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Methodological Approaches to the Evaluation of Innovation in Polish and Ukrainian Regions, Taking into Account Digitalization

Olha Popelo https://orcid.org/0000-0002-4581-5129
Dr. of Economic Sciences, Associate Professor, Chernihiv Polytechnic National University, Chernihiv, Ukraine, e-mail: popelo.olha@gmail.com

Svitlana Tulchynska https://orcid.org/0000-0002-1409-3848
Dr. of Economic Sciences, Professor, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine, email: tuha@ukr.net

Alona Revko https://orcid.org/0000-0001-7888-3657
Dr. of Economic Sciences, Professor, Chernihiv Polytechnic National University Chernihiv, Ukraine, e-mail: alohaha19@gmail.com

Mykola Butko https://orcid.org/0000-0002-4349-1298
Dr. of Economic Sciences, Professor, Chernihiv Polytechnic National University Chernihiv, Ukraine, e-mail: butko.mykola@ukr.net

Marta Derhaliuk https://orcid.org/0000-0002-9244-1625
Ph.D. in Economics, Senior Lecturer of the Department of Economics and Entrepreneurship, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine, e-mail: marta17.06@ukr.net

Abstract

The article offers aqualimetric assessment of the innovation in regional economic systems, taking into account digitization. The study was based on the methodology of general scientific methods of cognition and special methods of scientific research in the field of the development of productive forces and regional economy. Namely, we used the dialectical method of scientific cognition to identify contradictions and interrelations of innovative development of the subjects of regional economic systems; analysis and synthesis to identify the mechanism for identifying and implementing priority areas of innovation in the regions; the grouping method for clustering regions according to the calculated values of the integrated index of innovation of the regions of Ukraine and Poland; statistical and economic-mathematical modeling for calculations and modeling of innovation of regions, and other methods. The calculations and analysis of the values of integrated indices of innovation activity in the regions of Ukraine and Poland are performed. These regions are grouped according to this indicator. The cartographic analysis is presented, and the region leaders, region outsiders, and regions with the average value of the integrated index of innovation are singled out. This study has theoretical and applied significance for the development of productive forces and regional economy as it provides for the development of a methodological approach to assessing the innovation activity of the regions of Ukraine and Poland, taking into account digitalization processes.

Keywords: innovation, innovation activity, social innovation, infrastructure, modernization, digitization

JEL: B41, O3, O35, R1

Introduction

Ukraine's strategy to join the high-tech, competitive environment necessitates the formation of an innovative development model. This transition requires a continuous and focused process of searching for, preparing, and implementing innovations that can not only improve production efficiency, but also fundamentally change its development. Modernizing the domestic economy leads to the search for such innovative forms of management that are able to quickly adapt to today's changing environment, and are competitive and profitable in conditions of fierce competition, uncertainty, and risk.

Creating a new effective modern business model requires a change in traditional market relations, management methods, and new management decisions, which is currently impossible without information technology. Increasing spending on research, development, and the implementation of digital technologies in enterprises should be associated with the key role of digitalization in innovation (the development and availability of digital infrastructure, improving the quality of communication networks, introducing new data transmission technologies, etc.). In turn, this will lead to the development of digital technologies in all economic spheres in the world.

Literature review

The study by Fan, Urs, and Hamlin (2019) on the example of Romania demonstrates that city-regions have become the focused locations for economic development and policy intervention for innovation. As the existing literature mostly studied innovative city-regions of the Global North, there is an urgent need to examine the emerging latecomers, particularly those from transitional economies. In this paper, Cluj-Napoca, Romania, was used to study the rising innovative city-regions in transitional economies, their role in the global innovation networks, and the development of domestic innovation capability.

Falck, Koenen, and Lohse (2019) evaluated one of the largest place-based innovation policies in Germany – the Innovative Regional Growth Cores (IRGC) program. It subsidizes collaborative development and commercialization projects of firms and public research institutes co-located in regions of Eastern Germany, with the explicit goal of generating local spillovers to promote regional economic development. They studied three potential types of effects with respect to a broad set of outcomes at the firm and regional level: the policy's effects on directly subsidized firms; spillover effects on non-subsidized innovative firms located in the same region; aggregate effects on regional-level economic outcomes.

Also in Germany, Richter examined how social enterprises foster social innovation in rural regions. By applying the social network approach and a cross-case analysis of social enterprises in rural regions of Austria and Poland, he showed how rural social enterprises mobilize ideas, resources, and support from external sources not primarily for their own benefit but for that of their rural region. As *embedded intermediaries*, they contribute to transformational change and wellbeing, albeit they are only one of many forces that drive rural development (Richter 2019, p. 181).

Social entrepreneurs and their networks demonstrate an unrelenting focus on systemic social change that disregards institutional and organizational norms and boundaries. Realizing that basic social services are essential, also for businesses, has meant that innovations such as saving food stores, keeping schools open, and making the bank branches stay in business are pressing issues (Revko 2017, p. 312).

Xu and Li (2020) consider that with the rapid development of the knowledge economy and network, innovative human capital is an important factor in regions. At present, there are some features of Chinese innovative human capital, such as the low quantity of human capital storage, a lack of talent, and unbalanced distribution. As people are carriers of innovation, innovative human capital combinespeople and innovation, which is the core of regional economies.

According to Popelo et al., (2021, p. 685), the implementation of an innovative model of state economic development requires significant modernization transformations and the complex use of not only the newest technology, but also scientific approaches to management. This is especially true for ensuring sustainable development of priority segments of the national economy.

Hlaváček and Sivíček (2017, p. 65) focused on mapping the innovation potential of the regions in the Czech Republic, Slovakia, and Poland. They have their own elected institutions, which may influence the development of the innovation potential of the regions. The correlation analysis and calculation of the aggregate index were used to compare the regions. The research was based on their own construction of the Innovation Potential Index, which uses six indicators: a) GDP per capita in EUR, b) the share of inhabitants with a university degree in the population, c) the share of people involved in research and developmentin the workforce, d) gross fixed capital formation (GFCF) by region, and e) the number of patents and utility models per region. Better conditions for growing innovation potential can be seen in the metropolitan areas rather than in agricultural and old industrial regions. The main advantage of old industrial regions is that they can improve their innovative potential by transforming the economic potential, which is weak in the peripheral and agrarian regions.

Eva Ivanová and Jana Masárová (2016, p. 210) attempted to evaluate the innovative performance of Slovak regions. They evaluated the innovation performance in terms of the creation or substantial improvement of new materials, products, equipment; the creation of new processes, technological procedures, systems, and services or substantial improvement; publications and citations; and patents and utility models. The standardized variable method was used to evaluate the innovation performance of the Slovak regions.

The primary purpose of the study conducted by Gajdos and Żmurkow (2013) was to analyze the supply of highly qualified personnel in the context ofprospects for the future innovative development ofvoivodships in Poland. Analyzing these problems and the relationship between them was based on studies of the educational profile of regions and the analysis of potential trends and possibilities ofcreating a highly skilled labor force coming from the higher education system, as well as on the research of the innovation level and profile of particular voivodships.

The work of Inkinen (2015) shows that conceptually innovative cities are experiencing extensive change as they transform and change in order to become competitive providers of first-class living for a highly-skilled global workforce. Integrating spatial characteristics into the analysis of knowledge-intensive cities opens new theoretical openings for urban analysis, which serve as a platform for open innovation and the economy.

Avila-Lopez, Lyu, and Lopez-Leyva (2019) demonstrated that to achieve innovation, it is necessary to regularly evaluate policy design and financing needs. They recommend following practices that are increasingly used in other countries to promote innovation. The governmental agencies responsible for the funding of S&T (Science and Technology) and innovation projects should develop monitoring and assessment systems based on qualitative and quantitative information and indicators.

Methodical approach and algorithm for assessing innovation in the regions of Ukraine and Poland

The innovative path of development chosen today by the developed countries of the world significantly depends on their achievements and success in digitalization. Therefore, the development and implementation of digital innovations are vital for the successful functioning of the country as a whole and its regions, in particular, for individual business structures. Countries' digitalization strategies are directly linked to economic development and the creation of innovative enterprises, with the digital economic sphere based on innovative technologies.

The digital transformation of all spheres of life on the basis of innovation leads to positive economic and social effects. It provides a powerful impetus for states and regions, as well as for society, business structures, and individuals. Thus, we can say that innovative development based on digitization is a means of economic growth and a factor that ensures competitiveness in the context of integration and globalization.

To assess the innovative activity of regional economic systems, taking into account digitization, we offer a methodical approach to the qualimetricassessment of innovation in the voivodships of Poland and the oblasts of Ukraine using a matrix of pair correlations. Such an approach makes it possible to avoid linear dependence in the matrix. It is important, as the last causes multicollinearity when calculating innovationand makes it impossible. Also, such a method allows us to confirm the validity of the selected indicators for calculations. Thus, the input data of the matrix of paired correlations is a sample of estimated indicators for the province or region for a certain period. In turn, the estimates are statistical data, and therefore, they have a set of autocorrelations, and they can be distinguished using pairwise correlation, according to which: $|k|\times 0.7$. Estimates that have a correlation greater than $|k|$ are further analyzed to determine the presence between the indicators of linear-functional relationships. In this case, we used an approximate linear relationship of the form: $xp = a * xq + b$, or $yp = c * yq+d$.

Estimates in which the correlation is less than $|k|$ are used to calculate the integrated index of innovation, taking into account digitization for the voivodships of Poland and the oblasts of Ukraine. The use of matrices of pair correlations, due to the classical assumptions about the independence of the estimation indicators (x) and random error values of the regression model ((cov(x,)0)), makes it possible to prevent calculation of the integrated index of innovation, taking into account digitization.

Therefore, to evaluate innovation, taking into account the digitalization of the voivodships of Poland and the oblasts of Ukraine, we propose the following algorithm. A visualization of the stages of evaluating innovation, taking into account digitization, is presented in Figure 1.

First, we define the evaluation indicators. In order to substantiate the indicators of evaluation of innovation, one must follow certain principles. The first one is systematic, due to a certain set of indicators that should reflect the specific features of innovation, taking into account digitization. The second one is optimality – they should be kept to a minimum. The third one is universality, which, in our case, makes it possible to make calculations for the voivodships of Poland and the oblasts of Ukraine. The final one is consistency – certain indicators should be logically related to each other, but not duplicated.

Prior to the assessment, taking into account the principles of systematization, optimality, universality, and consistency, the following indicators were identified: the number of industrial enterprises that implement innovations (units), the volume of innovative products sold per capita (euro), and in relation to the total volume of industrial products sold (%), the amount of funding for innovation per capita (euro), and the share of households that have Internet access at home (%).

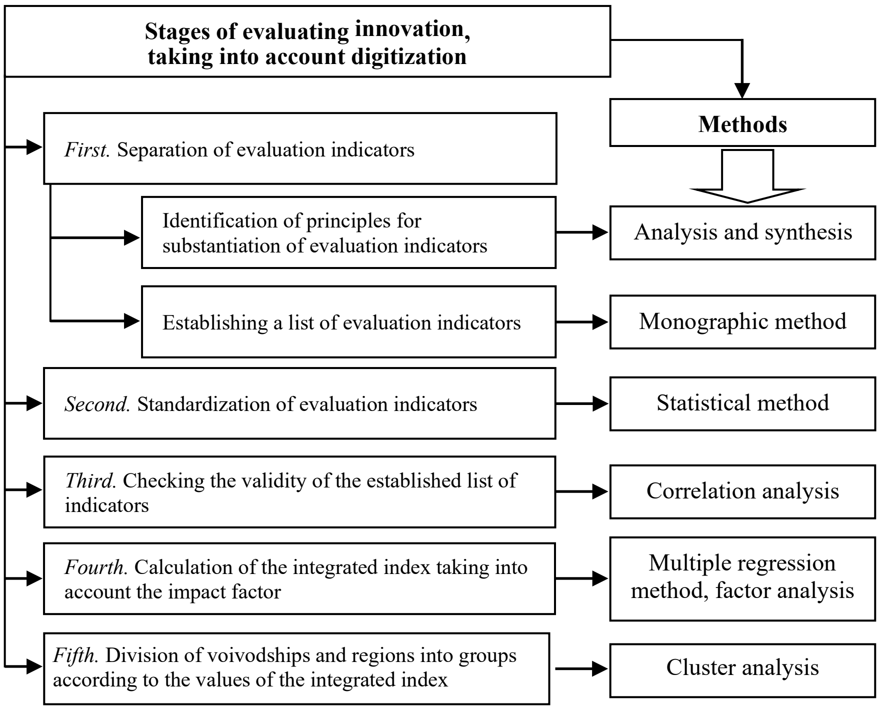

Figure 1. Stages of evaluating innovation, taking into account digitization
Source: suggested by the authors.

Then, the evaluation indicators are used to eliminate the possible impact of higher-order indicators and differences caused by different units of measurement. Rationing allows us not only to homogenize all the indicators, but also to maintain the existing functional relationships between them. For normalization, a method of mathematical expectation can be used:

$$\mathrm{x}_{\mathrm{ij}}^{r} = \frac{x_{jir}}{x_{j\eth ir}}, \tag{1}$$

$$\mathrm{X}_{\mathrm{ij}}^{r} = \left(x_{1ir}, x_{2ir} \ldots x_{jir}\right), \tag{2}$$

where:

– $\mathrm{x}_{\mathrm{ij}}^{r}$ – normalized value of the j-th evaluation indicator of innovation, taking into account digitization j = 1, …, 5, which characterizes the i-th region;

- r – research period (years) 2010–2019 (r = 1, …, 10);
- x_{jir} – natural value of the j-th partial indicator;
- xj_{cpir} – estimation of mathematical expectation of the j-th selected estimation indicator of the i-th region for the studied period;
- X_{ij}^{r} – the matrix of the defined estimation indicators.

Third, we analyze the evaluation indicators using correlations and regression ratios. To find the correlation of indicators (rij) we use the formula:

$$r_{xi,xj} = \frac{cov(xi, xj)}{D\left[x_i^2\right] \cdot D\left[x_j^2\right]}, \tag{3}$$

where:
- xi, xj – estimated indicators of the i-th region;
- cov (x_i, x_j) – covariance between samples of normalized evaluation indicators xi, xj;
- $D[x_i^2]$, $D[x_j^2]$ – are the corresponding variances of the estimated indicators that are not equal to the zero value.

Fourth, the preliminary calculations allow us to determine the integrated index of innovation using the multiple regression method. It makes it possible to determine the impact factors (K) among the indicators that represent the regression function:

$$K = \left[(X_1^T \cdot X_1)^{-1} \cdot X_1^T\right]^T, \tag{4}$$

where:
- K – impact factor, respectively, for indicators $x_1 - x_5$.
- X_1 – the matrix of normalized evaluation indicators of regions for a certain period (r = 10) has the following form:

$$X_1 = \begin{pmatrix} x_{1_1} & x_{1_2} & \dots & \dots & x_{1_{10}} \\ x_{2_1} & x_{2_2} & \dots & \dots & x_{2_{10}} \\ \dots & \dots & \dots & \dots & \dots \\ x_{j_1} & x_{j_2} & \dots & \dots & x_{j_{10}} \\ x_{j_{s1}} & x_{j_{s+1}} & \dots & \dots & x_{j_{s+1}} \end{pmatrix}$$

where x_{j_s} – normalized evaluation indicators.

Having obtained a quadratic matrix, the integrated index of innovation is similarly calculated for Polish voivodships and oblasts of Ukraine.

Fifth, regions are grouped according to the results of the calculation of the integrated index of innovation.

Analysis of the dynamics of integrated indices of innovation in the regions of Ukraine and Poland

Methodologically, this research isbased onstatistical and dynamics methods used insynthetic analysis, which characterizes the innovation of the Ukrainian regions and Polishvoivodships, taking into account digitization. All indicators were taken for the period 2010–2019. The ten-year period makes it possible to track the changes that have taken place in the integrated indices and to identify existing trends. All calculations are performed using Mathcad software, which makes it possible to obtain high-accuracy calculations. The Mazowieckie voivodship is taken arbitrarily as an example for considering the clarity of the calculations. Table 1 presents the input estimates and their normalized values.

Rationing the evaluation indicators makes it possible to determine the current coefficients of influence (K) of variables x1–x5 on the integral index (scale 0–1.00) from multiple regression in the absence of signs of simultaneity and multicollinearity in the relationships between variables ($|r1| \neq 0$). Checking the correlations between variables, in general, is as follows.

Substituting the value, we get:

$$r1 := \begin{pmatrix} corr(x1,x1) & corr(x1,x2) & corr(x1,x3) & corr(x1,x4) & corr(x1,x5) \\ corr(x2,x1) & corr(x2,x2) & corr(x2,x3) & corr(x2,x4) & corr(x2,x5) \\ corr(x3,x1) & corr(x3,x2) & corr(x3,x3) & corr(x3,x4) & corr(x3,x5) \\ corr(x4,x1) & corr(x4,x2) & corr(x4,x3) & corr(x4,x4) & corr(x4,x5) \\ corr(x5,x1) & corr(x5,x2) & corr(x5,x3) & corr(x5,x4) & corr(x5,x5) \end{pmatrix}$$

$$r1 = \begin{pmatrix} 1 & 0.252 & -0.223 & -0.229 & 0.47 \\ 0.252 & 1 & 0.797 & 0.355 & -0.509 \\ -0.223 & 0.797 & 1 & 0.402 & -0.807 \\ -0.229 & 0.355 & 0.402 & 1 & -0.514 \\ 0.47 & -0.509 & -0.807 & -0.514 & 1 \end{pmatrix}$$

Checking the correlations between variables confirms the validity of their choice and makes it possible to move to the next stage – calculating the integrated index of innovation using the method of multiple regression. Figure 2 presents the results of the calculations of the coefficients of influence on the integrated index.

Table 1. Estimates and their normalized values in accordance with the proposed methodological approach for the Mazowieckie voivodship, 2010–2019

Indicator	Year									
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
X1	695	623	552	604	773	827	705	902	838	1161
Normalized value x1	0.905	0.811	0.719	0.786	1.007	1.077	0.918	1.174	1.091	1.512
X2	2425.45	1974.38	1523.31	1698.34	2078.95	1521.68	1525.60	1599.75	1933.45	2.149.5
Normalized value x2	1.316	1.071	0.827	0.921	1.128	0.826	0.828	0.868	1.049	1.166
X3	13.02	10.59	8.16	8.09	9.45	7.74	8.32	8.09	8.43	8.5
Normalized value x3	1.44	1.172	0.903	0.895	1.045	0.856	0.920	0.895	0.933	0.940
X4	1456.46	1086.76	1488.19	1120.76	1040.75	1000.00	896.93	1300.44	1043.72	1070.56
Normalized value x4	1.386	1.034	1.417	1.067	0.991	1.000	0.854	1.238	0.993	1.019
X5	69.0	71.4	73.1	75.8	77.4	78.5	78.4	79.4	76.6	69.0
Normalized value x5	0.91	0.942	0.964	1.0	1.021	1.036	1.035	1.034	1.047	1.01

Source: compiled by the authors based on statistics and calculation results.

The influence of variables (x1–x5) for the Mazowieckie voivodship in descending order has the following sequence: x5, x2, x3, x1, x4. As a result of the calculations, we obtain the value of the integrated index, which is presented for the Mazowieckie voivodship, as well as all for other voivodships, in Table 2.

If we analyze the results of the calculations according to the proposed methodological approach to assessing innovation, it can be noted that from 2010 to 2017, according to the determined arithmetic mean of the integrated index, there is a gradual increase from 0.569 to 0.583. However, in 2018 there was a decrease to 0.576; 2019 had the same value. The arithmetic mean value of the average integral index for 2010–2019 was 0.576.

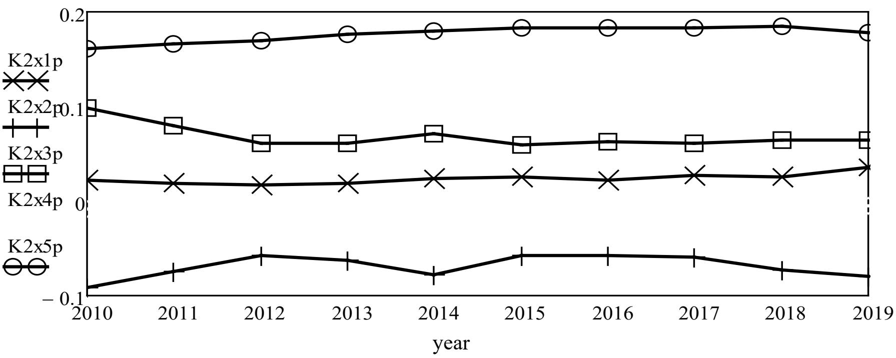

Figure 2. Coefficients of influence on the value of the integrated index of innovation taking into account digitization
Source: calculated by the authors.

Mazowieckie voivodship takes first place in terms of the value of the average integrated index, with an index value of 0.867; Slaskie voivodeship comes second with a value of 0.858; third place goes to Pomorskie voivodship with 0.846.

Swietokrzyskievoivodship has the lowest value of the integrated indices with 0.334, followed by Podlaskie voivodship – 0.344 and Warminsko-Mazurskie voivodship – 0.360. The difference between Mazowieckie and Swietokrzyskie voivodships is 2.6 times.

The proposed methodological approach was also tested, and the integrated index of innovation was calculated for the regions of Ukraine. The results of the calculations are given in Table 3.

Table 2. The value of the integrated index of innovation, taking into account the digitalization of Polish voivodships

Region name	The value of the integral index										The average value of the integrated index for 2010–2019	Rank of the region
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019		
Dolnoslaskie	0.653	0.654	0.659	0.660	0.664	0.670	0.673	0.668	0.664	0.661	0.663	6
Kujawsko-pomorskie	0.514	0.507	0.494	0.505	0.517	0.516	0.528	0.522	0.526	0.520	0.515	9
Lubelskie	0.380	0.380	0.384	0.389	0.383	0.388	0.395	0.396	0.375	0.389	0.386	13
Lubuskie	0.411	0.414	0.410	0.410	0.406	0.406	0.397	0.409	0.397	0.413	0.407	12
Lodzkie	0.602	0.613	0.622	0.612	0.622	0.623	0.619	0.624	0.616	0.609	0.616	7
Malopolskie	0.728	0.735	0.750	0.756	0.757	0.751	0.746	0.749	0.737	0.736	0.745	5
Mazowieckie	0.855	0.859	0.857	0.859	0.865	0.882	0.878	0.877	0.869	0.865	0.867	1
Opolskie	0.404	0.409	0.400	0.416	0.410	0.411	0.398	0.414	0.408	0.409	0.408	11
Podkarpackie	0.585	0.597	0.601	0.592	0.603	0.605	0.595	0.611	0.594	0.591	0.597	8
Podlaskie	0.340	0.344	0.346	0.345	0.344	0.344	0.345	0.352	0.337	0.344	0.344	15
Pomorskie	0.834	0.835	0.842	0.844	0.848	0.856	0.860	0.853	0.848	0.844	0.846	3
Slaskie	0.845	0.847	0.858	0.856	0.863	0.862	0.859	0.861	0.869	0.856	0.858	2
Swietokrzyskie	0.330	0.330	0.338	0.329	0.337	0.331	0.335	0.342	0.335	0.333	0.334	16
Warminsko-mazurskie	0.356	0.353	0.348	0.353	0.367	0.355	0.368	0.367	0.373	0.361	0.360	14
Wielkopolskie	0.817	0.810	0.803	0.829	0.829	0.832	0.849	0.820	0.820	0.829	0.824	4
Zachodniopomorskie	0.447	0.452	0.459	0.447	0.453	0.448	0.452	0.459	0.455	0.452	0.452	10
The arithmetic mean value of the integrated index by voivodships	0.569	0.571	0.573	0.575	0.579	0.580	0.581	0.583	0.576	0.576	0.576	–

Source: calculated by the authors according to the proposed methodological approach.

Table 3. The value of the integrated index of innovation, taking into account the digitalization of the regions of Ukraine

Region name	The value of the integral index										The average value of the integrated index for 2010–2019	Rank of the region
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019		
Vinnytska	0.120	0.130	0.136	0.140	0.138	0.130	0.120	0.130	0.106	0.102	0.125	13
Volynska	0.065	0.050	0.057	0.075	0.066	0.044	0.065	0.050	0.052	0.051	0.058	18
Dnipropetrovska	0.181	0.258	0.301	0.323	0.306	0.332	0.181	0.258	0.234	0.229	0.260	5
Donetska	0.054	0.062	0.065	0.061	0.042	0.033	0.054	0.062	0.027	0.027	0.049	22
Zhytomyrska	0.056	0.060	0.063	0.065	0.064	0.060	0.056	0.060	0.048	0.047	0.058	19
Zakarpatska	0.044	0.032	0.033	0.044	0.032	0.032	0.044	0.032	0.032	0.031	0.036	25
Zaporizka	0.134	0.163	0.130	0.115	0.112	0.117	0.134	0.163	0.137	0.134	0.134	12
Ivano-Frankivska	0.191	0.174	0.152	0.132	0.114	0.093	0.191	0.174	0.065	0.063	0.135	11
Kyivska	0.340	0.330	0.320	0.305	0.310	0.330	0.340	0.330	0.367	0.359	0.333	2
Kirovogradska	0.196	0.186	0.168	0.147	0.142	0.149	0.196	0.186	0.171	0.167	0.171	10
Luhanska	0.053	0.056	0.059	0.039	0.019	0.017	0.053	0.056	0.029	0.028	0.041	23
Lvivska	0.189	0.182	0.236	0.209	0.188	0.230	0.189	0.182	0.170	0.166	0.194	8
Mykolayivska	0.070	0.066	0.046	0.085	0.047	0.050	0.070	0.066	0.048	0.047	0.060	15
Odeska	0.195	0.211	0.221	0.227	0.224	0.211	0.195	0.211	0.171	0.167	0.203	7
Poltavska	0.206	0.335	0.199	0.272	0.255	0.199	0.206	0.335	0.210	0.206	0.242	6
Rivenska	0.053	0.061	0.059	0.054	0.046	0.043	0.053	0.061	0.052	0.051	0.053	21
Sumska	0.061	0.065	0.062	0.059	0.055	0.053	0.061	0.065	0.059	0.058	0.060	16
Ternopilska	0.052	0.074	0.066	0.052	0.050	0.065	0.052	0.074	0.054	0.053	0.059	17
Kharkivska	0.274	0.320	0.342	0.320	0.260	0.352	0.274	0.320	0.346	0.338	0.315	3
Khersonska	0.055	0.060	0.063	0.064	0.064	0.060	0.055	0.060	0.049	0.048	0.058	20
Khmelnytska	0.345	0.378	0.300	0.269	0.225	0.233	0.345	0.378	0.168	0.165	0.281	4
Cherkaska	0.041	0.044	0.045	0.040	0.037	0.036	0.041	0.044	0.037	0.036	0.040	24
Chernivetska	0.200	0.211	0.208	0.157	0.151	0.165	0.200	0.211	0.178	0.174	0.186	9

Region name	The value of the integral index										The average value of the integrated index for 2010–2019	Rank of the region
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019		
Chernihivska	0.062	0.067	0.070	0.072	0.071	0.067	0.062	0.067	0.055	0.053	0.065	14
Kyiv City	0.636	0.687	0.718	0.739	0.728	0.687	0.636	0.687	0.556	0.544	0.662	1
*The arithmetic mean value of the integrated index for all regions (**I_{in} срариф**)*	0.155	0.171	0.165	0.163	0.150	0.151	0.155	0.171	0.137	0.134	0.155	–

Source: calculated by the authors according to the proposed methodological approach.

The results of the calculations of the integrated index of innovation of the regions of Ukraine make it possible to note that if we consider the trend of changes in the arithmetic mean of the integrated index for all regions, there is no single trend. Thus, the highest value of the arithmetic mean of the integrated index at 0.171 was observed in 2011 and in 2017. Starting from 2017, there is a significant decrease in the arithmetic mean, to 0.137 in 2018 and 0.134 in 2019. For the study period 2010–2019, the average value for all regions was 0.155.

If we consider the regions, the highest value of the average integrated index is in Kyiv City – 0.662, Kyiv region – 0.333, and Kharkiv region – 0.315. Zakarpattia has the lowest average – 0.036, followed by Cherkasy – 0.040, Luhansk – 0.041, and Donetsk – 0.049. The difference between the value of the average integrated index of Kyiv City and the Zakarpattia region is 18.4 times.

The dynamics of changes in the arithmetic mean of the index of innovation of the voivodships of Poland and the regions of Ukraine are presented in Figure 3.

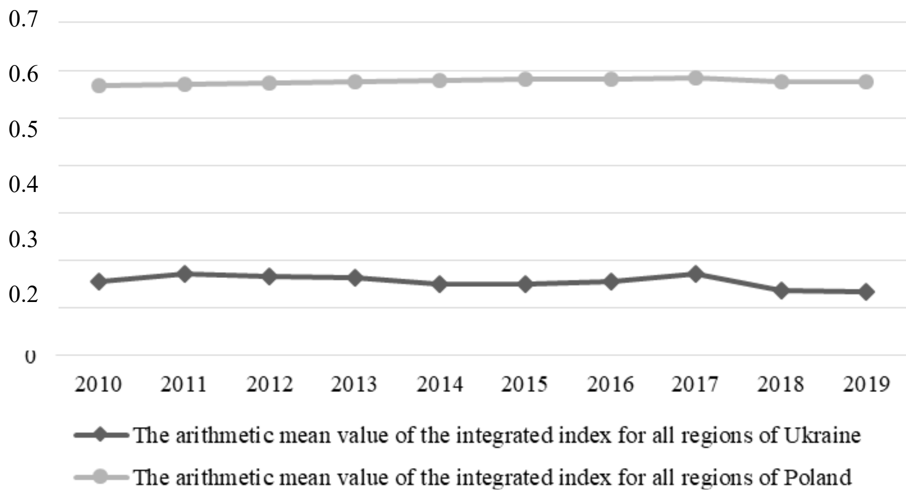

Figure 3. Dynamics of changes in the arithmetic mean of the integrated index of innovation taking into account digitization of the regions of Poland and Ukraine, 2010–2019
Source: constructed by the authors based on the results of calculations.

Grouping of the regions of Ukraine and Poland according to the integrated index of innovation activity

The calculations make it possible to group regions according to the calculated values of the integrated index of innovation; they are presented in Tables 4 and 5.

Table 4. The value of the integrated index of innovation, taking into account the digitization of the Polish regions

Region name	The average value of the integrated index for 2010–2019	The level of value of the average integral index	Rank of the region
Dolnoslaskie	0.663	Average	6
Kujawsko-pomorskie	0.515	Average	9
Lubelskie	0.386	Low	13
Lubuskie	0.407	Low	12
Lodzkie	0.616	Average	7
Malopolskie	0.745	High	5
Mazowieckie	0.867	High	1
Opolskie	0.408	Low	11
Podkarpackie	0.597	Average	8
Podlaskie	0.344	Low	15
Pomorskie	0.846	High	3
Slaskie	0.858	High	2
Swietokrzyskie	0.334	Low	16
Warminsko-mazurskie	0.360	Low	14
Wielkopolskie	0.824	High	4
Zachodniopomorskie	0.452	Low	10

Source: calculated by the authors according to the proposed methodological approach.

Table 5. The value of the integrated index of innovation taking into account the digitalization of the Ukrainian regions

Region name	The average value of the integrated index for 2010–2019	The level of value of the average integral index	Rank of the region
Vinnytsia	0.125	Low	13
Volyn	0.058	Low	18
Dnipropetrovsk	0.260	Average	5
Donetsk	0.049	Low	22
Zhytomyr	0.058	Low	19
Zakarpattia	0.036	Low	25
Zaporizha	0.134	Low	12
Ivano-Frankivsk	0.135	Low	11
Kyiv	0.333	High	2
Kirovograd	0.171	Low	10
Luhansk	0.041	Low	23
Lviv	0.194	Low	8
Mykolayiv	0.060	Low	15
Odesa	0.203	Low	7
Poltava	0.242	Low	6
Rivne	0.053	Low	21
Sumy	0.060	Low	16

Region name	The average value of the integrated index for 2010–2019	The level of value of the average integral index	Rank of the region
Ternopil	0.059	Low	17
Kharkiv	0.315	High	3
Kherson	0.058	Low	20
Khmelnytsk	0.281	Average	4
Cherkasy	0.040	Low	24
Chernivtsi	0.186	Low	9
Chernihiv	0.065	Low	14
Kyiv City	0.662	High	1

Source: calculated by the authors according to the proposed methodological approach.

The grouping of regions by the average value of the integrated index makes it possible to note that the voivodships of Poland have a more even distribution (Figure 4).

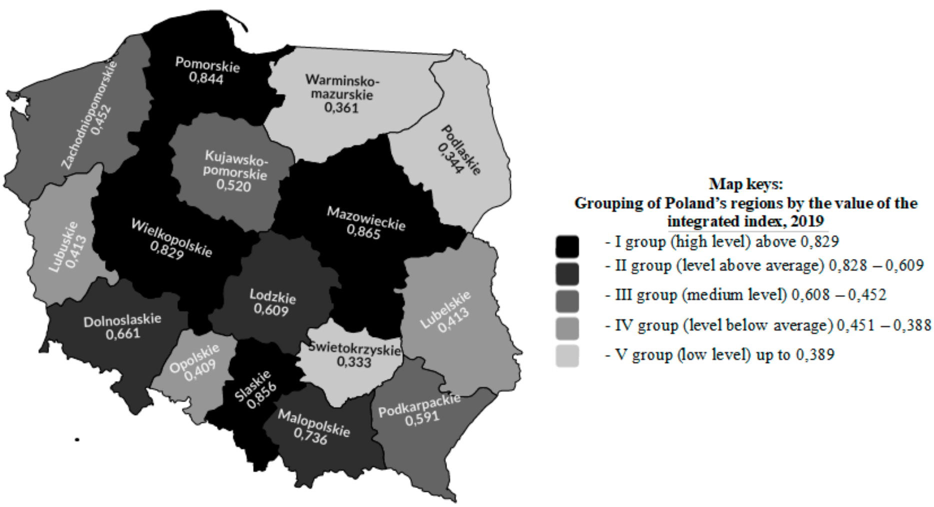

Figure 4. Map of regional differentiation of the integrated index of innovation, taking into account digitization in Poland, 2019
Source: compiled by the authors.

Thus, group I, with a high integrated index, consists of four voivodships (the biggest one in Poland): Mazowieckie, Slaskie, Pomorskie, and Wielkopolskie. Group II consists of three voivodships with an above-average level: Malopolskie, Dolnoslaskie, and Lodzkie voivodships. Due to their medium level, a further three voivodships (Podkarpackie, Kujawsko-pomorskie, and Zachodniopomorskie) were classified into group III. Group IV also consists of three voivodships with a below-average level: Lubelskie, Opolskie, and Lubuskie. Finally, group V contains voivodships with a low average level: Podlaskie, Warminsko-Mazurskie, and Swietokrzyskie.

However, in Ukraine, there is a different picture for the grouping of regions (Figure 5), as the difference between Kyiv City, with the highest integrated index, and the Zakarpattia region is very high.

Eighty percent of regions (twenty in total) belong to the group with a low integrated index. In the group with an average level, there are only two regions; Kharkiv, Kyiv regions and Kyiv City had a high integrated index in 2019.

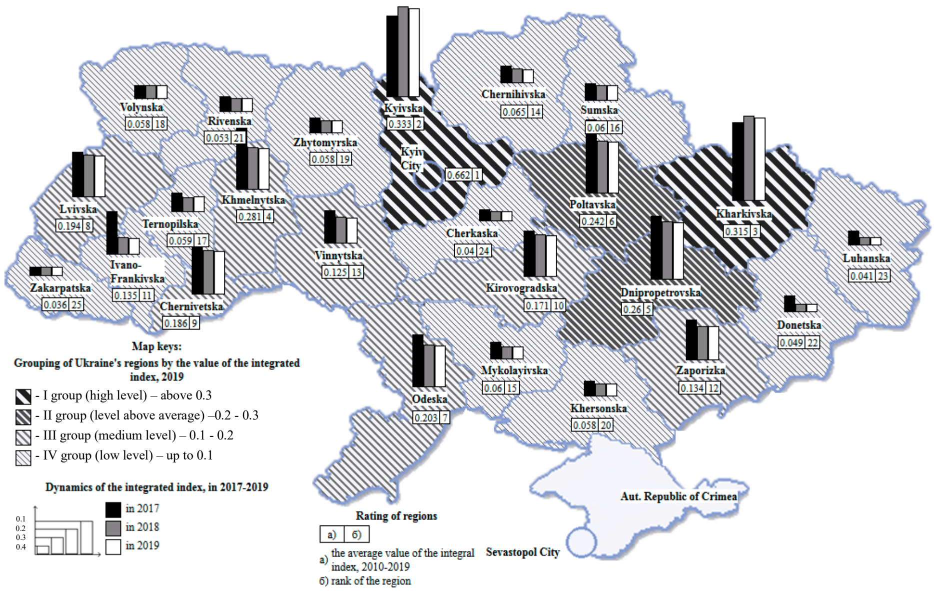

Figure 5. Map of regional differentiation of the integrated index of innovation activity taking into account digitization processes in Ukraine, 2019
Source: built by the authors.

Discussions and conclusions

The modernization priorities of economic development, the intensification of competition, the saturation of markets, and limited resources require enterprises to take a broad, innovative approach and maximize the innovative potential of the regions. Innovations are an incentive for the competitive development of enterprises; they create leading positions and the opportunity to enter world markets.

In the current conditions of the COVID–19 pandemic and the decline of economic indicators, fierce competition dictates the need to intensify innovation as a dominant component of the rapid development of regions and the most effective way to increase their competitiveness.

We have demonstrated that innovation is a defining characteristic of modern scientific, technical, industrial, socio-economic, and other social processes. The fate of a country depends on mastering innovative development mechanisms, i.e., will it move in the direction of becoming a developed country, or will it remain a stagnant country on the sidelines of scientific, technological, and social progress? This is due to the general laws of social development, according to which the world is moving from a predominantly reproductive to an innovative type of development.

The scientific novelty of this study is the development of a methodological approach to assessing innovation within the regions of Ukraine and Poland, taking into account digitalization, which, unlike existing studies, involves the use of analysis and synthesis, monographic, statistical, and multiple regression, and factor, correlation, and cluster analysis. It shows the development of the mechanism of definingand realizing directions of innovation within regions.

The authors proposed a methodological approach to assessing innovation, taking into account digitization, which includes the following stages: 1) separating evaluation indicators of their rationing based on a statistical method, 2) verifying the established list of indicators using correlation analysis, 3) calculating the integrated index of innovation, taking into account digitization. There was also multiple regression and factor analysis, and grouping regions by calculated values. The proposed methodological approach was tested for thevoivodships of Poland and the regions of Ukraine. The results of the analysis showed that the arithmetic mean value of the integrated index in Poland, except for the last two years, tended to increase, but in Ukraine, except for a significant decline in the arithmetic mean index for the last two years, there was no positive trend. The difference between the value of the integrated index of Mazowieckie and Swietokrzyskie voivodships is 2.6 times, and the difference between the integral index of Kyiv City and the Zakarpattiaregion is 18.4 times.

According to the results of the study, the authors consider it appropriate to develop a mechanism for identifying and implementing priority areas of innovation in order to accelerate the transition of the economy to an innovative path of development. This mechanism should improve the structure of priority areas of science and technology; use the program-target approach to realize scientific and technical, and innovative medium-term defined priorities of national value; anticipate an effective program management mechanism. Innovative priorities for economic development encourage the widespread introduction of the achievements of advanced scientific and technological developments, which give impetus to structural changes in the economy, stimulating the production of new high-tech products.

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Olha Popelo, Svitlana Tulchynska, Alona Revko, Mykola Butko, Marta Derhaliuk

Podejścia metodologiczne do oceny innowacyjności regionów Polski i Ukrainy z uwzględnieniem procesów cyfryzacji

Artykuł przedstawia kwalimetryczną ocenę innowacyjności regionalnych systemów gospodarczych z uwzględnieniem procesów cyfryzacji. Badania oparto o generalne naukowe metody poznawcze oraz specjalne metody badań naukowych w obszarze rozwoju sił wytwórczych i gospodarki regionalnej. Zastosowano dialektyczną metodę poznania naukowego do identyfikacji sprzeczności i wzajemnych powiązań innowacyjnego rozwoju podmiotów działających w ramach regionalnych systemów gospodarczych; metodę analizy i syntezy w celu określenia mechanizmów identyfikacji i wdrażania priorytetowych obszarów innowacji w regionach; metodę grupowania w celu pogrupowania regionów według obliczonych wartości zintegrowanego wskaźnika innowacyjności regionów Ukrainy i Polski; metodę modelowania statystycznego i ekonomiczno-matematycznego do obliczenia i modelowania innowacyjności regionów, a także inne metody. Przeprowadzono kalkulację i analizę wartości zintegrowanych wskaźników działalności innowacyjnej w regionach Ukrainy i Polski. Regiony te zostały pogrupowane według wartości tego wskaźnika. Przedstawiono analizę kartograficzną i wyodrębniono regiony będące liderami, regiony zapóźnione oraz regiony o średniej wartości zintegrowanego wskaźnika innowacyjności. Niniejsze opracowanie ma znaczenie teoretyczne i aplikacyjne dla rozwoju sił wytwórczych i gospodarki regionalnej, gdyż prezentuje propozycję podejścia metodologicznego do oceny aktywności innowacyjnej regionów Ukrainy i Polski z uwzględnieniem procesów cyfryzacji.

Słowa kluczowe: innowacyjność, działalność innowacyjna, innowacje społeczne, infrastruktura, modernizacja, cyfryzacja

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