regions.

4. Conclusion

According to the authors, it is advisable to recommend the use of DEA technology to assess the level of innovative development of regions from a position of sustainability. The assessment results can be used to build a special rating system for the constituent entities of the Russian Federation according to the level of their innovative sustainability. The system of assessment indicators can be adjusted (both from the point of view of their qualitative component and from the position of quantitative composition), based on the goals of the strategic development of the regions and the technical capabilities of DEA technology. In addition, DEA technology makes it possible to formulate specific assessments of the desired changes in inputs/outputs that would allow inefficient regions to be brought to the so-called efficiency margin (the term “inefficient”, as noted above, in this case will mean innovatively unstable, less favorable situation in terms of sustainable innovation development).

On the other hand, the problem of using this method may lie in the fact that statistics can be overstated and differ from the real situation in the region. In this regard, some conclusions may possibly be incorrect due to incorrect initial information on the indicators.

Therefore, it is advisable to use DEA technology in conjunction with other assessment methods. The combination of various methods (indicative, normalized values method, integral), allows to ensure the adequacy of the assessment system. As a result, the analysis of the assessment results becomes the basis for their use by regional government bodies to monitor the state of the innovation sphere in the region, as well as to adjust the current tools of the implemented innovation policy.

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