Conceptual Foundations of Evaluation and Forecasting of Innovative Development of Regions

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Abstract

The authors propose to assess and forecast the innovative development of regions using an improved methodological approach, which consists of substantiating statistical indicators of the innovative development, which are verified by correlation analysis (thereby avoiding autocorrelation between indicators of the innovative development of regions). Verification of the evaluation indicators makes it possible to determine the impact factors and the most influential indicators according to the integrated index of the innovative development of regions. Using the Bartlett method for modelling and making predictions makes it possible to take into consideration the impact of the most influential indicators on the values of the integral index, as well as to adjust the predicted values of the integral index. The calculated and forecasted integrated index of the innovative development of regions can be used by local authorities to develop measures that aim to intensify the innovative development of regions, taking into account the most influential factors for each region. The proposed methodological approach for estimating and forecasting the integrated index of the innovative development of regions was tested on the example of Polish voivodeships. To permit a more detailed consideration of the results obtained, three voivodeships, Kujawsko-Pomorskie, Pomeranian and Swiętokrzyskie, were studied and compared. The results showed that these voivodeships have different values on the integrated index, which can be attributed to different regions having different levels of innovation development. The most influential factors also differ for each of the regions.

Keywords

innovative develpoment, integrated index, evaluation, forecasting, region, regional economic system, sustainable development, voivodeships

1 Introduction

The challenges of today's world economy, which have coincided with market volatility as a result of unforeseen impacts, increasingly determine the relevance of forecasting the development in general – or more specifically, the innovative development – of regional systems. One of the main shortcomings of previous methodological approaches to assessing and forecasting the innovative development of regions has been their level of accuracy. Ensuring high accuracy in assessing and forecasting the innovative development of regions requires the use of diverse methods as well as combinations of them, which makes it possible to eliminate shortcomings and provide a higher degree of scientific backing for decisions that aim to increase innovation in the area of regional development. In order to improve verification of forecasts, it is necessary to evaluate the system under examination, which in our case is the innovative development of regions over an extended period of at least five years (in our case, the evaluation was conducted for ten years from 2010 to 2019). Verification of the forecast can also be enhanced by the use of special methods, such as the economic and mathematical modelling of the most influential indicators on

the generalizing parameter of the studied system, as well as the use of the Bartlett method in forecasting. This combination makes it possible to model the system's behavior and predict it using the Bartlett method, which provides:

- clarity in the results of calculations and dynamics of changes of estimation indicator, plus the dynamics of changes to the calculated and forecast indicators and indices;
- validation of the study of complex economic systems;
- identification of processes occurring in the system and clarification of their effects on its effectiveness, which helps to increase the efficiency of the system as a whole;
- practicality and the ability to change, if necessary, the estimated parameters of the system, as well as the simple application and unambiguous interpretation of the obtained results of evaluation and forecasting.

The listed advantages of this method of estimation and forecasting of the innovative development of regions offers researchers a chance to improve the verification of their results.

2 Literature review

Many scientific works of domestic and foreign scientists ardevoted to research of the innovative activity of regions, modelling, evaluation and forecasting of the basic indicators of the innovative development. The article of Popelo et al. (2021) proposes a methodical approach to assessing the effectiveness of innovative development of regional economic systems in the development of creative economy. The study of Vovk et al. (2021) simulated the choice of innovation and investment strategy for the realization of modernization potential. In accordance with the profile levers, the authors identified targets and alternative benefits of innovation and investment strategies. In the framework of the research of Tulchynska et al., (2021) the resource provision of innovation and investment strategies in the conditions of digitalization is analyzed.

The study of Firsova and Tsypin (2021) argues that the effectiveness of the spatial innovation development is a very important problem today in connection with the increased impact of innovation on economic growth. The cluster analysis and the correlation-regression method were used to assess structural changes in the innovative development of the regions of Russia.

The purpose of the study of Vertakova et al. (2020) is to study and generalize the opinions of experts representing regional authorities and business structures on the threats

to the innovative economy development. They analyzed the threats that negatively affect the innovative economy development of the regions.

The paper of Ključnikov et al., (2020) aims to explore the potential of the innovative regional development of a structurally disadvantaged industrial region focused on the mining and metallurgical industries at the expense of the local currency.

The aim of the study of Sukhovey and Golova (2020) is to produce a differentiated approach to the development of strategies for the innovative development of the regions of Russia, which allows to effectively implement innovation paradigms taking into consideration the peculiarities of the scientific and technical, innovation and production activities and technological potential of the regions.

Arinas (2020) examines the first regional laws concerning circular economy to determine whether they are simply programmatic or truly innovative. He identified several legislative options that meet the requirements of the broad concept of circular economy in different ways, demonstrating gradual consolidation of this concept as a general principle of law.

In the article of Bezrukova et al., (2016), the possibilities and prospects for improving the modelling and forecasting of the innovative development of business structures in the conditions of global competition are examined. The authors advocate using the method of fuzzy logic to increase the efficiency of this process, outline the method and its application to specific examples, and provide a rationale for opting for it in preference to other methods.

An article authored by Polish scientists aims to find out whether innovations affect the competitiveness and sustainable development of small and medium enterprises. Their study focuses on identifying the processes and changes taking place in enterprises so far as understanding the concept of the sustainable development is concerned (Malik and Jasińska-Biliczak, 2018).

Using primary data at the company level, Swedish researchers compare collaboration models for innovation in the choices of Swedish, Norwegian, Chinese, and Indian regions specializing in ICT. The results show that companies in regional innovation systems in developed economies are generally more tied to innovation networks that are truly global in character, especially in terms of global innovation (Plechero and Chaminade , 2016).

Scientists from the Czech Republic and Portugal believe that accurate forecasting of regional innovation indicators plays a key role in the implementation of policies aimed at supporting innovation, as it can be used to model the consequences of actions and strategies. Scientists have

developed a model for solving the problem of regional forecasting of innovation indicators (Hajek et al., 2019).

The development of models for forecasting the innovative development level of countries, as well as to identify the most significant factors influencing the innovative development became the basis of work undertaken by Russian researchers. The scientific novelty of their approach lies in the application of a systematic, integrated approach to the selection of factors that have statistical significance and constitute drivers of innovative development, together with the subsequent construction of econometric models and their testing (Nevezhin et al., 2019).

According to the polish author Zajkowska (2017), the reasons why significant changes are observable in approaches to innovation – which has given rise to the emergence of a new generation of models of innovation processes – are the growing pace of technological progress, intense competition, and the prevalence of volatile markets in modern society. An open innovation model is based on the constant quest for, as well as research into and the actual use of, sources of opportunities for innovation that offer commercial potential.

3 Methodical approach

Analysis of existing approaches (Bezrukova et al., 2016; Hajek et al., 2019; Revko et al., 2020; Shkarlet et al., 2020) suggests that today there is no single "correct" approach to assessing and forecasting the innovative development of regions.. Consequently, researchers need to improve their methodology and thus contribute to the development of measurement instruments and better focused efforts on the part of local authorities who wish to increase the innovative activity of their regions.

The authors of the current paper propose an algorithm for assessing and forecasting the innovative development of regions (Fig. 1).

According to the authors, forecasting of the innovative development should be carried out based on the integrated index of the innovative development of regions. The calculation of the integrated index makes it possible to eliminate possible autocorrelations between the input parameters, which are statistical estimates of the innovative development of regions. In the study, the authors use four evaluation indicators, but it should be noted that the number and composition of indicators may vary depending on the goals of forecasting. The use of matrices of pair correlations makes it possible to calculate the coefficients of influence on the integral index, as well as to remove, if any arise, linear dependences that make it impossible to calculate the matrices. In turn, the selection of the most
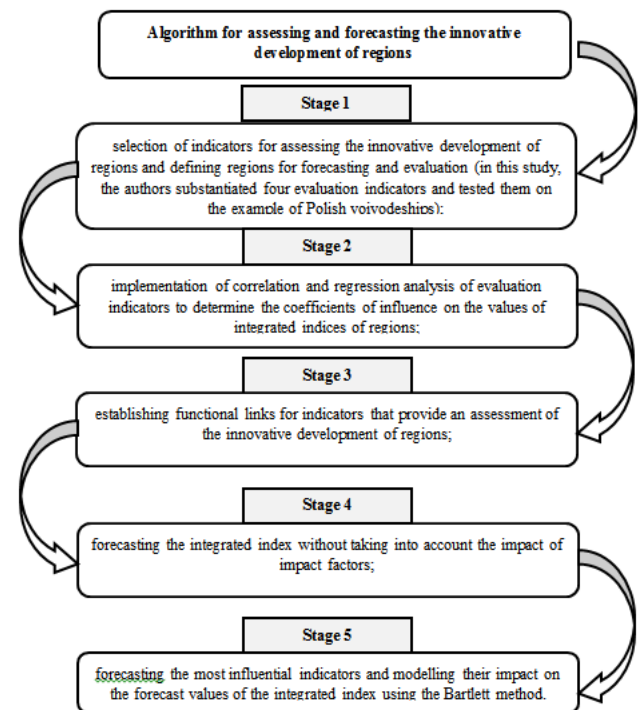

Fig. 1 Algorithm for assessing and forecasting the innovative development of regions. Source: developed by the authors

influential indicators provides more accurate calculations of forecast values and reduces errors in forecasting.

The control of input data, which are statistical data, is performed by the level of the pairwise correlation index, where $|k| \geq 0.7$. Estimates in which the correlation is less modulo than $|k|$ combine to determine the integrated index of a particular region for a given year. Thus, the integrated indices are calculated for each year.

Simulation is used in cases where there is a fairly large array of variable data, which constitute statistical indicators (in this study for the period 2010–2019). Simulation allows you to describe the system's behavior, namely the innovative development of regions, as well as to build hypotheses for modelling system behavior when certain parameters are changed (Lazarenko et al., 2020; Solosich et al., 2021). In the current study, such variable parameters may be the indicators that have the highest coefficients of influence. Consideration of variable parameters makes it possible to predict the future behavior of the system as well as to assess the changes that are possible, considering changes in certain parameters.

Estimation of the regression model makes it possible to perform regression and forecasting through the given scenarios of the system development (the innovative development of regions) and thus to model the influence of parameters (the most influential indicators found by determining the coefficients of influence) of the constructed econometric model on the integrated index.

When developing a multiple regression model, it is necessary to find out the dependences of the existence of such a model. It is not possible to construct a multiple regression model for any structure of relations between the given features $X = (x^{(1)}, x^{(2)}, \ldots x^{(p)})^T$ on the model. In other words, not all parameters that have been selected based on statistical data can really characterize a particular system by determining the impact on common factors such as $f^{(1)}, \ldots, f^{(p')}$. Alternatively, it may be necessary to prove their existence, which would explain the existing correlation between pairs of features $x^{(i)}$, $x^{(j)}$ within a given statistics v. Through formulae, this can be expressed as Eqs. (1) and (2):

$$X = Q*F + U, \tag{1}$$

or

$$x_v^{(i)} = \sum_{j=1}^{p'} f_v^{(j)} q_{ij} + u_v^{(i)}, \quad i = 1, \ldots, p; \quad v = 1, \ldots, n, \tag{2}$$

where v - the test number.

In that case, if the estimation parameters allow the construction of a multiple regression model, then the definition of the corresponding factors $F^T = (f^{(1)}, \ldots, f^{(p')})$ and coefficients of the linear transformation $Q = (q_{ij})$, which connects X and F, is unique. This, in turn, determines the transformation matrix Q and the covariance matrix $V = (v_{ij})$ of residual specific factors $u^{(1)}, \ldots, u^{(p')}$, with the result that the definition of the parameters of the multiple regression model arrived at would be unique.

In the opinion of the authors, to forecast innovation of the regions, it is advisable to use the Bartlett method, which considers separately for each fixed number of observations econometric model, as a regression of the sign X_V by arguments $\hat{q}_1, \hat{q}_2, \ldots, \hat{q}_n$.

Using the method of least squares, the calculated impact factors to minimize the function are determined as Eq. (3):

$$\sum_{i=1}^{p} \frac{1}{\sigma_{ii}} (x_v^{(i)} - \sum_{j=1}^{p'} \hat{f}_v^{(j)} \hat{q}_{ij})^2 = \min_{F_v} \sum_{i=1}^{p} \frac{1}{\sigma_{ii}} \times (x_v^{(j)} - \sum_{j=1}^{p'} f_v^{(j)} \hat{q}_{ij})^2 \tag{3}$$

Thus, we obtain regression relations (Eq. (4)):

$$\hat{F}_v = (\hat{Q}^T \hat{V}^{-1} \hat{Q})^{-1} \hat{Q}^T \hat{V}^{-1} X_v, \quad (v = 1, \ldots, n). \tag{4}$$

With a normal distribution of the values of the variables X, the calculated values of the mathematical expectations will be optimal. If quantities q_{ij} and v_{ij} are replaced, approximate values $\hat{q}_{ij}$ and $\hat{v}_{ij}$ are calculated as estimates of coefficients of influence $f^{(1)}, \ldots, f^{(p')}$.

Consequently, the relations (formulas 3–4) are used by the Bartlett method in the construction of matrices, which take the following form (Eq. (5)):

$$E \left\{ \left| \begin{array}{c} x^{(1)} \\ x^{(p)} \\ f^{(1)} \\ f^{(p')} \end{array} \right| (x^{(1)}, \ldots, x^{(p)}, f^{(1)}, \ldots f^{(p')}) \right\} = \left(\begin{array}{cc} QQ^T + V & Q \\ Q^T & I_{p'} \end{array} \right). \tag{5}$$

In the process of creating the model, mathematical and statistical formalisation of indicators that affect the integrated index of the innovative development of regions is adopted.

4 The results of forecasting and analytical evaluation

According to the results of the statistical data analysis, in Table 1 the authors present the estimated initial indicators that were selected for calculations and forecasting of the innovative development of regions on the example of Polish voivodeships.

The authors grouped the voivodeships of Poland by the average value of the integrated index of innovation activity, which is presented in Fig. 2.

The authors made calculations for all voivodeships of Poland, but in this scientific article we proposed to visualise and compare the results for three voivodeships, which gave rise to the following findings:

- firstly, there are different values of the integrated average innovation indices of the regions, namely: Pomeranian: 0.855, Kujawsko-Pomorskie: 0.506, Swiętokrzyskie: 0.321;
- secondly, the values of the average integrated index can be attributed to different groups of regions when they are grouped depending on the value of the integrated index of innovation of the regions;
- thirdly, they have different most influential parametric indicators, both for the Pomeranian voivodeship (X3 - the volume of sold innovative products in% to the total volume of sold industrial products (%)), Kujawsko-Pomorskie (X2 - the volume of sold innovative products, per 1 population (euro)), Swiętokrzyskie (X1 – the number of industrial enterprises that implemented innovations (units));

When undertaking calculations, for all voivodeships, in addition to the above indicators, the fourth indicator was also used, the amount of funding for innovation activities per capita (euro) (X4).

It can be instructive to analyse the forecasting results in more detail. In Fig. 3, a visualisation of the results of calculations of impact factors for Kujawsko-Pomorskie Voivodeship is presented. To decrease the influence on the

Table 1 Indicators for assessing the innovative development of Polish voivodeships

Indicator	Years									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Kujawsko-Pomorskie Voivodeship										
X1	331	349	329	260	295	304	345	338	458	331
X2	1943.5	835.2	973.3	1010.9	1170.7	1645.3	1048.9	1109.0	1043.1	1943.5
X3	15.93	6.76	7.60	7.75	9.09	12.62	8.50	7.66	6.9	15.93
X4	327.50	197.88	197.65	197.48	339.49	290.98	235.31	265.41	219.07	213.93
Pomorskie Voivodeship										
X1	309	313	214	315	350	315	346	376	553	309
X2	8332.9	8993.6	9585.0	4395.6	6046.7	3520.4	2298.6	2555.6	2522.8	8332.9
X3	49.76	47.80	46.85	23.57	31.76	21.01	13.50	13.30	12.2	49.76
X4	672.9	399.6	318.3	318.7	455.8	462.7	497.5	568.2	503.7	537.7
Swiętokrzyskie Voivodeship										
X1	146	138	164	165	134	123	139	178	178	146
X2	438.28	446.44	555.14	676.99	378.32	460.57	608.08	730.59	716.9	438.28
X3	6.25	6.05	6.84	8.20	4.72	5.78	6.77	6.53	5.8	6.25
X4	134.84	136.30	319.95	319.83	89.39	152.29	120.25	209.79	209.45	209.83

X1 – the number of industrial enterprises that have implemented innovations, units;
X2 – the volume of sold innovative products by industrial enterprises, per 1 economically active person, euro;
X3 – the volume of sold innovative products by industrial enterprises, in% to the total volume of sold industrial products;
X4 – the amount of funding for innovation, per 1 economically active person, euro
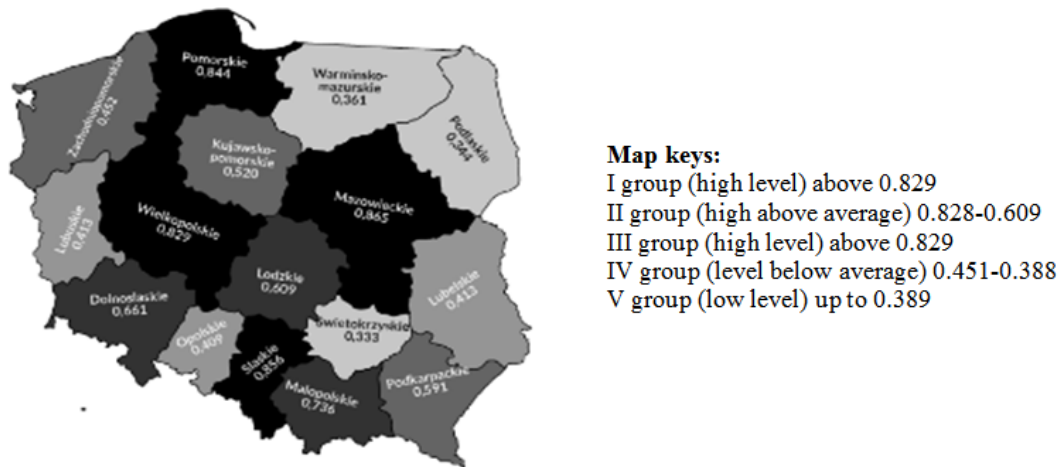Source: calculated by the authors based on statistical data

Map keys:
I group (high level) above 0.829
II group (high above average) 0.828-0.609
III group (high level) above 0.829
IV group (level below average) 0.451-0.388
V group (low level) up to 0.389

Fig. 2 Map of regional differentiation of the integrated index of innovation activity in Poland, 2019; Source: built by the authors
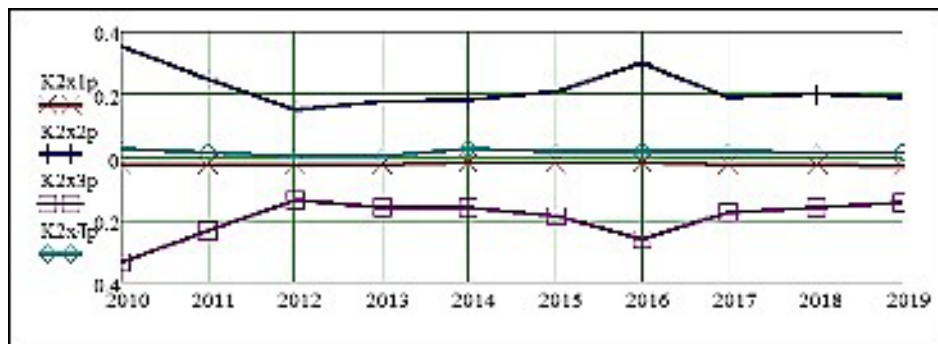

Fig. 3 Visualisation of the results of calculations of impact factors for Kujawsko-Pomorskie Voivodeship; Source: calculated by the authors

integrated index for Kujawsko-Pomorskie Voivodeship, the indicators X2, X3, X1, X4 appear, having the following coefficients of influence $K_{X2} = 0.218$; $K_{X3} = 0.196$; $K_{X1} = -0.022$; $K_{X4} = 0.015$.

In Fig. 4, the results of the calculated integrated indices for 2010–2019 and its forecast values for Kujawsko-Pomorskie Voivodeship are presented, taking into consideration the impact of the most influential indicator on the value of the integrated index. It should be noted that in general, and bearing in mind the emphasis on increasing the volume of sold innovative products, changes in the average forecast integrated index will increase the average integrated index for the forecast period by 0.015.

The average value of the calculated integrated index for 2010–2019 for Kujawsko-Pomorskie Voivodeship is 0.506, while the average value of the projected integrated index is 0.535.

The results of the calculation of impact coefficients for Pomeranian Voivodeship were on average as follows: $K_{X3} = -0.165$; $K_{X2} = 0.152$; $K_{X1} = -0.036$; $K_{X4} = 0.031$. Indicators X3, X2, X1, X4 appear in the order of decreasing influence on the integral index.

The result of the projected integrated index of innovation of the Pomorskie Voivodeship by its arithmetic mean value for 2020–2030 is 0.855. It should be noted that the arithmetic mean of the projected integrated index for the Pomeranian Voivodeship is 0.869, which is 0.014 more than the projected value of the integrated index of this voivodeship, not considering the impact of the most influential indicator.

As already mentioned, the authors selected for a more detailed assessment of the proposed methodological approach three voivodeships with different values of the integrated index and different most influential indicators. Calculations of impact factors for Swiętokrzyskie Voivodeship on average had the following values: $K_{X1} = -0.078$; $K_{X2} = 0.073$; $K_{X4} = 0.009$; $K_{X3} = -0.001$. Indicators X1, X2, X4, X3 appear in the order of decreasing influence on the integral index.

For the Swiętokrzyskie Voivodeship the difference in the average value between the integrated indices, taking into consideration the influence of the most influential indicator and without is 0.012.

Table 2 presents the calculations according to the proposed methodological approach of the values of the integrated indices selected for the analysis of the Polish voivodeships.

Table 3 presents the forecast values of the most influential indicators and integrated indices of innovative development of regions on the example of Polish voivodeships.

The forecasting of the values of the integrated indices presented in Table 3 was carried out by forecasting the indicators, on whose basis the forecasting of the integrated indices in turn took place. Thus, the proposed methodological approach to assessing and forecasting the innovative development of regions involves the use of the Bartlett method, which provides a rough approximation of the forecast indicators and through several iterations a more accurate calculation of the forecast values of the integrated index of regional innovation. It should be noted
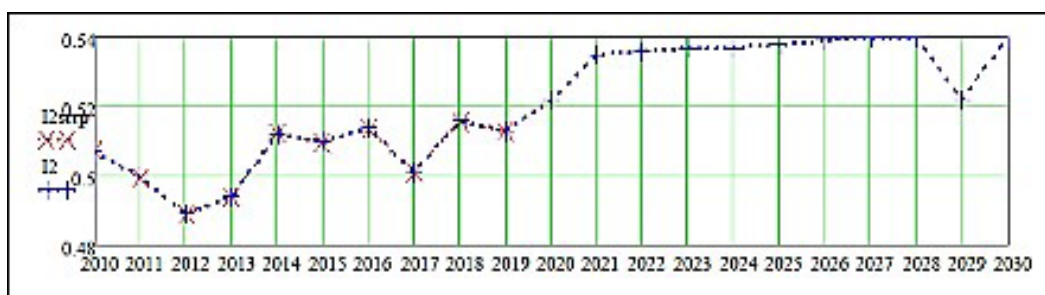

Fig. 4 Visualisation of the dynamics of the integrated index and its forecast values for Kujawsko-Pomorskie Voivodeship taking into consideration the impact of the most influential indicator (2010–2019 - retrospective period, 2020–2030 - forecast period); Source: calculated by the authors

Table 2 The values of the integrated index of innovative development of Polish voivodeships

Voivodeships	Years										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	The average value of the integral index
Kujawsko-Pomorskie	0.507	0.500	0.489	0.494	0.512	0.510	0.514	0.501	0.516	0.513	0.506
Pomorskie	0.857	0.866	0.876	0.885	0.885	0.894	0.894	0.883	0.883	0.882	0.855
Swiętokrzyskie	0.336	0.345	0.345	0.350	0.349	0.349	0.344	0.343	0.343	0.342	0.321

Source: calculated by the authors on the basis of statistical data

Table 3 The Predicted values of the most influential indicators and integrated indices of the innovative development of Polish voivodeships

Calculated and predicted values	Years										
	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Kujawsko-Pomorskie Voivodeship											
The most influential indicator X2	1125.9	1109.0	1120.3	1122.5	1124.8	1137.2	1147.3	1134.8	1137.6	1126.5	1131.9
Forecast integrated index	0.522	0.535	0.536	0.537	0.538	0.539	0.538	0.54	0.54	0.522	0.54
Pomorskie Voivodeship											
The most influential indicator X3	21.08	21.17	21.25	21.36	21.44	21.53	21.61	21.69	21.78	21.88	21.97
Forecast integrated index	0.857	0.866	0.876	0.885	0.885	0.894	0.894	0.883	0.883	0.882	0.881
Świętokrzyskie Voivodeship											
The most influential indicator X1	165	167	169	172	174	176	178	180	183	185	187
Forecast integrated index	0.336	0.345	0.345	0.350	0.349	0.349	0.344	0.343	0.343	0.342	0.330

X1 – the number of industrial enterprises that have implemented innovations, units;
X2 – the volume of sold innovative products by industrial enterprises, per 1 economically active person, euro;
X3 – the volume of sold innovative products by industrial enterprises, in% to the total volume of sold industrial products
Source: calculated by the authors based on statistical data

that all calculations were performed using Mathcad software, using built-in forecasting functions which have the calculation of built-in errors. This also has a positive effect on improving the accuracy of forecast values.

5 Conclusions

In this research, the authors proposed a new methodological approach that allows researchers to assess and predict the innovative development of regions, based on:

- firstly, the correlation analysis for processing the estimated parameters of regional innovation and isolation in the presence of autocorrelation, which allows researchers to calculate the value of the integrated index of regional innovation;
- secondly, multiple regression to calculate the coefficients of influence and determine the most influential indicators on the value of the integrated index of the innovative development of regions, as well as

the use of a tool for modelling the behaviour of the system represented by the calculated values of the integrated index;

- thirdly, the Bartlett method and simulation for forecasting. The application of the Bartlett method in forecasting the value of the integrated index allows an rough approximation of the forecast estimates, on whose basis the forecast of the integrated index takes place. As a result of the rough approximation, the initial approximation is adjusted and the forecast integral indices are recalculated.

The accuracy of the predicted values is justified by the fact that the correlation analysis of the estimated indicators excludes the possibility of functional relationships between them and makes it possible to perform reliable calculations using multiple regression.

References

Arinas, R. J. S. (2020) "Innovación normativa para la economía circular en leyes autonómica" (Regulatory innovation for the circular economy in regional laws), Revista General de Derecho Administrativo, 55, pp. 1–43. (in Spanish)

Bezrukova, T. L., Gyiazov, A. T., Bazieva, A. M. (2016) "Modelling and forecasting of innovative development of entrepreneurial structures under the global competition", Actual Problems of Economics, 182(8), pp. 344–351. [online] Available at: http://nbuv.gov.ua/UJRN/ape_2016_8_44 [Accessed: 25 April 2021]

Firsova, A. A., Tsypin, A. P. (2021) "Assessment of structural changes in the spatial innovative development of Russian regions", Journal of Physics: Conference Series, 1784(1), Article number: 012011. https://doi.org/10.1088/1742-6596/1784/1/012011

Hajek, P., Henriques, R., Castelli, M., Vanneschi, L. (2019) "Forecasting performance of regional innovation systems using semantic-based genetic programming with local search optimizer", Computers and Operations Research, 106, pp. 179–190. https://doi.org/10.1016/j.cor.2018.02.001

Ključnikov, A., Civelek, M., Krajčík, V., Ondrejmišková, I. (2020) "Innovative regional development of the structurally disadvantaged industrial region by means of the local currency", Acta Montanistica Slovaca, 25(2), pp. 224–235. https://doi.org/10.46544/AMS.v25i2.9

Lazarenko, I. S., Saloid, S. V., Tulchynska, S. O., Kyrychenko, S. O., Tulchinskiy, R. V. (2020) "Necessity of implementating data science course in economics curricula", Information Technologies and Learning Tools, 78(4), pp. 132–144. https://doi.org/10.33407/itlt.v78i4.3505

Malik, K., Jasińska-Biliczak, A. (2018) "Innovations and other processes as identifiers of contemporary trends in the sustainable development of SMEs: The case of emerging regional economies", Sustainability, 10, Article number: 1361t.
https://doi.org/10.20944/preprints201803.0260.v1

Nevezhin, V. P., Zhiglyaeva, A. V., Smirnov, V. V., Muravitskaya, N. K. (2019) "Econometric Models for Forecasting Innovative Development of the Country", Journal of Reviews on Global Economics, 8, pp. 767–775.
https://doi.org/10.6000/1929-7092.2019.08.66

Plechero, M., Chaminade, C. (2016) "The role of regional sectoral specialisation on the geography of innovation networks: a comparison between firms located in regions in developed and emerging economies", International Journal of Technological Learning, Innovation and Development, 8(2), pp. 148–171.
https://doi.org/10.1504/IJTLID.2016.077106

Popelo, O., Tulchynska, S., Garafonova, O., Kovalska, L., Khanin, S. (2021) "Methodical approach to assessing innovative development efficiency of regional economic systems in the conditions of the creative economy development", WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT, 17, pp. 685–695.
https://doi.org/10.37394/232015.2021.17.66

Revko, A., Butko, M., Popelo, O. (2020) "Methodology for Assessing the Influence of Cultural Infrastructure on Regional Development in Poland and Ukraine", Comparative Economic Research. Central and Eastern Europe, 23(2), pp. 21–39.
https://doi.org/10.18778/1508-2008.23.10

Shkarlet, S., Ivanova, N., Popelo, O., Dubyna, M., Zhuk, O. (2020) "Infrastructural and Regional Development: Theoretical Aspects and Practical Issues", Studies of Applied Economics, 38(4), Special Issue: The Recent Economic Trends and their Impact on Marketing.
https://doi.org/10.25115/eea.v38i4.4002

Solosich, O., Popelo, O., Nusinova, O., Derhaliuk, M., Tulchynska, S. (2021) "Ensuring economic security of regions as a potential-forming space in the conditions of intellectualization", Academy of Entrepreneurship Journal, 27(6), pp. 1–8.

Sukhovey, A. F., Golova, I. M. (2020) "Differentiation of innovative development strategies of regions for improving the effectiveness of socio-economic policy in the Russian Federation", Economy of Region, 16(4), pp. 1302–1317.
https://doi.org/10.17059/ekon.reg.2020-4-20

Tulchynska, S., Popelo, O., Vovk, O., Dergaliuk, B., Kreidych, I., Tkachenko, T. (2021) "The Resource Supply of Innovation and Investment Strategies of the Microeconomic Systems Modernization in the Conditions of Digitalization", WSEAS TRANSACTIONS on ENVIRONMENT and DEVELOPMENT, 17, pp. 819–828.
https://doi.org/10.37394/232015.2021.17.77

Vertakova, Y., Risin, I., Treshchevsky, Y., Klimov, N. (2020) "Financial, Institutional and Personnel Threats to Innovative Development of the Region", IOP Conference Series: Materials Science and Engineering, 953(1), Article number: 012096.
https://doi.org/10.1088/1757-899X/953/1/012096

Vovk, O., Kravchenko, M., Popelo, O., Tulchynska, S., Derhaliuk, M. (2021) "Modeling the Choice of the Innovation and Investment Strategy for the Implementation of Modernization Potential", WSEAS TRANSACTIONS on SYSTEMS and CONTROL, 16, pp. 430–438.
https://doi.org/10.37394/23203.2021.16.38

Zajkowska, M. (2017) "Open models of innovation processes as a future management challenge for small and medium-sized enterprises in Poland", Journal of Management and Business Administration. Central Europe, 25(4), pp. 193–208.
https://doi.org/10.7206/jmba.ce.2450-7814.214