“Assessment of the development of innovation activities in the regions: Case of Ukraine”

Pavlo Hrytsenko
Viacheslav Voronenko
Yevhen Kovalenko
Tetiana Kurman
Vitalii Omelianenko

This work is licensed under a Creative Commons Attribution 4.0 International License

"Problems and Perspectives in Management"

1727-7051
1810-5467
LLC “Consulting Publishing Company “Business Perspectives”

30
0
8

© The author(s) 2021. This publication is an open access article.
Abstract

The development of innovation activities is of great importance on the path to achieving the goals of sustainable development. Success on this path is closely related to the presence of comparable information on the development of innovation activities at the regional level. The aim of the paper is to assess the development of innovation activities in the regions of Ukraine and identify differences in results. The study is performed using relative indicators for the assessment of the development of innovation activities in the regions of Ukraine. The indicators were averaged and normalized. To analyze how innovation activities change over time, the dynamic indices based on the geometric mean of the growth rate of the relative indicators were used. The obtained results have significant differences in the regions being assessed. Most regions have a heterogeneous development of innovation activities. At the same time, they are at the top and bottom of the rankings of the regions in different indicators of the development of innovation activities. Only Cherkasy and Zaporizhzhia oblasts are at the top of the rankings in at least 75% of indicators. However, in 2017–2019, all indicators improved in at least 29% of regions. In addition, 75% of indicators improved in at least 54% of regions. Therefore, over time, most regions progressed in the development of innovation activities. Management decisions for the development of innovation activities should be complex for all regions and implemented primarily in the regions where there is no improvement over time.

Keywords
innovation activity, industrial enterprise, sustainable development, management decision, regional competitiveness

JEL Classification
O30, O31, O32

INTRODUCTION

In 2015, the United Nations approved the Agenda for Sustainable Development 2030 (United Nations, 2015), which is a rich and global action plan focused on achieving economic prosperity, environmental sustainability, and social integration. The Agenda contains seventeen goals in the field of sustainable development, including goal No. 9 – to create sustainable infrastructure, promote comprehensive and sustainable industrialization and innovation. That is, its achievement of sustainable development depends on the development of innovation activities. Nowadays, many countries in the world are experiencing problems with the development of innovation activities. To solve these problems, countries are focused on developing necessary tools and means to enhance and catalyze innovation. The development of innovation activities at the regional level is of great importance on this path. The development of innovation activities is closely related to the availability of appropriate regional capabilities and resources.
The development of innovation at the regional level depends on management decisions. The results of innovation management are reflected in the innovation competitiveness of the regions. Therefore, to make successful management decisions, it is necessary to have relevant results of the assessment of the development of innovation activities. The problem is that it is difficult to conduct assessments at the regional level due to the specifics of individual territories, different scales, and features. Therefore, there is a certain lack of assessment of the development of innovation at the sub-national level and the innovation competitiveness of the regions. Based on this assessment it is possible to find probable management decisions for the development of innovation activities at the regional level. It also applies to Ukraine, where each region has both individual and national characteristics.

1. LITERATURE REVIEW

Innovation activities are organizational, scientific, technological, financial, and business performance, which leads to the introduction of innovations. The development of innovation activities includes creation, managing, and coordination of corresponding organizational networks.

In the world, there are various assessments of the development of innovation activities, which in most cases assess the structural components of innovation. There are many kinds of assessments of these components at the macro-level, on which basis innovative development ratings of countries and economies are compiled. Existing assessments mainly include gross product performance, investment in innovation, and number of people engaged in innovations. These assessments include the Global Innovation Index (Cornell University et al., 2020), which is a common ranking. In addition to the Global Innovation Index, there are many other assessments for countries, among which are the Technology Achievement Index (United Nations Statistics Division, 2001), the Innovation Capacity Index (Lopez-Claros & Mata, 2010), the Bloomberg Innovation Index (Bloomberg Business, 2015), the Social Innovation Index (Economist Intelligence Unit, 2016), the European Innovation Scoreboard (European Commission, 2020), the European Digital Social Innovation Index (Nesta, 2021), etc. The advantages of these assessments are that they are modern and informative for countries. However, as already noted, there is a certain shortage of such assessments for the regional level. Significant attempts to take into account the specifics of each individual territory in assessing the innovation development of regions were made in particular for the Innovation Index 2.0, made by the Indiana Business Research Center (2016). However, this assessment is suited to the territories of the USA for which it was designed.

The development of innovation activities in the regions has been studied even before the appearance of mentioned assessments. Nauwelaers and Reid (1995) analyzed the existing research at the time to assess the regional technological innovation potential and concluded that regional innovative databases should be developed. The continuation of the study in this direction was in the work of Autio (1998), where it is argued that regional systems of innovation are significantly different from national ones, and, thus, other approaches are called for in the assessment of regional systems of innovation. Oughton et al. (2002) investigated the regional innovation paradox concerning the contradiction in spending money on innovation in the regions. Doloreux and Parto (2005) generalized important ideas and arguments for theorizing regional innovation systems. Tödtling and Trippl (2005) analyzed different types of regions, considering their prerequisites for innovation, network and innovation barriers, and developed regional policy and strategy options.

Arnkil et al. (2010) showed the importance of supporting innovation by regional authorities. Sarkar (2013) proved that innovation stimulates sustainable development of the environmental sector and promotes green economic growth at all levels. Sotnyk et al. (2013) investigated the influence of innovative information and communication technologies for achieving sustainable development of the country. Shkarupa (2015) developed an effective functional system for the phased process of innovative modernization and management of socio-economic systems in the region.
In subsequent years, significant progress has been made. Ivanova and Masarova (2016) assessed the innovation activities of the Slovak regions, using the variable standardized method. The advantage of the method is that it considers the relative variability of indicators. The results showed that the innovation activities of the Slovak regions were changing continually. Then Ivanova and Kordos (2017) continued the research and assessed differences in innovation activities in individual regions of Slovakia, using a multi-criteria scoring method. The advantage of the method is its relative simplicity. The results showed strong differences in regions being assessed what is reflected in their economic performance and competitiveness differences. Stejskal et al. (2018) created a new method for assessing regional innovation systems and applied it to individual regions in the Czech Republic. The advantage of the method is that it can be easily used practically to map the development of individual innovative systems in a region. Horobchenko and Voronenko (2018) analyzed the impact of innovation factors on sustainable development in Ukraine. Kniazevych et al. (2018) assessed the effectiveness of the innovation infrastructure of Ukraine using the factor modeling method. The advantage of factor modeling is its simplicity. The results showed that the degree of development of innovation infrastructure is one of the main factors in the development of the Ukrainian innovation system. Ilyash et al. (2018) determined the correlation between the volume of industrial products sold and the main indicators of innovation in Ukraine using the math modeling method. The advantage of the method is that it reflects most of the information of the indicators. The results showed that the levels and ratios at the regional level had significant differences. Boronos et al. (2020) assessed the level of innovative development of the territories of Ukraine using methods based on theoretical and empirical research. The advantage of the method is that it characterizes the results of the regional eco-friendly innovation policy. The results showed that Ukrainian regions are different from each other both in terms of scientific-technical and production potentials and in terms of socio-economic development. Kartanaitė et al. (2021) showed the necessity of assessment in forming a suggestion for decision-makers in the context of the innovation Industry 4.0.

2. **AIMS AND METHODS**

The paper aims to assess the development of innovation activities in each region of Ukraine and identify differences in assessment results.

The paper adds some relative indicators for the assessment of the development of innovation activities in the regions of Ukraine that were created from selected absolute indicators. Selected absolute indicators consider the innovation and research activities of organizations and enterprises, the implementation of innovative products, involvement of employees in innovation research, innovation costs, and expenses for research and development (R&D). The development of innovation activities in the regions of Ukraine was assessed using the next four relative indicators:

1. The indicator of involvement of industrial enterprises in innovation activities. It is defined as the ratio of the number of innovation active industrial enterprises in the region to the total number of active industrial enterprises in the region:

\[ I_I = \frac{E_{IA}}{E_I}, \]

where \( I_I \) - the indicator of involvement of industrial enterprises in innovation activities, \( E_{IA} \) - the number of innovation active industrial enterprises in the region, units, \( E_I \) - total number of active industrial enterprises in the region, units.

2. The indicator of innovative productivity of employees in the implementation of R&D. It is defined as the ratio of the volume of innovative industrial goods and services sold by the region to the number of employees involved in R&D in the region:

\[ I_P = \frac{P_E}{N_E}, \]

where \( I_P \) - the indicator of innovative productivity of employees in the implementation of R&D,
monetary units/person, $P_v$ – the volume of innovative industrial goods and services sold by the region, monetary units, $N_y$ – the number of employees involved in R&D in the region, person.

3. The indicator of cost-effectiveness for innovation of industrial enterprises. It is defined as the ratio of the volume of innovative industrial goods and services sold by the region to expenses for innovation of industrial enterprises in the region:

$$I_E = \frac{P_v}{C_E}, \quad (3)$$

where $I_E$ – the indicator of cost-effectiveness for innovation of industrial enterprises, $P_v$ – the volume of innovative industrial goods and services sold by the region, monetary units, $C_E$ – expenses for innovation of industrial enterprises in the region, monetary units.

4. The indicator of the availability of costs for performance of R&D. It is defined as the ratio of expenses for performance of R&D in the region to the number of organizations in the region that performed R&D:

$$I_S = \frac{C_R}{O_R}, \quad (4)$$

where $I_S$ – the indicator of the availability of costs for performance of R&D, monetary units/units, $C_R$ – expenses for performance of R&D in the region, monetary units, $O_R$ – the number of organizations in the region that performed R&D, units.

Increasing of all indicators characterizes the improvement of the level of the development of innovation activities. The optimal direction of changing $I_E, I_P, I_S, I_S$ is growth. The first and fourth indicators characterize the conditions and factors for innovation activities (input indicators), the second and third indicators characterize the results (output indicators). The relative character of the indicators makes regions more comparable, eliminating the impact of the size of the region.

To smooth out fluctuations of indicators and analyze them over several years, the average values of indicators for each region were calculated using the arithmetic mean method.

Comparing the values of the indicators between regions, it is possible to assess the competitiveness of the regions in innovation activities. For this, the commonly known method of relative assessment of indicators compared to the best of the indicators was used. Since the optimal direction of changes in all four indicators is an increase, it is necessary to compare with the maximum values of the indicators. Relative assessment of competitiveness for each individual indicator $I_P, I_S, I_E, I_S$ was performed by the formula:

$$C_I = \frac{I}{I_{\text{max}}}, \quad (5)$$

where $C_I$ – the indicator of the relative assessment of the competitiveness of the region in innovation activities for individual indicators $I_P, I_S, I_S, I_{\text{max}}$, $I$ – the value of indicator $I_P, I_S, I_S$, respectively, for each region, $I_{\text{max}}$ – the maximum of values of the indicator $I_P, I_S, I_S, I_S$ from all compared regions.

Thus, the normalization of indicators was used. The indicators of the relative assessment of the competitiveness of regions in innovation activities were calculated with average values, average maximum values of indicator $I_P, I_S, I_S, I_S$ for each region.

To analyze how innovation activities change over time, the dynamic indices of the development of innovation activities were designed. They show whether the regions are moving toward improving the values of $I_P, I_S, I_S, I_S$. The dynamic indices base on the geometric mean of the growth rate of indicators $I_P, I_S, I_S, I_S$ and are calculated by formulas:

$$i_j = \sqrt[N_r-1]{\prod_{n=1}^{N_r-1} \left( \frac{I_{j[n+1]}}{I_{j[n]}}, \right)}, \quad (6)$$

$$i_p = \sqrt[N_r-1]{\prod_{n=1}^{N_r-1} \left( \frac{I_{p[n+1]}}{I_{p[n]} \cdot (1 + r_{[n+1]})), \right)}, \quad (7)$$

$$i_E = \sqrt[N_r-1]{\prod_{n=1}^{N_r-1} \left( \frac{I_{E[n+1]}}{I_{E[n]}}, \right)}, \quad (8)$$

$$i_s = \sqrt[N_r-1]{\prod_{n=1}^{N_r-1} \left( \frac{I_{S[n+1]}}{I_{S[n]} \cdot (1 + r_{[n+1]})), \right)}, \quad (9)$$
where \( i_I, i_P, i_E, i_S \) – dynamic indices of the development of innovation activities for indicators \( I_I, I_P, I_E, I_S \); \( N \) – the number of years during which analysis is conducted; \( n \) – the designation number of the year; \( r \) – the inflation rate.

The optimality criterion for \( i_I, i_P, i_E, i_S \) is the value greater than 1.

The study was performed for Ukrainian oblasts, which are the regions of Ukraine. The data for Donetsk and Luhansk oblasts are incomplete and available from enterprises, institutions, and organizations that reported to the state statistics bodies of Ukraine. The data come from the State Statistics Service of Ukraine (2018, 2019, 2020). The Ukrainian hryvnia was used as the currency in the calculations.

### 3. RESULTS

The study was conducted for the period 2017‒2019. The results for Donetsk and Luhansk oblasts could be distorted due to incomplete data.

Table 1 presents the results of calculating the indicators of involvement of industrial enterprises in innovation activities.

As one can see from the results of the calculations (Table 1), the largest number of innovation active industrial enterprises in the region in relation to the total number of active industrial enterprises was in the Ternopil oblast in 2019, although in the previous two years the value of this indicator was lower. Except for Ternopil oblast, also the indicator of Kharkiv oblast is larger than the indicators of other regions in 2019. In previous years, the values of the indicator of Kharkiv oblast were even higher. The smallest indicators have Zakarpattia and Khmelnytskyi oblasts with values amount to 0.008 in 2019. In previous years, the values of these regions were also low and decreased. Chernivtsi and Chernihiv oblasts have low values of the indicator compared to other regions. In these regions, over 2017‒2019, the indicators changed towards a decrease. In general, in most regions, the number of innovation active industrial enterprises in relation to the total number of active industrial enterprises is relatively small.

Table 1. Results of calculation of indicators \( I_I \) by regions of Ukraine, 2017‒2019

| Region of Ukraine         | Indicator \( I_I \) |
|---------------------------|---------------------|
|                           | 2017    | 2018    | 2019    |
| Vinnytsia oblast          | 0.019   | 0.018   | 0.019   |
| Volyn oblast              | 0.024   | 0.018   | 0.013   |
| Dnipropetrovsk oblast     | 0.014   | 0.018   | 0.016   |
| Donetsk oblast             | 0.014   | 0.016   | 0.018   |
| Zhytomyr oblast            | 0.016   | 0.013   | 0.015   |
| Zakarpattia oblast        | 0.014   | 0.012   | 0.008   |
| Zaporizhzhia oblast       | 0.021   | 0.017   | 0.021   |
| Ivano-Frankivsk oblast    | 0.021   | 0.019   | 0.015   |
| Kyiv oblast               | 0.012   | 0.018   | 0.013   |
| Kirovohrad oblast          | 0.028   | 0.028   | 0.020   |
| Luhansk oblast             | 0.014   | 0.010   | 0.019   |
| Lviv oblast                | 0.018   | 0.016   | 0.015   |
| Mykolayiv oblast           | 0.023   | 0.012   | 0.018   |
| Odesa oblast               | 0.016   | 0.011   | 0.014   |
| Poltava oblast             | 0.021   | 0.022   | 0.022   |
| Rivne oblast               | 0.009   | 0.008   | 0.019   |
| Sumy oblast                | 0.027   | 0.027   | 0.024   |
| Ternopil oblast            | 0.031   | 0.024   | 0.032   |
| Kharkiv oblast             | 0.031   | 0.032   | 0.030   |
| Kherson oblast             | 0.015   | 0.014   | 0.012   |
| Khmelnytskyi oblast        | 0.008   | 0.010   | 0.008   |
| Chernivtsi oblast          | 0.014   | 0.015   | 0.011   |
| Chernihiv oblast           | 0.011   | 0.016   | 0.011   |

Source: State Statistics Service of Ukraine (2018, 2019, 2020).
Table 2 presents the results of calculating the indicators of innovative productivity of employees in the implementation of R&D.

**Table 2. Results of calculation of indicators $I_p$ by regions of Ukraine, 2017–2019**

| Region of Ukraine | Indicator $I_p$, thousand Ukrainian hryvnias/person | 2017 | 2018 | 2019 |
|-------------------|----------------------------------------------------|------|------|------|
| Vinnytsia oblast  | 725                                               | 821  | 1,374|
| Volyn oblast      | 213                                               | 1,043| 1,086|
| Dnipropetrovsk oblast | 33                                               | 132  | 136  |
| Donetsk oblast    | 13,874                                             | 4,816| 36,004|
| Zhytomyr oblast   | 380                                               | 501  | 900  |
| Zakarpattia oblast | 637                                              | 1,159| 253  |
| Zaporizhzhia oblast | 959                                              | 988  | 720  |
| Ivano-Frankivsk oblast | 182                                              | 972  | 294  |
| Kyiv oblast       | 427                                               | 968  | 575  |
| Kirovohrad oblast | 806                                               | 2,640| 6,071|
| Luhansk oblast    | 38                                                | 135  | 2,154|
| Lviv oblast       | 163                                               | 266  | 210  |
| Mykolaiv oblast   | 184                                               | 63   | 645  |
| Odesa oblast      | 52                                                | 309  | 318  |
| Poltava oblast    | 206                                               | 738  | 503  |
| Rivne oblast      | 25                                                | 157  | 24   |
| Sumy oblast       | 289                                               | 458  | 802  |
| Ternopil oblast   | 352                                               | 1,276| 1,136|
| Kharkiv oblast    | 169                                               | 248  | 286  |
| Kherson oblast    | 393                                               | 614  | 814  |
| Khmelnytskyi oblast | 73                                               | 56   | 590  |
| Cherkasy oblast   | 827                                               | 1,741| 2,095|
| Chernivtsi oblast | 57                                                | 67   | 44   |
| Chernihiv oblast  | 494                                               | 1,334| 1,318|

According to the calculated indicators of recent years (Table 2), Donetsk oblast can be considered the most innovatively productive. Additionally, Kirovohrad, Luhansk, and Cherkasy oblasts demonstrate relatively large values. Vinnytsia, Volyn, Ternopil, and Chernihiv oblasts demonstrate the worst results. Two regions have low values of indicators in 2019, among them – Rivne and Chernivtsi oblasts. Generally, it can be stated that the level of innovative productivity of workers in the performance of R&D in most regions is relatively low, because one employee engaged in R&D has a much smaller volume of sold innovative products than in other leading regions, and this is a problem for the entire country.

Table 3 presents the results of calculating the indicators of cost-effectiveness for innovation of industrial enterprises.

**Table 3. Results of calculation of indicators $I_E$ by regions of Ukraine, 2017–2019**

| Region of Ukraine | Indicator $I_E$, 2017 | 2018 | 2019 |
|-------------------|-----------------------|------|------|
| Vinnytsia oblast  | 4.528                 | 1.401| 0.794|
| Volyn oblast      | 0.412                 | 3.871| 2.357|
| Dnipropetrovsk oblast | 0.264              | 1.662| 0.486|
| Donetsk oblast    | 4.552                 | 1.501| 10.495|
| Zhytomyr oblast   | 14.933                | 1.484| 1.433|
| Zakarpattia oblast | 13.641              | 30.172| 3.111|
| Zaporizhzhia oblast | 2.900               | 0.989| 4.110|
| Ivano-Frankivsk oblast | 0.786              | 3.859| 0.615|
| Kyiv oblast       | 2.660                 | 2.634| 2.794|
| Kirovohrad oblast | 0.804                 | 8.107| 7.069|
| Luhansk oblast    | 0.649                 | 2.922| 17.242|
| Lviv oblast       | 2.461                 | 2.982| 2.548|
| Mykolaiv oblast   | 1.284                 | 0.531| 1.028|
| Odesa oblast      | 1.049                 | 3.493| 3.655|
| Poltava oblast    | 3.544                 | 7.066| 0.420|
| Rivne oblast      | 1.267                 | 9.221| 0.255|
| Sumy oblast       | 1.006                 | 1.340| 0.835|
| Ternopil oblast   | 1.157                 | 3.211| 0.572|
| Kharkiv oblast    | 2.824                 | 2.779| 5.331|
| Kherson oblast    | 5.122                 | 8.547| 5.408|
| Khmelnytskyi oblast | 1.131              | 1.328| 14.065|
| Cherkasy oblast   | 4.676                 | 10.207| 12.029|
| Chernivtsi oblast | 1.775                 | 0.899| 1.746|
| Chernihiv oblast  | 4.817                 | 8.204| 11.197|

From the results of the calculation of indicators for 2017–2019 (Table 3), the ratio of sold innovative industrial goods and services to the cost of innovation of industrial enterprises in Donetsk, Luhansk, Khmelnytskyi, Cherkasy, and Chernihiv oblasts is relatively large, indicating good cost-effectiveness of innovation enterprises compared with other regions. The worst value of the cost-effectiveness for innovation is in Rivne oblast, for which it is 0.255 in 2019. In addition, relatively low values are in Poltava and Dnipropetrovsk oblasts, where the value of the indicator is less than 0.5 in 2019. In total, there are seventeen regions where the value of the indicator is greater than 1 in 2019. However, the cost of innovation has an effect only after a few years in the form of a significant increase in sales of innovative products.

Table 4 shows the results of calculating the indicators of the availability of costs for the performance of R&D.
The results of the calculation of indicators (Table 4) show that most regions have relatively low costs for R&D per relevant organization. However, some regions, such as Dnipropetrovsk, Zaporizhzhia, Kyiv, Mykolaiv, Ternopil, and Kharkiv oblasts, show relatively better results. Volyn, Donetsk, and Rivne oblasts demonstrate smaller values. Note the relatively small deviations in the values of indicators for all regions over 2017–2019.

Tables 5 and 6 show the results of calculating the average values of the indicators $I_s$, $I_p$, $I_e$, $I_s$, and for them, the values of the indicator $C_I$ over 2017–2019 for each region. Values are ranked in descending order, i.e. the regions with the best indicators are at the top of the list.

### Table 4. Results of calculation of indicators $I_s$ by regions of Ukraine, 2017–2019

| Region of Ukraine          | Indicator $I_s$, thousand Ukrainian hryvnias/units | 2017   | 2018   | 2019   |
|----------------------------|--------------------------------------------------|--------|--------|--------|
| Vinnytsia oblast           |                                                   | 2,037  | 2,336  | 2,201  |
| Volyn oblast               |                                                   | 2,046  | 2,048  | 1,658  |
| Dnipropetrovsk oblast      |                                                   | 41,888 | 36,246 | 40,526 |
| Donetsk oblast             |                                                   | 736    | 955    | 1,548  |
| Zhytomyr oblast            |                                                   | 3,122  | 3,406  | 4,395  |
| Zakarpattia oblast         |                                                   | 6,905  | 9,388  | 7,769  |
| Zaporizhzhia oblast        |                                                   | 29,486 | 53,381 | 56,980 |
| Ivano-Frankivsk oblast     |                                                   | 1,650  | 3,422  | 3,008  |
| Kyiv oblast                |                                                   | 9,974  | 13,693 | 14,919 |
| Kirovohrad oblast          |                                                   | 5,041  | 6,717  | 2,487  |
| Luhansk oblast             |                                                   | 1,955  | 3,073  | 3,022  |
| Lviv oblast                |                                                   | 4,880  | 5,928  | 6,747  |
| Mykolai oblast             |                                                   | 13,436 | 13,779 | 10,756 |
| Odesa oblast               |                                                   | 5,630  | 6,504  | 6,710  |
| Poltava oblast             |                                                   | 2,999  | 4,036  | 2,626  |
| Rivne oblast               |                                                   | 1,248  | 1,757  | 1,468  |
| Sumy oblast                |                                                   | 10,044 | 13,031 | 7,201  |
| Ternopil oblast            |                                                   | 1,477  | 2,516  | 3,233  |
| Kharkiv oblast             |                                                   | 16,104 | 22,301 | 20,605 |
| Kherson oblast             |                                                   | 3,505  | 4,273  | 3,439  |
| Khmelnytskyi oblast        |                                                   | 2,189  | 2,661  | 2,137  |
| Cherkasy oblast            |                                                   | 4,868  | 4,929  | 3,253  |
| Chernivtsi oblast          |                                                   | 3,796  | 4,885  | 8,133  |
| Chernihiv oblast           |                                                   | 3,164  | 3,517  | 4,634  |

### Table 5. Average values of indicators $I_s$, $I_p$, and for them, the values of the indicator $C_I$ by regions of Ukraine, 2017–2019

| Region of Ukraine          | $I_s$ for $I$ | Region of Ukraine | $I_p$ for $I_s$ |
|----------------------------|---------------|-------------------|-----------------|
| Kharkiv oblast             | 0.031         | Donetsk oblast    | 18,231          |
| Ternopil oblast            | 0.029         | Kirovohrad oblast | 3,172           |
| Sumy oblast                | 0.026         | Cherky oblast     | 1,554           |
| Kirovohrad oblast          | 0.025         | Chernihiv oblast  | 1,049           |
| Cherny oblast              | 0.023         | Vinnytsia oblast  | 973             |
| Poltava oblast             | 0.022         | Ternopil oblast   | 921             |
| Zaporizhzhia oblast        | 0.02          | Zaporizhzhia oblast | 889         |
| Vinnytsia oblast           | 0.019         | Volyn oblast      | 781             |
| Ivano-Frankivsk oblast     | 0.019         | Luhansk oblast    | 776             |
| Volyn oblast               | 0.018         | Zakarpattia oblast | 683         |
| Mykolaiv oblast            | 0.018         | Kyiv oblast       | 657             |
| Lviv oblast                | 0.016         | Kherson oblast    | 607             |
| Donetsk oblast             | 0.016         | Zhytomyr oblast   | 594             |
| Dnipropetrovsk oblast      | 0.016         | Sumy oblast       | 516             |
| Zhytomyr oblast            | 0.015         | Ivano-Frankivsk oblast | 483      |
| Luhansk oblast             | 0.014         | Poltava oblast    | 482             |
| Kyiv oblast                | 0.014         | Mykolaiv oblast   | 298             |
| Kherson oblast             | 0.014         | Khmelnytskyi oblast | 240     |
| Odesa oblast               | 0.014         | Kharkiv oblast    | 234             |
| Chernivtsi oblast          | 0.013         | Odesa oblast      | 226             |
| Chernihiv oblast           | 0.013         | Lviv oblast       | 213             |
| Rivne oblast               | 0.012         | Dnipropetrovsk oblast | 100        |
| Zakarpattia oblast         | 0.011         | Rivne oblast      | 68              |
| Khmelnytskyi oblast        | 0.009         | Chernivtsi oblast | 56              |

Source: State Statistics Service of Ukraine (2018, 2019, 2020).
Tables 5 and 6 show that Cherkasy and Zaporizhzhia oblasts are the most competitive regions in innovation activities over 2017–2019 in Ukraine: they are at the top of the rankings in three indicators. Innovation management in these regions is better. Several other regions – Kharkiv, Ternopil, Sumy, Kirovohrad, and Vinnytsia oblasts – are leading in two indicators. Outsiders include Khmelnytskyi, Chernivtsi, and Rivne oblasts; they are at the end of the competitiveness ranking in three indicators. Odesa and Rivne oblasts are at the bottom of the ranking in two indicators. Most regions fall simultaneously at the top and bottom of the list in different indicators.

Tables 5 and 6 show that Cherkasy and Zaporizhzhia oblasts are the most competitive regions in innovation activities over 2017–2019 in Ukraine: they are at the top of the rankings in three indicators. Innovation management in these regions is better. Several other regions – Kharkiv, Ternopil, Sumy, Kirovohrad, and Vinnytsia oblasts – are leading in two indicators. Outsiders include Khmelnytskyi, Chernivtsi, and Rivne oblasts; they are at the end of the competitiveness ranking in three indicators. Odesa and Rivne oblasts are at the bottom of the ranking in two indicators. Most regions fall simultaneously at the top and bottom of the list in different indicators.
Table 8. Results of calculating dynamic indices \( i_1 \) and \( i_5 \) by regions of Ukraine, 2017–2019

| Region of Ukraine | \( i_1 \) | Region of Ukraine | \( i_5 \) |
|-------------------|-----------|-------------------|-----------|
| Luhansk oblast     | 5.15      | Ternopil oblast   | 1.38      |
| Khmelnytskyi oblast| 3.53      | Chernivtsi oblast | 1.37      |
| Kirovohrad oblast  | 2.97      | Donetsk oblast    | 1.36      |
| Volyn oblast       | 2.39      | Zaporizhzhia oblast| 1.30      |
| Odesa oblast       | 1.87      | Ivano-Frankivsk oblast| 1.26      |
| Cherkasy oblast    | 1.60      | Luhansk oblast    | 1.16      |
| Chernihiv oblast   | 1.52      | Kyiv oblast       | 1.14      |
| Donetsk oblast     | 1.52      | Chernihiv oblast  | 1.13      |
| Kharkiv oblast     | 1.37      | Zhytomyr oblast   | 1.11      |
| Dnipropetrovsk oblast | 1.36   | Lviv oblast       | 1.10      |
| Zaporizhzhia oblast| 1.19      | Kharkiv oblast    | 1.06      |
| Kherson oblast     | 1.03      | Odesa oblast      | 1.02      |
| Kyiv oblast        | 1.02      | Rivne oblast      | 1.01      |
| Lviv oblast        | 1.02      | Zakarpattia oblast| 0.99      |
| Chernivtsi oblast  | 0.99      | Vinnytsia oblast  | 0.97      |
| Sumy oblast        | 0.91      | Kherson oblast    | 0.93      |
| Mykolayiv oblast   | 0.89      | Khmelnytskyi oblast| 0.92      |
| Ivano-Frankivsk oblast | 0.88    | Dnipropetrovsk oblast| 0.92      |
| Ternopil oblast    | 0.70      | Poltava oblast    | 0.88      |
| Zakarpattia oblast | 0.48      | Volyn oblast      | 0.84      |
| Rivne oblast       | 0.45      | Mykolayiv oblast  | 0.84      |
| Vinnytsia oblast   | 0.42      | Sumy oblast       | 0.79      |
| Poltava oblast     | 0.34      | Cherkasy oblast   | 0.76      |
| Zhytomyr oblast    | 0.31      | Kirovohrad oblast | 0.66      |

From the calculation results of Tables 7 and 8, according to the values of the dynamic indices \( i_P \), \( i_E \) \( i_S \), respectively, 83%, 58%, 54% of the regions of Ukraine have an increase over time in the values of three indicators of the development of innovation activities. In such regions the values of dynamic indices are higher than 1.

Only 29% of the regions have \( i \) values greater than 1, which means that the share of innovatively active industrial enterprises in other regions is decreasing. The \( i \) index is less than 1 in only four regions, which indicates a decrease in time over the volume of innovative products sold by the region per employee involved in research. Less than half of the regions have values of the \( i_1 \) and \( i_5 \) indices less than 1, which is unsatisfactory for them. Moreover, most regions show an increase in performance and, accordingly, they have better competitiveness.

4. DISCUSSION

The obtained values of \( I_i \) indicators determine the share of innovatively active enterprises in all considered regions as small, while the contribution of innovatively active industrial enterprises to the overall development of innovation activities in the region is the most significant. In many cases, a small value of the indicator points to a small investment in innovation.

The results of calculating \( i_P \) indicators specify the productivity of the release of innovative goods and services per one employee engaged in R&D as relatively low in most regions. This can indicate that such regions have low integration of education, science, industry, and business.

From the results of calculating the \( i_1 \) indicators, one can see that the ratio of the volume of sold innovative industrial goods and services to the costs of innovation of industrial enterprises in most regions is relatively small. Although, high costs of innovation are a positive factor, as they will have a positive effect in the future.

Based on the obtained data for calculating the \( i_S \) indicators, one can see that most regions have relatively low costs for performing R&D per organization that may be due to the underfunding of this area from both the regional budget and the state. However, this can indicate that the network of scientific organizations is not optimal.

The results of calculations of the average values of indicators \( I_P \), \( I_E \), \( I_S \) and the indicators for their relative assessment of competitiveness in innovation activities demonstrate that no region would fall to the top of the competitiveness rankings in all four indicators. Moreover, most regions fall simultaneously at the top and bottom of the rankings that indicates the heterogeneity of the development of innovation activities and confirms the results.

The values of \( i_1 \), \( i_P \), \( i_E \), \( i_S \) indices for most regions are greater than 1, which indicates that these regions progress in innovation activities over time and potential for further development. However, regions with relatively large index values may need large investments to maintain the pace of innovation. The
regions with values less than 1 have a declining level of the development of innovation activities.

The obtained results are generally a continuation of the research of other scientists. Comparing with results by Kniazeyvych et al. (2018), it is found that the management decisions for the development of innovation activities in the region are also the main factors in the development of the Ukrainian innovation system. Results by Ilyash et al. (2018) are traced in this study in $I_p, I_e$ indicators for the regions. Boronos et al. (2020) developed normalized indicators for assessing the level of development of the territorial innovation system, where the basis of comparison is the best absolute value of the indicator. It is suitable for assessing the competitiveness in innovation. Results showed that Ukrainian regions are different from each other in innovation development. The method in this study is quite simple and at the same time it covers the main areas of innovation activities of the regions with the opportunity to be improved. Indicators have the relative character that makes them comparable, eliminating the scope of absolute values of their components. Some components of indicators in any form are used in calculations of popular global indices, but they are quite universal, which allows using them at the regional level. In addition, the method contains dynamic indices that show changes in characteristics over time. This is especially important in cases where the factor used in the calculations has a delayed effect. The results show that in comparison with the existing results, most regions of Ukraine also have relatively low values of the indicators of the development of innovation activities, but over time, most of them have improved.

**CONCLUSION**

Assessment of the development of innovation activities in the individual regions of Ukraine using the relative indicators show that all considered regions of Ukraine have significant differences in results. For most regions, the values of indicators of the development of innovation activities are relatively low. The average values of these indicators and the indicators of the competitiveness in innovation activities demonstrate that most considered regions have heterogeneous development of innovation activities. However, over time all indicators improved in at least 29% of regions. In addition, on three indicators out of four, the values improved in at least 54% of regions.

Such differences in results are influenced by the nature of regional management decisions. The goal of ensuring the high competitiveness of the region through the development of innovative activities is common at the level of each region since competitiveness and innovation are interdependent. According to the above, management decisions in all considered regions of Ukraine should be aimed at the implementation of integration processes on an innovative basis in education and science, industry and business, as well as increasing the level of innovation activity of enterprises, especially in the form of promoting appropriate investment. It should be increasing in funding for the implementation of R&D, and the optimization of the activities of organizations engaged in R&D. However, efforts should be aimed not so much at increasing the costs of innovation, but at increasing the efficiency of these costs. Management decisions should be comprehensive for all considered regions. For the regions where there is no improvement over time, the proposed management decisions should be implemented first.

The different competitiveness of the regions reflects the differences in the development of innovation activities of the regions. The most notable impact on the development of innovation activities is the funding of innovation activities. The sufficient funding of innovation activities in each region can be one of the means of mitigating regional differences. Therefore, it is important to ensure effective funding for innovation activities at the regional level in Ukraine.

The practical use of the obtained results is the application of the proposed assessment methods, management decisions regarding the development of innovation activities in the region, and increasing the competitiveness of the region in innovation activities.
Opportunities for future research in this direction lie in the plane of identifying specific factors influencing the innovation activities of the most competitive regions. In addition, the study of new sources of progress in sustainable development based on the development of innovation activities in the regions is of scientific interest.

AUTHOR CONTRIBUTIONS

Conceptualization: Pavlo Hrytsenko, Viacheslav Voronenko.
Data curation: Pavlo Hrytsenko, Viacheslav Voronenko.
Formal analysis: Pavlo Hrytsenko, Viacheslav Voronenko.
Funding acquisition: Pavlo Hrytsenko, Viacheslav Voronenko, Yevhen Kovalenko, Tetiana Kurman, Vitalii Omelianenko.
Investigation: Pavlo Hrytsenko, Viacheslav Voronenko, Yevhen Kovalenko, Tetiana Kurman, Vitalii Omelianenko.
Methodology: Pavlo Hrytsenko, Viacheslav Voronenko.
Project administration: Viacheslav Voronenko.
Resources: Pavlo Hrytsenko, Viacheslav Voronenko, Yevhen Kovalenko, Tetiana Kurman, Vitalii Omelianenko.
Software: Pavlo Hrytsenko, Viacheslav Voronenko, Yevhen Kovalenko, Tetiana Kurman, Vitalii Omelianenko.
Supervision: Viacheslav Voronenko.
Validation: Pavlo Hrytsenko, Viacheslav Voronenko, Yevhen Kovalenko, Tetiana Kurman, Vitalii Omelianenko.
Visualization: Pavlo Hrytsenko, Viacheslav Voronenko, Yevhen Kovalenko, Tetiana Kurman, Vitalii Omelianenko.
Writing – original draft: Pavlo Hrytsenko, Viacheslav Voronenko.
Writing – review & editing: Viacheslav Voronenko.

ACKNOWLEDGMENTS

The paper is prepared within the scientific research project “Sustainable development and resource security: from disruptive technologies to digital transformation of Ukrainian economy” (No. 0121U100470).

REFERENCES

1. Arnkil, R., Jarvensivu. A., Koski, P., & Piirainen, T. (2010). Exploring Quadruple Helix: Outlining user-oriented innovation models (Working Papers 85/2010). University of Tampere. Retrieved from https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.864.3864&rep=rep1&type=pdf
2. Autio, E. (1998). Evaluation of RTD in regional systems of innovation. European Planning Studies, 6(2), 131-140. https://doi.org/10.1080/09654319808720451
3. Bloomberg Business. (2015). The Bloomberg Innovation Index. Retrieved from https://www.bloomberg.com/graphics/2015-innovative-countries/
4. Boronos, V. H., Plikus, I. Y., Kubakh, T. H., & Fedchenko, K. A. (2020). Methodology for assessing the level of innovative development of the territories. Revista ESPACIOS, 41(07). Retrieved from http://www.revistaespacios.com/a20v41n07/20410711.html
5. Cornell University, INSEAD, & WIPO. (2020). The Global Innovation Index. Retrieved from https://www.globalinnovationindex.org
6. Doloreux, D., & Parto, S. (2005). Regional innovation systems: Current discourse and unresolved issues. Technology in Society, 27(2), 133-153. https://doi.org/10.1016/j.techsoc.2005.01.002
7. Economist Intelligence Unit. (2016). Social Innovation Index. Retrieved from https://eiuperspectives.economist.com/technology-innovation/old-problems-new-solutions-measuring-capacity-social-innovation-across-world-0
8. European Commission. (2020). European Innovation Scoreboard 2020. Retrieved from https://ec.europa.eu/commission/presscorner/detail/en/QAN-DA_20_1150
9. Horobchenko, D., & Voronenko, V. (2018). Approaches to the formation of a theoretical model for the analysis of environmental and economic development. Journal of Environmental Management
10. Ilyash, O., Dzhadan, I., & Ostasz, G. (2018). The influence of the industry's innovation activities indices on the industrial products' revenue of Ukraine. *Economics and Sociology, 11*(4), 317-331. https://doi.org/10.14254/2071-789X.2018/11-4/21

11. Indiana Business Research Center. (2016). *Driving Regional Innovation. The Innovation Index 2.0.* Retrieved from https://www.stat-samdra.org/ii2/reports/Driving-Regional-Innovation.pdf

12. Ivanova, E., & Kordos, M. (2017). Competitiveness and innovation performance of regions in Slovak Republic. *Marketing and Management of Innovations, 1*, 145-158. https://doi.org/10.21272/mmi.2017.1-13

13. Ivanova, E., & Masarova, J. (2016). Assessment of innovation performance of Slovak regions. *Journal of International Studies, 9*(2), 207-218. https://doi.org/10.14254/2071-8330.2016/9-2/16

14. Kartanaite, I., Kovalov, B., Kubitko, O., & Krušinskas, R. (2021). Financial modeling trends for production companies in the context of Industry 4.0. *Investment Management and Financial Innovations, 18*(1), 270-284. http://dx.doi.org/10.21511/imfi.18(1).2021.23

15. Kniazeych, A., Kyyrylenko, V., & Golovkova, L. (2018). Innovation infrastructure of Ukraine: assessment of the effectiveness of the action and ways of improvement. *Baltic Journal of Economic Studies, 4*(1), 208-218. https://doi.org/10.30525/2256-0742/2018-4-1-208-218

16. Lopez-Claros, A., & Mata, Y.N. (2010). The Innovation Capacity Index: Factors, Policies, and Institutions Driving Country Innovation. In *The Innovation for Development Report 2009–2010*. London: Palgrave Macmillan. https://doi.org/10.1057/9780230285477_1

17. Nauwelaers, C., & Reid, A. (1995). Methodologies for the evaluation of regional innovation potential. *Scientometrics, 34*, 497-511. https://doi.org/10.1007/BF02018016

18. Nesta. (2021). *The European Digital Social Innovation Index.* Retrieved from https://www.nesta.org.uk/feature/european-digital-social-innovation-index

19. Oughton, C., Landabaso, M., & Morgan, K. (2002). The Regional Innovation Paradox: Innovation Policy and Industrial Policy. *The Journal of Technology Transfer, 27*, 97-110. https://doi.org/10.1023/A:1013104805703

20. Sarkar, A. N. (2013). Promotion of Eco-Innovation to Leverage Sustainable Development of Eco-Industry and Green Growth. *European Journal of Sustainable Development, 2*(1), 171-224. https://doi.org/10.14207/ejsd.2013.v2n1p171

21. Shkarupa, O. V. (2015). Management of region’s social and economic development environmental modernization. *Economic Annals-XXI, 7-8*(2), 57-60.

22. Sotnyk, I. M., Volk, O. M., & Chortok, Y. V. (2013). Increasing ecological & economic efficiency of ICT introduction as an innovative direction in resource saving. *Actual Problems of Economics, 147*(9), 229-235.

23. State statistics service of Ukraine. (2018). *Scientific and innovative activities in Ukraine.* Retrieved from http://www.ukrstat.gov.ua/druk/publicat/kat_u/2018/zb/09/zb_nauka_2017.pdf

24. State statistics service of Ukraine. (2019). *Scientific and innovative activities in Ukraine.* Retrieved from http://www.ukrstat.gov.ua/druk/publicat/kat_u/2019/zb/09/zb_nauka_2018.pdf

25. State statistics service of Ukraine. (2020). *Scientific and innovative activities in Ukraine.* Retrieved from http://www.ukrstat.gov.ua/druk/publicat/kat_u/2020/zb/09/zb_nauka_2019.pdf

26. Stejskal, J., Kuviková, H., Meričková, B. M. (2018). Regional Innovation Systems Analysis and Evaluation: The Case of the Czech Republic. In J. Stejskal, P. Hajek & O. Hudec (Eds.), *Knowledge Spillovers in Regional Innovation Systems* (pp. 81-113). Cham: Springer. https://doi.org/10.1007/978-3-319-67029-4_3

27. Tödtling, F., & Trippl, M. (2005). One size fits all?: Towards a differentiated regional innovation policy approach. *Research Policy, 34*(8), 1203-1219. https://doi.org/10.1016/j.respol.2005.01.018

28. United Nations Statistics Division. (2001). *Technology Achievement Index.* Retrieved from https://measuring-progress.eu/technology-achievement-index

29. United Nations. (2015). *Transforming our world: the 2030 Agenda for Sustainable Development.* Retrieved from https://sdgs.un.org/2030agenda

30. Wu, M., Zhao, M., & Wu, Z. (2019). Evaluation of development level and economic contribution ratio of science and technology innovation in eastern China. *Technology in Society, 59*, 101194. https://doi.org/10.1016/j.techsoc.2019.101194