Information & Analytical Support of Innovation Processes Management Efficience Estimations at the Regional Level

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Summary
Innovations significantly affect the efficiency of the socio-economic systems of the regions, acting as a system-forming element of their development. Modern models of economic development also consider innovation activity, intellectual potential, knowledge as the basic factors for stimulating the economic growth of the region. The purpose of the study is to develop methodological foundations for evaluating the effectiveness of a regional innovation system based on a multidimensional analysis of its effects. To further study the effectiveness of RIS, we have used one of the methods of multidimensional statistical analysis - canonical analysis. The next approach allows adding another important requirement to the methodological provision of evaluation of the level of innovation development of industries and regions, namely – the time factor, the formalization of which is realized in autoregressive dynamic economic and mathematical models and can be used in our research. Multidimensional Statistical Analysis for RIS effectiveness estimation was used to model RIS by typological regression. Based on it, multiple regression models were built in groups of regions with low and relatively high innovation potential. To solve the methodological problem of RIS research, we can also use the approach to the system as a "box" with inputs and outputs.

Keywords:
regional innovation system, model, analysis.

1. Introduction

Innovations significantly affect the efficiency of the socio-economic systems of the regions, acting as a system-forming element of their development. According to J. Schumpeter, economic development is based not so much on the quantitative growth of production as a result of additional investment, but on the action of internal mechanisms leading to qualitative changes in the economy, accompanied by the production of new goods, the introduction of new production technologies, the development of new markets, the receipt of new sources of materials, carrying out the reorganization of industries.

Modern models of economic development also consider innovation activity, intellectual potential, knowledge as the basic factors for stimulating the economic growth of the region. In the context of the growing need to transfer regional economies to an innovative development path, the issues of ensuring and evaluating the effectiveness of innovative development are of particular importance.

Insufficient theoretical development of the issues of assessing the effectiveness of the regional innovation system (RIS), taking into account the influence of its individual elements, the need to separate the results of the infrastructure and the impact of the infrastructure component, and the lack of methodological justification for such an assessment, the role of which in the implementation of the innovation strategy is significantly increasing, determined the relevance of choosing such development tasks of appropriate information and analytical support:

- to study of the theoretical foundations of the formation of the evaluation of the effectiveness of the RIS;
- based on the analysis of innovation activity, the functioning of the RIS and the system for monitoring the innovation activity of the regions, to identify problems in the development of the RIS;
- to perform a comparative analysis of existing methods for assessing the RIS;
- to determine the requirements and develop a system of indicators of the methodology that characterize the changes in the RIS;
- to develop a methodology for assessing the

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effectiveness of the development of a regional innovation system and make proposals for its improvement.

The purpose of the study is to develop methodological foundations for evaluating the effectiveness of a regional innovation system based on a multidimensional analysis of its effects.

2. Multidimensional Statistical Analysis for RIS effectiveness estimation

To further study the effectiveness of RIS, we will use one of the methods of multidimensional statistical analysis - canonical analysis. The method is the most effective for the purposes of real research due to the fact that it allows to identify relationships between sets of variables, in our case - between the "inputs" and "outputs" of RIS. Being a generalization of multiple linear regression, this method allows you to determine in each set of variables those that affect the opposite set of indicators.

Canonical analysis makes it possible to identify and evaluate the interdependencies between the integral "input" and the integral "output", without destroying the possible latent relationships of variables in each set.

Suppose there are non-centered output variables X and Y and performed ratios of the form:

$$a = a_1 x_1 + a_2 x_2 + \ldots + a_n x_n, \quad (1)$$

$$v = b_1 y_1 + b_2 y_2 + \ldots + b_m y_m, \quad (2)$$

where $a = (a_1, \ldots, a_k),\ b = (b_1, \ldots, b_k)$,

a_i і b_j – unknown parameters, $\overline{i = 1, n}$, $\overline{j = 1, m}$.

The task of the method is to find such pairs of vectors $\{a_i, b_j\}$, that the correlation between them will be greatest and y_i will be best explained by values vj. Vectors x, y are commonly called canonical variables.

As a result of the canonical analysis we obtain a description of the relationship between the studied variables through significant weighted linear combinations of the form:

$$a_1 x_1 + a_2 x_2 + \ldots + a_n x_n \leftrightarrow b_1 y_1 + b_2 y_2 + \ldots + b_m y_m, \quad (3)$$

where ai – the canonical weight of the i-th variable of the first group ("input" set of indicators), which reflects its contribution to the linear combination of variables that are integral "output";

bk – the canonical weight of the k-th variable of the second group ("original" set of indicators), which reflects its contribution to the linear combination of variables that are integral "output";

↔ – sign means stochastic interdependence between linear combinations of variables of both sets.

To calculate the canonical correlations it is necessary to form the following block matrix:

$$R = \begin{bmatrix} R_{pp} & R_{pq} \\ R_{qp} & R_{qq} \end{bmatrix} \quad (4)$$

where R_{pp} – matrix of correlations of dimension 6 by 6 between the variables of the first group, ie "input", the elements of which are the usual coefficients of linear Pearson correlation, calculated by the formula:

$$r_{XY} = \frac{\overline{xy} - \bar{x}\,\bar{y}}{\sigma_X \sigma_Y} \quad (5)$$

$R_{pq} = R_{qp}^T$ – matrix of correlations between the variables of the first and second groups and the second and first groups, respectively;

R_{qq} – matrix of correlations between group variables ("output").

Next, you need to calculate the eigenvalues of the matrix B, which has the form:

$$B = R_{pp}^{-1} \cdot R_{pq} \cdot R_{qq}^{-1} \quad (6)$$

Moreover, the analysis requires as many eigenvalues of the matrix B as the variables contained in the group of smaller size.

In our case, the input group contains 6 variables, and the output - 4, so you need to calculate 4 eigenvalues of the matrix B.

Each eigenvalue of the matrix B is a canonical root and allows us to write the relationship between the studied lists of variables in the form of a formula.

In practice, we limit ourselves to considering only the most statistically significant canonical roots, which are rarely more than two, ie describe the relationship between the variables X and B pairs of weighted linear combinations.

In the analysis of the structure of different economic systems, traditional algorithms used in standard packages of applied statistical programs, as a rule, provide an unambiguous assignment of each object to a particular class. Such a division of the studied population corresponds to a structure with rigid boundaries. However, in cases where the studied objects differ slightly from each other in the values selected for structural modeling of features, the construction of regression models in uniquely defined strata may not meet the requirement of adequacy of reflection of real economic phenomena.

A similar situation is observed in the study of regional innovation potential: a significant number of regions are in the "border" state, each of them may have the characteristics of different strata, so it seems impractical to unambiguously attribute these objects to one of them. Therefore, in this case it is necessary to implement a fuzzy approach to the classification of regions, which is more in line with the real regional structure.

The selection of classes with vaguely delineated boundaries involves determining the function of belonging of each object to each of the selected groups.

Membership function object *i* to the group *j* can be defined as the ratio of the value of the weighted probability density of a given stratum to the total probability density for a given object:

$$mf_{ij} = \frac{q_j f_j(y_i;\theta_j)}{\sum_{j=1}^{k} q_j f_j(y_i;\theta_j)}, \quad (7)$$

where $\theta_j = (\mu_j;\sigma_j)$ – vector of probability density parameters f for j group;

q_j – the share of the *j* group in the general law of distribution.

The membership function shows that the object *i* is on $mf_{ij} \cdot 100\%$ belongs to the group *j*.

Changing the values of the membership function gives a clear idea of the dynamics of the transition of the object from one group to another. The objects that belong to this stratum to the maximum extent form the core of the group. "Border" objects are included simultaneously in two strata with weights corresponding to the values of the function of belonging to these objects, which ensures the adequacy of the model to the described phenomenon.

3. Multiplicative dynamic model for RIS effectiveness estimation

The next approach allows adding another important requirement to the methodological provision of evaluation of the level of innovation development of industries and regions, namely – the time factor, the formalization of which is realized in autoregressive dynamic economic and mathematical models and can be used in our research.

Compliance with all the requirements set to the methodological support of evaluation of innovation development of Ukrainian industry provides the following multiplicative dynamic model of J. Tinbergen's production function:

$$Q = A\, K^{\alpha}\, L^{\beta}\, e^{\gamma t}, \quad (8)$$

where Q – is the result of the production and economic activity of the evaluation object (the volume of production or sale of industrial products (goods, works, services) in physical or in cash, or income from sales);

K – factor of physical capital (cost of fixed assets or non-current assets, or aggregate assets, etc.);

L – labor factor or factor of human capital (average number of employees or annual wage fund);

parameter A – is a free member (numeric value Q, if $\alpha = \beta = \gamma = 0$);

parameter α – coefficient of elasticity of production volume under the physical capital factor (for how many % Q will increase by K growth of 1%);

parameter β – coefficient of elasticity of production volume under labor factor (or factor of human capital) (for how many % Q by L growth of 1%), with $\beta = 1 - \alpha$;

parameter γ – parameter of technological progress or coefficient of elasticity of production volume according to technological progress;

e – the Euler number (the basis of the natural logarithm);

t – factor of technological progress (serial number of the year) [15, p. 227].

A key component of the given J. Tinbergen's dynamic model of production function is the "technological progress parameter γ" which in our study will reflect the level of innovation development of industrial production at both macro and micro levels.

Thus, in the case of $\gamma > 0$, it is concluded that the innovation development of the research object corresponds to the existing technological progress, since advanced modern technologies are introduced into production, the workplaces are automated as well as logistic processes, which ultimately provides an additional increase of $+\gamma\%$ of output (or sales) of industrial products and the growing return on the scale of production.

Then the technological progress parameter $\gamma > 0$ will act as an indicator of extended intensive reproduction.

In the opposite case ($\gamma < 0$), the innovation dynamics of the research object can be considered extensive, which corresponds to a simple reproduction, since the introduced innovation technologies in production are outdated, "lagging" from the new ones, in connection with which the firm loses $-\gamma\%$ of the release (or sale) of industrial products due to the downward impact on the scale of production as a result of inconsistencies in technological progress. For further use in the simulation, let's write the formula (1) in logarithmic form:

$$\ln Q = \ln A + \alpha \ln K + (1-\alpha)\ln L + \gamma t. \quad (9)$$

Having made a number of algebraic transformations, in the form acceptable for modeling the innovation development of industrial production, we write the J. Tinbergen production function as follows [16, p. 59]:

$$\ln Q - \ln L = \ln A + \alpha(\ln K - \ln L) + \gamma t. \quad (10)$$

4. Multidimensional Statistical Analysis for RIS effectiveness estimation

This approach was used to model RIS by typological regression. Based on it, multiple regression models were built in groups of regions with low and relatively high innovation potential. Carrying out modeling in the group of leading regions (1st stratum) is impractical due to the small number of observations to obtain the proper explanatory capacity of the model. To compare the results of modeling obtained using a fuzzy decision rule with the results of traditional typological regression, these strata also built regression models based on strict classification.

The dependent variable in all cases was the logarithm of internal expenditures on research and development per capita, which is used to characterize RIS, and as regressors - the above indicators that determine the innovation potential of the region, namely:

x_1 – number of personnel engaged in research and development (per 1,000 employees);

x_2 – number of students of higher educational institutions (per 10 thousand people);

x_3 – number of small enterprises (per 10 thousand people).

The statistically significant regressors in these models include only one indicator x_1, which clearly does not provide an adequate reflection of the multifaceted economic processes involved in the formation of RIS. The rather weak explanatory power of these models was also reflected in the low values of the coefficients of determination.

When included in the considered group of observations in accordance with the values of the membership function, the model for 2019 is supplemented by an indicator x_3:

$$\hat{y}^* = \underset{(47,73)}{6,2535} + \underset{(4,71)}{0,0037}\,x_1 + \underset{(1,87)}{0,0041}\,x_3, \quad R^2 = 0,42, \quad F_{розр} = 17,2. \quad (11)$$

In the given regression equation, the coefficient for the variable is significant at the level of 1%, while the coefficient for the regressor is statistically significant at the level of $\alpha = 0,067$.

5. Inputs and Outputs Analysis for RIS effectiveness estimation

To solve the methodological problem of RIS research, you can use the approach to the system as a "box" with inputs and outputs. RIS can be attributed to the class of parameterized systems, the parameters of which are indicators of the quality of the institutional environment and regional governance.

We introduce the following group of relative indicators to assess the "inputs" of RIS:

X1 - coefficient of "localization" of science, calculated by the formula:

$$X_1 = \frac{X_{зс}(i)}{X_{зг}(R)}, \quad (12)$$

where Xзг (i) is the ratio of the number of researchers in the region to the number of economically active population in the i-th region;

X2 – share of persons with higher professional education in the employed population;

X3 – net financial result of organizations per 1 thousand people. population;

X4 - the amount of investment in fixed capital per capita in the region, divided by the maximum amount of investment in fixed capital per capita in all regions (ranking of the region by volume of investment per capita) plus the volume of foreign investment per capita in the region, divided on the maximum volume of foreign investment in all regions (rating of the region on the volume of foreign investment per capita).

In formulaic form, this indicator - an integrated indicator of investment activity within the RIS - can be expressed as follows:

$$X_4 = \frac{\frac{V_t^{inv}}{P_t}}{\max_i\left(\frac{V_t^{inv}}{P_t}\right)}, \quad (13)$$

where Viinv - the amount of investment in fixed assets in the i-th region;

Pi - population in the region and.

X5 – internal costs of research and development for the number of researchers (call this indicator the financial security of research).

X6 – the ratio of loans and other funds placed in gr. units and currency (for credit institutions and branches located in the region) provided to non-financial organizations, to the number of employees in the region's economy. Let's call this indicator an indicator of credit security RIS.

The introduction of indicator X6 in the group of "input" indicators of RIS is due to the fact that for research purposes it is necessary to assess not only the potential research resources available in RIS, but also the resource of commercialization of innovation and modernization of the economy on an innovative basis.

To assess the "outputs" of RIS we will use the following group of relative indicators:

Y1 – the ratio of the number of patents for inventions and utility models to the total number of personnel conducting research and development;

Y2 – the ratio of the number of advanced technologies created to the total number of research staff.

It is easy to see that these indicators reflect the productivity of research work if the result is considered to be the creation of industrial property. However, we also need to consider commercialization as one of the "outputs" produced by RIS.

As a result of the above, we will make the following relative indicators in the resulting group:

Y3 – share of innovative products (goods, works, services) in total products;

Y4 – the ratio of funds received from the export of technologies and services of a technical nature, to the total number of personnel employed in research and development.

In addition, it is advisable to include in the initial indicators of RIS an indicator that reflects the state of affairs in the field of export and import of technologies and services of a technical nature:

Y5 – payment of funds for technology imports (thousand UAH per year).

The groups of "input" and "output" indicators compiled in this way allow to obtain a fairly complete picture of innovation processes in the region.

Due to the fact that the amount of required calculations is quite large, we will use the STATISTICA application package to calculate canonical roots and canonical weights. We use the Canonical Analytics module to calculate the canonical correlation between the studied lists of variables - "inputs" and "outputs" of RIS.

6. Multidimensional Statistical Analysis for RIS effectiveness estimation

In order to analyze the impact of the innovation policy on steel development in the context of the problems of this research, we should first look at the impact of the TsSR 9 on the other side. Analysis of scientific and methodological approaches to the analysis of the interrelationship between the SDG and these factors, giving the possibility to see such groups:

1) hierarchical approach, for example, Folke et al. (2016) [17], to show the trivi- merous diagram of concentric balls, as it shows that the economy and the economy should be considered as if a part of the biosphere has been awakened;

2) come, that convey the vision of the providing (key) factor, for example, Rockström and Sukhdev (2016) [18] confirm that all the SDG are without intermediary) that zero hunger (SDG 2) will require gender equality (SDG 5), jobs (SDG 8) and a change in inequality (SDG 10);

3) cluster approaches, for example, at the boundaries of the global next initiative "The World in 2050" (2018 [19], 2020 [20]) it is shown the boundaries that signify the reach of the SDG with five mutual clusters of the CSR (socio-economic development (SDG 8, 9, 11), universal values (SDG 4, 5, 10), global factors (CSR 13, 14, 15), steel resource recovery (CSR 6, 7, 12) and basic human consumption (SDG 1, 2, 3)); B. Fu (Fu) et al. (2019) [21]. the need for surviving people (SDG 2, 6, 7, 14 and 15), maximizing the number of people (SDG 1, 3, 4, 5, 8, 10 and 16); for the fulfillment of the most important needs, the natural sciences and technologies, which are also necessary for the achievement of the maximum goals, are necessary.

4) visualization of variations in interdependence for the help of lace diagrams.

Le Blanc (2015) [22] carried out a textual analysis of 107 subdivisions of the SDG to identify links between them. Acts of the SDG may be richer than sv'yazkiv, lower: for example, SDG 12 has linkages with 14 other SDG, even as CSR 14 appears to appear more than two others. Based solely on the basis of textual analysis, the diagram does not cover any less clear aspects of the CSS.

The second idea, which transfers the selection of tie-diagrams for SDG analysis, is known from the researcher Mohr. For a proponated approach, an analysis of treadmill indications is carried out in order to determine if the numbers can be more pleasurable, with the help of such indicators:

1) steps (Degree) – showing the number of steps, which is set by the SDG is linked with other SDG;

2) mutuality (Betweenness) - showing the number of times, if the SDG is on the shortest path between two other SDG;

3) power vector (Eigenvector) – showing how the SDG goes with others.

More accurately, the role of SDG 9 is shown by the experimental MICMAC metric, as we hope to be able to look at the level of the injection (the step by which the increase of the other factors affects the target) and the injection (the stage by which the factors decrease by the coefficient) on the Skin Element).

It is important that such a policy would not be effective for encouraging innovation policy, the stench of the Oslo Manual 2018 [24] is one hundred percent of the fact that the solution for the development of innovative systems and the promotion of their productivity in the industrial sector is being developed.

D. Zelinka and B. Amadeus [25] researched the idea of an Interlinkages Hub for the analysis of interlinkages between the SDG. Skin SDG module may have an equivalent correlation coefficient with values that are unique to skin SDG. Combining all the values of the coefficients of interconnection generates a matrix of cross-flow. On the thought of the scientists, important people, which is blamed in the context of the development of politics, is the identification of the hub. In our opinion, such a hub can be seen on the basis of the innovation factor (SDG No. 9, or the indicator of the innovation system).

Based on the results of the Sustainable Development Report for 3 years (2017–2019), on the basis of the Hefner coefficient, the interrelation between the innovative warehouse steel development (SDG No. 9) and the other 16 SDG was determined.

7. Conclusion

The study of the features of RIS modeling allowed to make the following conclusions.

The analysis showed that the most important task at this time is to increase the innovation potential in regions with its low level, as innovation potential is the most important factor in ensuring the competitiveness and development of the regional economy. Its solution is possible, first of all, by increasing the attractiveness of innovation in these regions, as well as the introduction of new promising production technologies, new product development and economic policy aimed at activating endogenous factors of development.

The application of mathematical methods in the regional economy has a long tradition. Many modeling approaches, such as optimization models and intersectoral balance models, have become classic to date. Econometric models are rightly considered to be the main tool of regional economic modeling today. With their help in the work the connections and formed models of interrelations of RIS indicators with various groups of factors, both for regions, and for national economy as a whole are revealed.

As a result of the system analysis of RIS development on the example of Sumy region and interrelations between elements of the system and its external environment, and also according to a technique of construction of econometric models the complex of models of forecasting of RIS development was developed.

Building a model adequate to RIS, objectively helps to identify the main trends in its development. The vague classification corresponds to the implicit division of regions into groups according to innovation potential, which provides an opportunity to implement a new approach to typological regression.

For a visual representation of RIS, its structure, main components, sequence of data processing in the system, to present its information support developed system models: structural-functional scheme (model), technological scheme, which reflects the relationship between modules and sequence of management data processing; the information model of the system is presented in the form of a logical model.

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