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The Role of Higher Education in Regional Development

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Abstract. Innovation is an indispensable element in any sphere of social life, offering new vision on the primary challenges in global and Russian development, particularly at the regional level. Numerous studies acknowledge the significant role of the regional innovation system as a crucial point of development of regional potential. Therefore, this study aimed to estimate the core role of universities in fostering innovative regional systems and establishing the link between universities and regional innovation. The correlation was identified by building a model, using the Data Envelopment Analysis (DEA). The results showed that the regions with the most active universities-driven innovation include the Moscow region, the Arkhangelsk region, St. Petersburg, the Republic of Mordovia, the Republic of Tatarstan, the Perm region, the Amur region, and the Magadan region.

Keywords: Innovation; Influence; Region; Socioeconomic development; Universities

1. Introduction

The development of innovative economy is currently a primary focus for the Russian regions (Karpenko, 2011). At the core of this development lies the transfer and management of knowledge, which is a significant task within university activity (Borovkov *et al.*, 2020). An exploration of the effectiveness of higher educational institutions has showed a growing interest in this subject within the Russian Federation, specifically during the 1990s (Grebenyuk, 2012). To address efficiency concerns, it is essential to investigate various social and economic factors (Alamah, AlSoussy, and Fakih, 2023; Nauffal, 2019; Rivchun, 2010) (Figure 1).

In this study, a nonparametric method for measuring relative efficiency was proposed for achieving the objectives (Hanid *et al.*, 2019), (Banker, Charnes, and Cooper, 1984). Through the application of the Data Envelopment Analysis (DEA) method (Rabar, Rabar, and Pavletic, 2022; Glukhov, Gorin, and Raskovalov, 2020), the significance of the dependent and independent variables used to determine the adequacy of the model was verified. Additionally, the Structural Equation Modelling (SEM) method was used to validate the model, and a "path" diagram was conducted to identify the most significant independent variables from the general list selected, according to the timetable and data set. The novelty incorporated a specific number of variables, yielding results that are both adequate and closely in line with reality (Farrell, 1957). These simulations can guide the fostering of more effective interaction between universities and the regional innovation

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system, as well as the formation of a more optimal strategic development model for innovative activity (Zabala-Iturriagagoitia *et al.,* 2007).

2. Experimental Methods

For the study, a nonparametric method was selected to measure relative efficiency, with a focus on the DEA method which provided more information about the effect of local universities on the local economy.

Initial data were collected from statistical reports on regional activities in the field of higher education. All data were then standardized and checked for normal deviation; those data that significantly exceeded the limits were excluded. The results were then incorporated into a DEA model.

The method comprises of constructing an efficiency boundary and analyzing the positioning of the studied objects(Rudskaya and Rodionov, 2017). When the point of the object lies on the efficiency boundary, then the functioning is considered effective. Using the DEA method, regions with high innovative results relative to resource limitations were identified and considered effective (Liu and Wang, 2019).

In the model, each object was referred to as a Decision-Making Unit (DMU) for transforming resources into outputs (Ellis, Christofides, and Panagiotis, 2015) (see Equation 1). Therefore, the aim is to determine a benchmark position of the region that optimally combines the effectiveness of the innovation system and regional resources (Rudskaya, 2017) (see Equation 2).

2.1. Size of Dataset

The model aims to maximize the ratio of "results" to "resources." Initially, the traditional model invented by Cooper and Rhodes (Cooper, Seiford, and Tone, 2007), was adopted to estimate constant returns to scale (Lee, Lee, and Kim, 2009).

In this model, the combination of values such as (x; y) and (tx; ty) is also allowed. The obtained efficiency factors include wide combinations of resource and output indicators with any non-negative coefficients. Consequently, the result can be equated to global technical efficiency indicators (Ji and Lee, 2010).

A composite indicator is derived from a set of resources (xi) and achieved results (yr) using ratios:

$$\begin{gathered} Input = v_1 x_{1o} + \cdots . + v_m X_{m_0} \\ Output = u_1 y_{1o} + \cdots . + u_s y_{s_0} \end{gathered} \tag{1}$$

where vi, i=[1, m]; ur, r=[1, s] – are the weights of each resource and the achieved result in the general indicator. The weights were not predefined, but were determined using linear programming in such a way as to maximize the ratio:

$$\frac{Output}{Input} \tag{2}$$

The weights were varied according to a version of DMU and actual data, where each unit had its own optimal set (see Equation 3). For each DMUj, vectors of resources and results with unique weights were obtained. The following shows the resource and result matrices:

$$X = \begin{pmatrix} X_{11} & X_{12} & \dots & X_{1n} \\ X_{21} & X_{22} & \dots & X_{2n} \\ . & . & \dots & . \\ . & . & \dots & . \\ X_{m1} & X_{m2} & \dots & X_{mn} \end{pmatrix}$$

$$Y = \begin{pmatrix} Y_{11} & Y_{12} & \dots & Y_{1n} \\ Y_{21} & Y_{22} & \dots & Y_{2n} \\ . & . & \dots & . \\ . & . & \dots & . \\ Y_{s1} & Y_{s2} & \dots & Y_{sn} \end{pmatrix} \quad (3)$$

if X is a matrix of size (×), Y-matrix (×).

The efficiency of each DMU is estimated and optimized, while, optimization problems are solved for the dimension of the matrices outlined in formula (see Equation 2). The estimated DMUj in each trial was denoted as DMUo (o = 1, 2, ..., n). To determine the optimal values of the resource weights (vi) (i = 1, ..., m) and the results (ur) (r = 1, ..., s), a linear fractional programming problem was solved:

$$(FP_0) \qquad \theta = \frac{u_1\, y_{10+}\, u_2\, y_{20\, ...} + u_s\, y_{s0}}{v_1\, x_{10+}\, v_2\, x_{20\, ...} + v_m\, y_{m0}} \to max, \quad (4)$$

$$\text{with} \quad \frac{u_1\, y_{1j} + \dots + u_s\, y_{sj}}{v_1\, x_{1j} + \dots + v_m\, x_{mj}} \geq 1 \;\; (j = 1, \dots, n), \quad (5)$$

$$v_1, v_2, \dots \dots v_m \geq 0 \quad (6)$$

$$u_1, u_2, \dots \dots u_s \geq 0 \quad (7)$$

The limits in the following model control the ratio of "results" to "resources" ensuring a value not exceeding 1 (with the ratio = 1, DMU can be named technically efficient) (Putri *et al.,* 2016). Therefore, the largest optimal value of θ* is 1(see Equation 4). A primary constraint of the model asserts that outputs and inputs are non-negative, showing the presence of some non-zero value(see Equations 5-7). While the limit may diverge from reality, it is removed when using more advanced models of data envelopment analysis (Wahid, and Ahmad, 2015).

2.2. Indicators as basic for the model

The deep description of fractional-linear programming is replaced by a linear programming problem in this part of the analysis (Liu *et al.,* 2010). Further elucidation can be discovered in the dissertation study by Rudskaya I.A., titled "Formation and Development of Regional Innovation Systems in the Russian Economy" (Rodionov, Rudskaya, and Gorovoi, 2013). Table 1 shows indicators chosen as basic for the model (Rudskaia and Rodionov, 2018; Rodionov, Rudskaya, and Gorovoi 2013).

Table 1 Model inputs and outputs

Input (universities resources)	Output (results)
- The number of higher education institutions, their branches, the number of students enrolled in undergraduate, graduate, and specialty programs, and the release of bachelors, specialists, and masters - indicators characterizing the potential capacity of educational institutions in the region.	Gross regional product per capita
- The number of research analysts by region	The innovative activity of organizations
- The number of teachers for undergraduate, graduate, and specialist programs. Teachers are a conduit for the transfer of knowledge.	The number of innovative goods, works, and services represents the innovative productivity of the region's economy.
- The value of expenditures on R&D. The indicator shows the availability of investments in R&D.	The amount of issued patents shows the efficiency of innovation processes in the region's economy.
	The niche of education in the sectoral structure of the GRP.

According to the explored input and output data, the model test coefficients were assigned the following designations given in Table 2 (Rudskaia and Rodionov, 2018; Rodionov, Rudskaya, and Gorovoi, 2013).

Table 2 Input and output coefficients of the model

Input (2011)	Output (2018)
- Amount of higher educational institutions, nHEI, units.	Gross regional product per capita, grp, million rubles
- Amount of branches of higher educational institutions, nbHEI, units.	Innovative activities of organizations, innact, share %
- Number of teachers for bachelor's, master's, and specialist's programs, nteach, units	The volume of innovative products and services, volinn, million rubles
- Quantity of students enrolled in bachelor's, master's, and specialist's programs, nstu, units.	Number of issued patents, patents, share%
- Graduation of bachelor's, masters, and specialists, ngrad, units.	The niche of education in the sectoral structure of GRP, educ, share %
- Amount of research analysts with a degree by region, study, and units.	
- Study and development expenditures, million rubles	

3. Results and Discussion

3.1. System Performance Benchmark

The result of a comprehensive assessment of the innovation environment showed that most regions were not technically effective in evaluating the consistent creation and commercialization of new knowledge and technologies. The characteristics of technically efficient regions are described in Table 3 (Rudskaia and Rodionov, 2018; Rodionov, Rudskaya, and Gorovoi, 2013).

Table 3 Technically efficient regional innovative

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)

According to the chat, the blue line, which indicates overall efficiency, consistently remains below the red and green lines, representing effectiveness at stages 1 and 2. The result of the first stage serves as a resource for the second stage and operates as intermediate indicators (Mayo, Shoghli, and Morgan, 2020; Xi, Li, and Lin, 2013). An effective model aims to minimize the resources of the intermediate stage, thereby achieving minimal resource investment at the initial stage system (Gozali *et al.*, 2020).

The graph shows that the vast majority of regions were not technically efficient in developing innovation processes concerning the creation and commercialization of new knowledge and technologies (Figure 1 and 2).

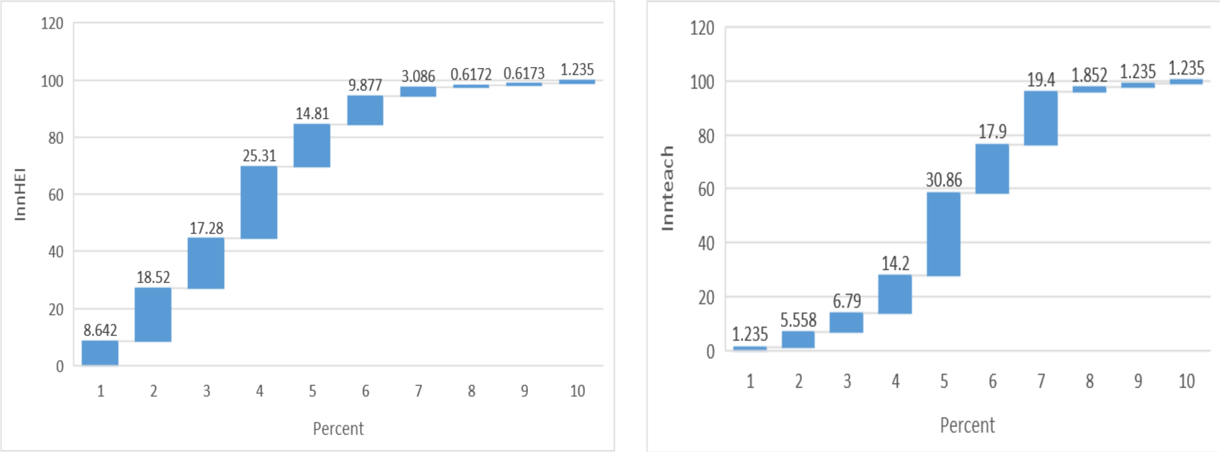

Figure 1 Histograms for independent variables after logarithmization, adapted from (Velichenkova and Rodionov, 2020; Velichenkova, 2020)

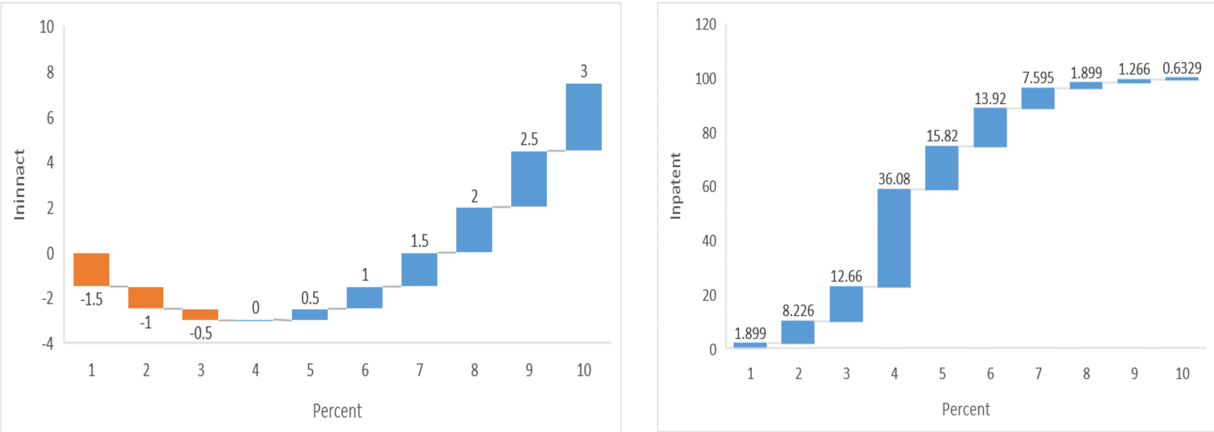

Figure 2 Histograms for dependent variables after logarithmization, adapted from (Velichenkova and Rodionov, 2020; Velichenkova, 2020)

3.1.1. Regional innovation rating result

Based on the analysis of the histograms, the visualizations of the results are slightly shifted to the left, showing a left-sided asymmetry. The solid orange line in the graph is plotted using a normal distribution function. An abnormal distribution was observed in the variable "lnnHEI," attributed to the uneven distribution of universities across the country, Regions, such as Moscow, St. Petersburg, and Kazan, had a higher number of universities. Similarly, the variable "lnpatent" also falls outside the normal distribution, suggesting significant variations in patent grants across different regions.

This disparity in innovative effectiveness across regions can be attributed to various factors. The absence of universities, small innovative enterprises, the lack of a state program supporting innovation, or a predominantly over-65 population, which is typical for certain constituent entities of the Russian Federation, all contribute to this variation.

Prominent regions with significant innovative performance include The Lipetsk Region, The Tula Region, The Republic of Mordovia, The Udmurtian Republic, The Yamalo-Nenets Autonomous District, and The Tyumen Region. However, an exception to this trend is the "weak" Chukotka Autonomous Region. The weakness is attributed to the limited availability of innovative tools, suggesting that marginal improvement can enhance the overall innovative system and effectiveness.

The aim is to provide a brief overview of another study opinion. Regions with the highest investment in innovation may not always use their potential effectively (Sergeev, Marikhina, and Velichenkova, 2017). This disparity in innovative effectiveness across regions can be attributed to various factors (International Monetary Fund, 2023). The absence of universities, small innovative enterprises, the lack of a state program supporting innovation, or a predominantly over-65 population, which is typical for certain constituent entities of the Russian Federation, all contribute to this variation (Panasenko, 2018).

Prominent regions exhibiting notable innovative performance include the Lipetsk Region, the Tula Region, the Republic of Mordovia, the Udmurtian Republic, the Yamalo-Nenets Autonomous District, and the Tyumen Region. However, an exception to this trend is found in the Chukotka Autonomous Region, which is considered "weak" in terms of innovation. This weakness is primarily attributed to the limited availability of innovative tools, indicating that a marginal improvement in this aspect could significantly enhance the overall innovative system and effectiveness (Rodionov and Velichenkova, 2020).

It's noteworthy that regions with the highest investment in innovation may not always utilize their potential effectively (Bogdanova and Karlik, 2020) as highlighted by Sergeev, Marikhina, and Velichenkova (2017). This overview aims to provide a brief synthesis of diverse opinions in the field (Zhogova, Zaborovskaia, and Nadezhina, 2020).

Based on the final result of the study, universities were identified as an effective tool for introducing innovation. The most effective region identified include the Moscow Region, Moscow, the Nenets Autonomous Region, the Arkhangelsk Region, St. Petersburg, the Republic of Adygea, the Republic of Crimea, Sevastopol, the Republic of Mordovia, the Republic of Tatarstan, Perm Territory, the Yamalo-Nenets Autonomous District, Amur Region, Magadan Region, and the Chukotka Autonomous Region.

For regions with unconsidered effectiveness, the following explanations (*) were provided. The Republic of Crimea and Sevastopol were not taken into account, since they were not part of the Russian Federation at the beginning of the analysis in 2011. Furthermore, the Republic of Adygea, the Yamalo-Nenets Autonomous Okrug, and the Chukotka Autonomous Okrug lack universities or branches, which serve as key resources for regional innovative development in Russia, thereby necessitating their removal from the sample.

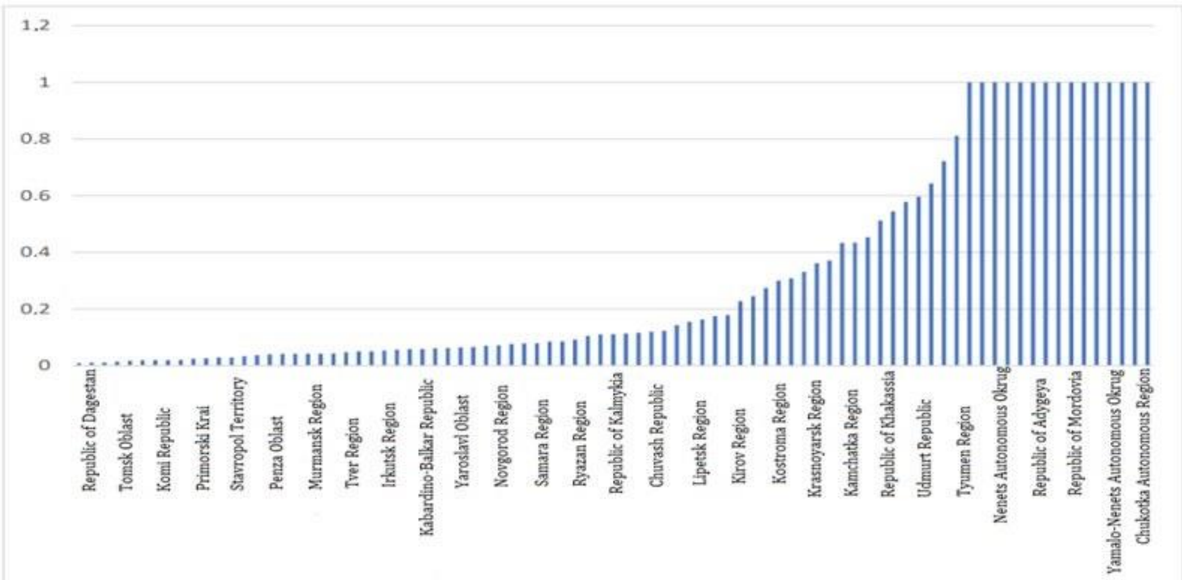

Figure 3 The remoteness of Russian regions from the efficiency frontier, adapted from (Velichenkova and Rodionov, 2020; Velichenkova, 2020)

Results showed that over 40 regions are inefficient due to limited development opportunities (Figure 3). These regions have low rates for graduates and scientists with a degree, as well as indicators such as insufficient funding and a low number of registered patents

A paradox arises when considering regions like the Mari El Republic which was considered depressed in 2018. This area is positioned close to the efficiency frontier, boasting a value of approximately 0.5. It is important to note that there are branches of universities from the leading regions, which have a positive impact on the acceleration of innovative activities.

4. Conclusions

In conclusion, the analysis covered different aspects of developing an innovative environment within the region. Firstly, it evaluated the technical efficiency of the resource base in promoting innovation. Secondly, the analysis identified the effectiveness of universities as part of the regional innovation environment. Both segments of the study yielded adequate and realistic results. The only identified trend was the lack of a well-functioning system for implementing the innovation process. However, a university-based innovation process was developed, showing significant results. The number of commercially successful innovation integrated into a real sector need to be augmented. This step was essential for enhancing economic efficiency and increasing innovation activity within universities to create a significant impact on the management. It is important to note that the selected variable is not exhaustive. The study had limited access to information about special programs in universities, which also had a significant effect on several regional economies. Therefore, new information about the pandemic period and its influence on the educational sector is needed for improvement purposes.

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