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Research Article

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Abstract

In this article a methodology and tools for numerical research aimed at solving various practical problems in regional economics. The approach is based on the econometric “Triple Helix” model and leverages a custom software tool developed in Python. The software enables: generation of data arrays in Excel spreadsheets and CSV files; export of calculation results as graphical illustrations in Excel format. The numerical calculation results are used to compare the integral index of indicators across various research objects for a given year. Numerical research findings are presented for the case of Arctic regions in 2024. Based on the presented software product, the authors recommend implementing a regional information and analytical system. Such a system would enable comprehensive assessment and monitoring of the scientific and technological development of regions, covering both economic and social spheres. The study's conclusions can be used to support management choices, especially in situations where interactions between the Triple Helix model's major players – government, business, and academia – must be taken into account.

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Keywords Triple Helix theory quantitative economic-mathematical model system actors composite integral index Python implementation regional ranking assessment

Introduction

According to the theoretical “Triple Helix” model, sustainable innovative development requires networked collaboration among three key actors: science (universities and research centers); business (companies); government (publicly public authorities). The core idea is that each actor not only performs its traditional functions but also partially assumes the roles of the others, thereby generating synergy effects.

According to the “Triple Helix” model, sustainable innovative development requires ensuring close and balanced interaction among three key forces: universities (science and education), business, and government. The model emphasizes synergy rather than the dominance of any single actor: participants complement each other, and breakthrough solutions emerge at the intersection of their activities. For instance: universities not only generate knowledge but also engage in its commercialization; businesses do not merely adopt technologies but actively participate in joint research projects; the government creates a supportive environment rather than merely exercising regulation [1–3].

The “Triple Helix” (TH) model has become a widely studied concept in global academia. Research by both international and Russian authors has covered its foundational theory as well as successful applications at multiple levels – from local territories to national economic systems. A thorough review of the existing literature is available in the author’s monograph [4]. The Russian scientific community has increasingly focused on regional aspects of the TH model in recent years. Research examines how the three key actors interact at the regional level and contribute to innovation system development across federal subjects. Priority topics include: defining roles and responsibilities; aligning innovation strategies; establishing commercialization infrastructure for scientific results [see, for instance, 5–11].

Notably, despite the Triple Helix's theoretical development model concept, there is currently no established system of practical tools enabling quantitative assessment of the level of innovative development – either for regions as a whole or for their sectoral segments – except for the developed simulation model of actor interaction [12, 13]. This fact significantly limits the possibilities for objective analysis of the effectiveness of interaction among key actors (government, business and science) within regional innovation systems. In this context, the author of the article has developed an econometric model of interaction between science, business, and government. Numerical research on a range of applied issues in the field of regional innovation economy is made possible by the model [4, 14].

Model and methodology

Econometric models are used to mathematically describe relationships between economic variables, particularly in correlation and regression analysis as well as for predictive modeling in economics. The functional dependence of an integral index on three parameters through their normalized values and weights can be described using a variety of formulas for various activities and data kinds. For example, an additive (weighted sum) model takes the following form:

$$I = \beta_1 z_1 + \beta_2 z_2 + \beta_3 z_3 \quad (1)$$

where:

I – integral index;

z_i – normalized parameter values;

β_i – parameter weights ($\sum \beta_i = 1$; $\beta_i \geq 0$).

Formula (1) is frequently employed for index-based assessments of quality of life and regional rankings, among other applications. To calculate the normalized values z_i , the min-max normalization method is typically applied to each parameter x_i , scaling the data to the range [0; 1]:

$$Z_i = \frac{x_i - x_{i,min}}{x_{i,max} - x_{i,min}} \quad (2)$$

where the variables in the formula are defined as follows:

x_i – the current data value;

$x_{i,min}, x_{i,max}$ – the minimum and the maximum value in the dataset.

In light of the above, this paper presents the author's economic-mathematical model of the Triple Helix (EMM TH) (Fig. 1), which serves as a highly convenient modern tool for addressing various applied problems in the field of regional economics.

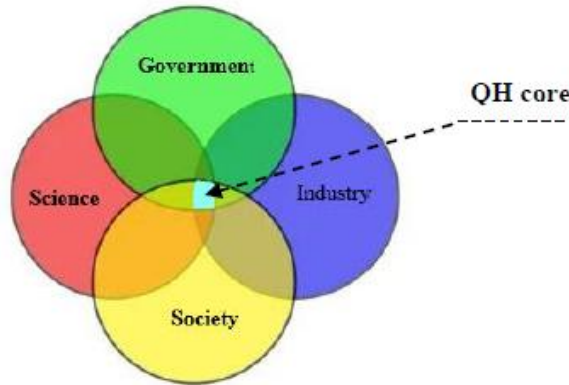


Fig. 1 The Quadruple Helix structural model describes how actors interact during the innovation process. *Source:* Compiled by the authors [4, 14]

The concentration and optimal utilization of resources from all actors within the EMM TH model, in the zone where their spheres of activity intersect, leads to the emergence of a synergistic effect, which is clearly illustrated in the accompanying figure. It should be noted that the subject of research under this model can be virtually any socio-economic entity: a country, a region, an economic sector, or a specific segment of the social sphere.

In accordance with the presented model illustration (Fig. 1) and Formula (1), the calculation of the composite integral index value (I_j) is performed based on the formula for determining the length of a radius vector through three spatial coordinates. In geometric interpretation, this is equivalent to determining the diagonal of a rectangular parallelepiped by taking the square root of its total squares:

$$I_j = \sqrt{(\beta_1 I_{jA})^2 + (\beta_2 I_{jB})^2 + (\beta_3 I_{jC})^2} \quad (3)$$

where:

I_{jA} – the indicator of scientific and educational potential of the j -th research object;

I_{jB} – the measure of the company's technological and scientific potential for the j -th research item;

I_{jC} – the indicator of state support for the j -th research object;

β_i – the weight coefficients of the actors, calculated according to the formula:

$$\beta_i = \sum_{i=1}^3 \frac{n_i}{N} \quad (4)$$

where n_i – the number of statistical indicators for the corresponding i -th actor; N – the total number of indicators for the three actors (I_{jA} , I_{jB} , I_{jC}).

The contribution share of each actor (A, B, C) to the overall integral index of the research object is estimated by the ratio (in percent):

$$S_j = (I_j / I_{j(A,B,C)})^2, \quad (5)$$

where:

$$\frac{(A_j/I_j)^2}{S} + \frac{(B_j/I_j)^2}{S} + \frac{(C_j/I_j)^2}{S} = 100\%, \quad (6)$$

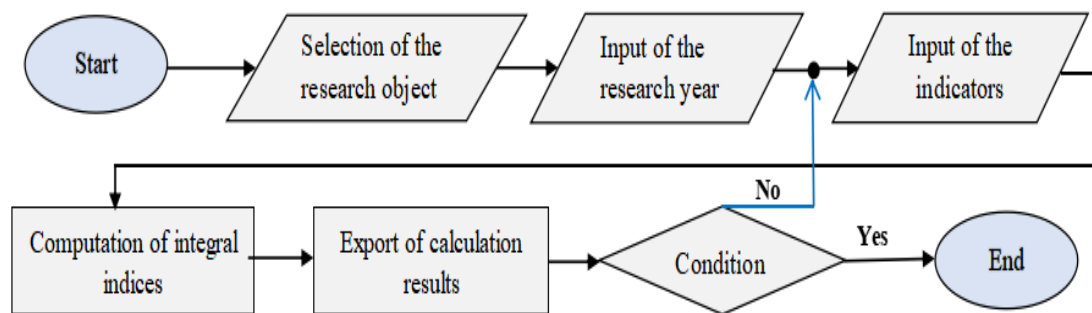
$$S = S_{jA} + S_{jB} + S_{jC} \quad (7)$$

To perform quantitative analysis and evaluate the integral index of research object indicators based on the EMM TH, a dedicated software tool has been developed in the Python programming language [15]. The outcomes of numerical calculations serve as the basis for comparative analysis

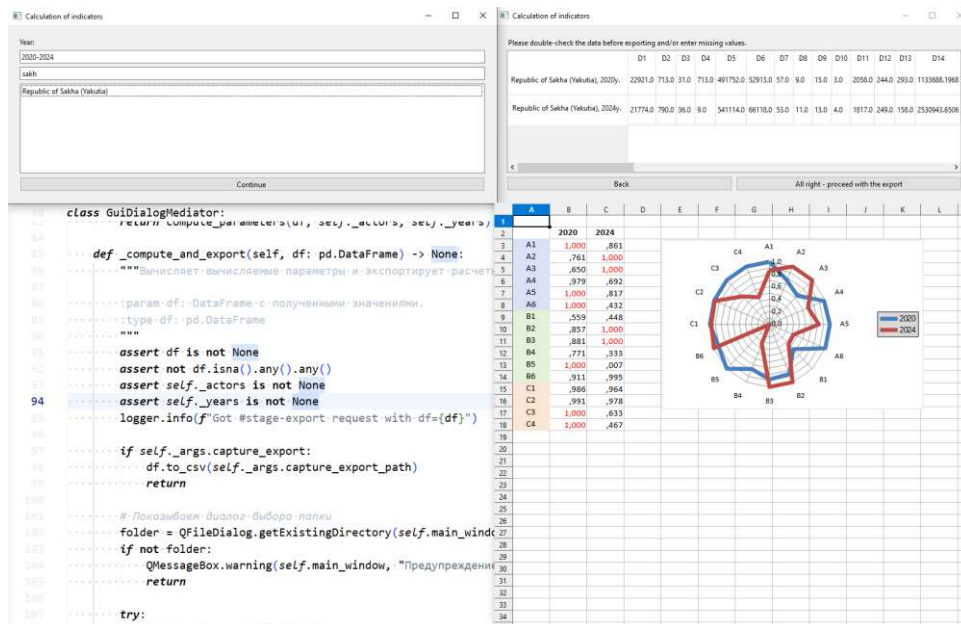
of integral indices across various research objects during a defined time period. The developed software solution offers the following functionalities:

- generation of structured data arrays;
- saving data in standard tabular formats (MS Excel spreadsheets and CSV files);
- direct export of calculation results into MS Excel workbooks for further processing and visualization.

The flowchart of the computational algorithm and a screenshot of the user window with program fragments are shown in Fig. 2. In this figure, the blue arrow is used in the course of simulation modelling of scenarios involving changes in the indicators of the research object.



a)



b)

Fig. 2 The flowchart of the computational algorithm (a) and a screenshot of the user window with program fragments (b) for the Triple Helix econometric model

The “Indicator Input” block facilitates the input of statistical data and the development of an indicator system aligned with the actors of the Triple Helix model. The functionality of this subroutine includes the following operation:

- building a database of statistical indicators based on data retrieved from web addresses, with storage in the internal format;
- normalizing the obtained indicators to a unified scaled form;
- exporting the indicator database from the system’s internal format to Excel and CSV files.

Results

Figure 3a presents a ranking of composite integral indices I_j (see Formula 3) as an illustration of the practical application of the developed methodology and research tools. Based on statistical data from Rosstat and other official sources, the indices were computed to evaluate the degree of scientific and inventive development of the component entities of Russia's Arctic regions. In total, 21 indicators were used for the analysis, characterising the key aspects of the process under study for the year 2024. The presented ranking scores make it possible to analyse the level of regional development based on a set of aggregated innovation indicators and to compare the regions with each other.

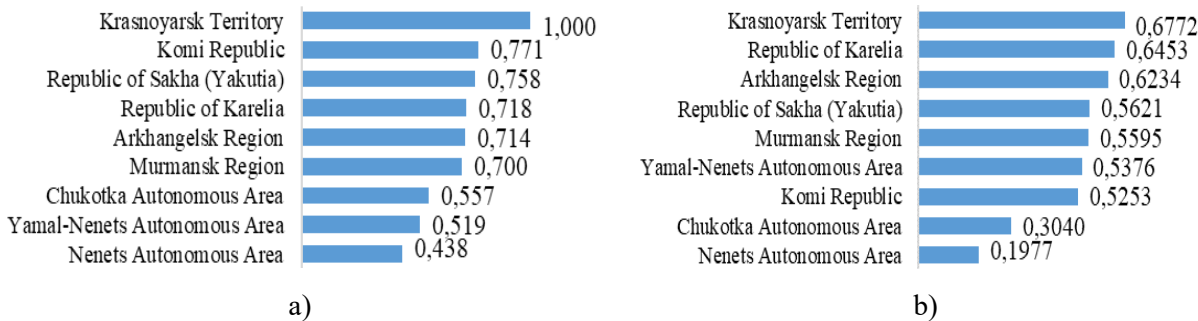


Fig. 3 Evaluation of the Arctic Zone of the Russian Federation's (AZRF) subjects on the composite integral index of scientific and innovative development:

- The author's computation using the TH model;
- Rating of the Regional Innovation Index (RII, HSE ISSEK)

In contrast, Figure 3b, which was created using the RII values, shows a ranking of the Russian Federation's constituent units according to their degree of inventive development. The calculation was performed using 55 statistical indicators available for the period 2021–2026¹.

¹ Russian Regional Innovation Scoreboard. Issue 11. Moscow: HSE ISSEK. DOI: 10.17323/978-5-7598-3119-8. <https://www.hse.ru/primarydata/rir>. 2026.

Illustrative materials of the numerical calculation results, depicting the share structure (Formula 5) and distribution of normalised actor values (Formula 2) within the Triple Helix model, are presented in the form of pie and radar charts (Fig. 4).

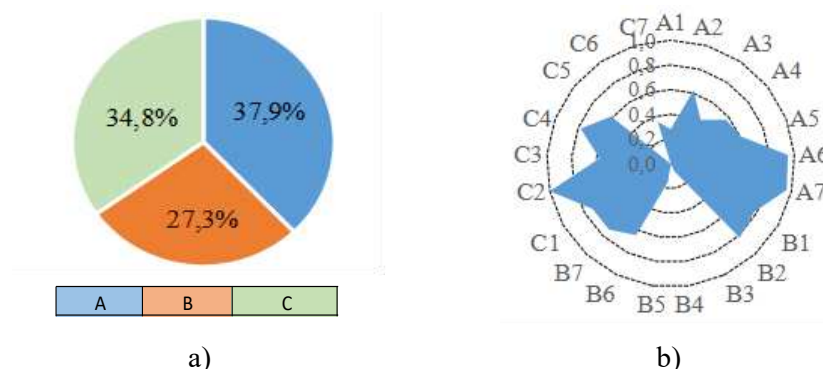


Fig. 4 Diagrams of the share structure (a) and integral indices of actors (b) within the Triple Helix model, Yakutia, 2024

Therefore, within the context of data analysis, histograms are created to evaluate each actor's contribution and graphically compare the rankings of the integral index of indicators (derived using Formula 3) in the Triple Helix model for the studied research object. This makes it possible to identify differences in the level of innovative development and to determine the key drivers of growth. The analysis of the actors' share structure within the model is performed using pie charts, which allow a visual assessment of each participant's contribution to the overall system (Fig. 4a). For a detailed analysis of the actors' characteristics, radar charts are employed (Fig. 4b). The normalised values of the actors' indicators in the TH model are structured to ensure a clear visual comparison of various aspects of scientific and innovative activities. This makes it possible to accurately identify the strengths of the subject, as well as to reveal weak links in the chain of interaction between science, business, and government.

Conclusion

Using the Triple Helix econometric model as a foundation, a methodology and tool for applied research have been proposed. These tools enable numerical calculations to address various practical problems in regional economics, using a custom-developed software solution implemented in the Python programming language. The integral values of the regional innovation development index obtained through the calculations are in good agreement with the authoritative ranking assessment by the Higher School of Economics, which demonstrates the practical applicability of the developed econometric toolkit for making management decisions that account for the interaction of key actors. The software also supports the solution of inverse problems for

situational modelling and forecasting: this is achieved by modifying the input data in the object's indicator system (Fig. 2).

The reliability of the obtained applied results is ensured using representative statistical data sourced from official open-access publications. In the area of innovation, quantitative evaluation is done using a set of indicators that has been specifically created. This system is flexible and can be adapted to specific goals and objectives in relation to various research objects. It should be emphasised that the scientific novelty of this study lies in its pioneering nature for economic theory: the study applies quantitative analysis and the Triple Helix econometric model to generate actionable solutions aimed at fostering the regional innovation economy..

The software package being described can be used to create a regional information and analysis system (RIAS) designed for comprehensive assessment and monitoring of the level of scientific and technological development (STD) of economic and social entities. The system's advanced analytical module and organized database allow for thorough quantitative research and scenario modeling. The implementation of the RIAS in regional governance practices will facilitate the creation of a unified data collection and processing system for STD. This will ensure a higher level of informational and methodological support for decision-making in science and innovation policy.

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Data Availability The current study included the compilation and analysis of a statistical dataset from Rosstat.