# Strategies for sustainable socio-economic development and mechanisms their implementation in the global dimension

**Collective monograph edited by M. Bezpartochnyi**

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The authors of the book have come to the conclusion that it is necessary to effectively use modern approaches to developing and implementation strategies of sustainable socio-economic development in order to increase efficiency and competitiveness of economic entities. Basic research focuses on assessment of effectiveness the investment projects, use of cluster analysis the innovative activity of regions, formation and use of financial resources, competitiveness management and use of modern methods sale of the goods, effectiveness the activities of territorial communities. The research results have been implemented in the different models and strategies of project-oriented resource management, state management of development of territorial communities, implementation of the concept inclusive oriented economic development, efficient functioning and development of electric power enterprises, agricultural production, tourist industry, lifelong learning concepts. The results of the study can be used in decision-making at the level the economic entities in different areas of activity and organizational-legal forms of ownership, ministries and departments that promote of development the economic entities on the basis of models and strategies for sustainable socio-economic development. The results can also be used by students and young scientists in modern concepts and mechanisms for management of sustainable socio-economic development of economic entities in the condition of global economic transformations and challenges.



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# Contents

8. *Social market economy: an organization for Ukraine / R. Klapgam, M. Lohmann, O. Oliynik ta in. : as amended R. Klapgama. - 2nd view. - TO. : FADA, LTD. - 2006. - 88 p.*

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# INNOVATIVE ACTIVITY OF UKRAINIAN REGIONS: CLUSTER ANALYSIS

The relevance of the study of innovative activity in special terms is defined by the high level of differentiation of the social and economic development of regions and further development of the decentralization policy in Ukraine. The assessment of the innovative activity of the regions is not only a factor in the rating dynamics of competitiveness but also an effective tool for designing strategies for the development of inter-regional industrial relations. In many cases, the lack of data on regional channels of technology and knowledge transfer or local levels of scientific and innovative activity becomes an obstacle to stand against the tension of international competition. The allocation of regional clusters by innovative activity helps identify gaps and specialization of the region and is the first step in more comprehensive regional development studies.

Most current methods of analyzing the innovative activity of regions are based on the division of regions into groups using integral indicators (for example, relatively strong, medium and weak regions). This approach is based on a quantitative comparison of regions without the possibility of a meaningful description of their peculiarities. However, innovation is a complex feature that incorporates heterogeneous indicators. Therefore, in this study, k-means clustering and hierarchical cluster analysis algorithms are used to analyze the innovation activity of Ukrainian regions. The application of multidimensional statistical analysis methods is implemented in the STATISTICA application package. The initial data for the analysis of the innovative activity of regions of Ukraine are presented in Table 1.8.

*Table 1.8*

**Indicators of the innovative activity of regions, 2017**

| Region | Number of R&D personnel | Number of enterprises realized innovative production, units | New technological processes put into service, units | Number of innovative products items, units |
|---|---|---|---|---|
| | $Var_1$ | $Var_2$ | $Var_3$ | $Var_4$ |
| Vinnytsia | 627 | 14 | 15 | 52 |
| Volyn | 314 | 12 | 8 | 7 |
| Dnipropetrovsk | 8954 | 18 | 107 | 84 |
| Donetsk | 238 | 13 | 69 | 101 |
| Zhytomyr | 410 | 20 | 13 | 20 |
| Zakarpattia | 562 | 9 | 7 | 8 |
| Zaporizhzhia | 4216 | 31 | 142 | 319 |
| Ivano-Frankivsk | 580 | 14 | 23 | 109 |
| Kyiv | 1805 | 22 | 38 | 116 |
| Kirovohrad | 503 | 13 | 16 | 36 |
| Luhansk | 350 | 3 | 4 | 11 |
| Lviv | 4680 | 24 | 41 | 247 |
| Mykolaiv | 2268 | 12 | 29 | 19 |
| Odesa | 3003 | 17 | 50 | 83 |
| Poltava | 1181 | 19 | 31 | 86 |
| Rivne | 378 | 3 | 8 | 6 |
| Sumy | 2081 | 17 | 225 | 217 |
| Ternopil | 361 | 9 | 78 | 39 |
| Kharkiv | 14851 | 77 | 230 | 396 |
| Kherson | 732 | 10 | 24 | 80 |
| Khmelnytsk | 380 | 4 | 7 | 7 |
| Cherkasy | 705 | 23 | 30 | 53 |
| Chernivtsi | 809 | 7 | 12 | 25 |
| Chernihiv | 699 | 7 | 75 | 97 |
| Kyiv city | 43587 | 52 | 549 | 199 |

*Note: Compiled based on the data of "Statistical collection. Ukraine in numbers in 2017"; data exclude the temporarily occupied territories of the Autonomous Republic of Crimea, the city of Sevastopol and some temporarily occupied territories in the Donetsk and Luhansk regions*

The k-means algorithm provides for the division of objects into classes, which minimizes distances between objects of the same class and maximizes distances between objects of different classes.

Mathematically, the k-means algorithm for the set task can be described as follows (James MacQueen, 1976; Brotikovskaia D., et al., 2018):

– given: a set of n observations X={x1, x2,..., xn}, xi∈Rd, i=1,...,n; k is the number of clusters k∈N, k≤n. In this study, n = 25 (number of regions and Kyiv city), *k* = 4 (number of clusters).

V-fold cross-validation was used to determine the number of clusters and a graph of cost sequence was constructed (Fig. 1.2).

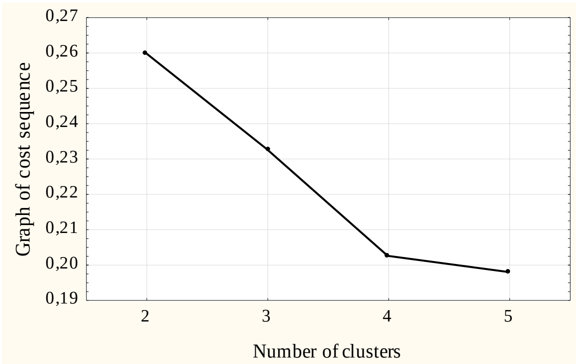


**Figure 1.2 Graph of cost sequence**

The graph of cost sequence displays the error function for a different number of clusters. The error function determines the average observation distances in the selection of the identified centroids of the cluster. Analyzing Figure 1.2, it can be determined that the error function quickly changes from the second to the third cluster solution and then "equalizes". Thus, the division of regions of Ukraine into four clusters is the optimal amount.

– *it is necessary to:* divide the set of observations *X* into *k* clusters

*S1, S2,..., Sk, where Si∩Sj = ∅, i ≠ j;* $\bigcup_{i=1}^{k} S_i = X$.

The k-means algorithm breaks the set *X* into *k* sets $S_1, S_2, \ldots, S_k$, to minimize the sum of squares of distances from each point of the cluster to its center (center of mass of the cluster). K-mean search matches:

$$\arg\min_S \sum_{i=1}^{k} \sum_{x \in S_i} p(x, \mu_i)^2 , \qquad (1.2)$$

where $\mu_i$ are the centers of the cluster, $i = 1,...,k$; $\rho\ (x, \mu_i)$ is the function of the distance between $x$ and $\mu_i$.

The Euclidean distance was used to distribute vectors by clusters $x_i \in X$, $i=1,...,n$ with cluster centers $\mu_1,...,\mu_k$.

$$v1, v2 \in R^d,\ \rho(v1, v2) = \|v_1 - v_2\| = \sqrt{\sum_{i=1}^{d} ((v)_{1,i} - v_{2,i})^2} \qquad (1.3)$$

Because the original data have different dimensions of feature space, the data were standardized before performing the cluster analysis. A standardized scale reflects the location of any value of the $x_i$ feature in the totality of the data, measuring its deviation from the arithmetic mean in units of standard deviation.

$$z_{ij} = \frac{(x_{iJ} - \bar{x})}{\sigma}, \qquad (1.4)$$

where $z_{ij}$ is a standard value for $x_{iJ}$; $x_i$ is observation, $\bar{x}$ is arithmetic mean of primary results; σ is the standard deviation.

Standardization means the replacement of individual attribute values $x_{ij} = (x_{1j}, x_{2j}, ..., x_{mj})$ with standardized $z_{ij} = (z_{1j}, z_{2j}, ..., z_{mj})$ with preservation of the ratios available between the indicators.

Using the starting data from Table 1.8 and methods of multidimensional statistical analysis in the STATISTICA application package, clusters of innovation activity of regions of Ukraine were identified (Table 1.9).

The characteristics of the identified clusters with the information on centroids and the quantitative structure of the clusters are presented in Table 1.10. Based on the data obtained, the distribution of regions of Ukraine by the cluster is disproportionate, which indicates a significant heterogeneity of the innovative activity.

*Table 1.9*

**Clustering of regions of Ukraine by k-means algorithm**

| Cluster | Region |
|---|---|
| Cluster 1 | Dnipropetrovsk, Donetsk, Ivano-Frankivsk, Kyiv, Odesa, Poltava, Kherson, Cherkasy, Chernihiv |
| Cluster 2 | Vinnytsia, Volyn, Zhytomyr, Zakarpattia, Kirovohrad, Luhansk, Mykolaiv, Rivne, Ternopil, Khmelnytsk, Chernivtsi |
| Cluster 3 | Kharkiv, Kyiv city |
| Cluster 4 | Zaporizhzhia, Lviv, Sumy |

*Note: Algorithm – k-means; distance method – Euclidean distances; initial centers – maximize initial distance*

*Table 1.10*

**Characteristics of clusters by indicators of the innovative activity**

| Cluster | Centroids of k-means clustering | | | | | |
|---|---|---|---|---|---|---|
| | $Var_1$ | $Var_2$ | $Var_3$ | $Var_4$ | Number of regions | (%) |
| Cluster 1 | -0,199684 | -0,131794 | -0,201225 | -0,065842 | 9 | 36% |
| Cluster 2 | -0,351559 | -0,522133 | -0,472311 | -0,734620 | 11 | 44% |
| Cluster 3 | 2,850967 | 2,902944 | 2,699634 | 1,947006 | 2 | 8% |
| Cluster 4 | -0,012543 | 0,374573 | 0,535727 | 1,593128 | 3 | 12% |

Table 1.11 shows standardized distances between centroids. The standardized distance between the centroids according to the k-means algorithm is calculated from the cluster averages for each measurement.

*Table 1.11*

**Standardized distance between centroids**

| Cluster | Standardized distance between centroids of k-means clustering | | | |
|---|---|---|---|---|
| | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 |
| Cluster 1 | 0,000000 | 0,206872 | 1,224057 | 0,480720 |
| Cluster 2 | 0,206872 | 0,000000 | 1,397279 | 0,684459 |
| Cluster 3 | 1,224057 | 1,397279 | 0,000000 | 0,933977 |
| Cluster 4 | 0,480720 | 0,684459 | 0,933977 | 0,000000 |

Analysis of variance to determine the significance of differences between the clusters obtained is presented in Table 1.12. The table shows quantitative characteristics of innovative activity indicators of areas: between cluster dispersion (*Between SS*), number of degrees of freedom for intercluster dispersion ($df_b$), variance within clusters (*Within SS*), number of degrees of freedom for intra-cluster dispersion ($df_w$) and criteria for testing the hypothesis of inequality of variances (*F*, *signif. p*).

*Table 1.12*

**Analysis of variance to determine the significance of differences between the clusters obtained**

| Variable | Analysis of Variance | | | | | |
|---|---|---|---|---|---|---|
| | *Between SS* | $df_b$ | *Within SS* | $df_w$ | *F* | *Signif. p* |
| Number of R&D personnel | 17,974 | 3 | 6,025 | 21 | 20,883 | 0,000 |
| Number of enterprises realized innovative production, units | 20,430 | 3 | 3,5674 | 21 | 40,062 | 0,000 |
| New technological processes put into service, units | 18,255 | 3 | 5,745 | 21 | 22,244 | 0,000 |
| Number of innovative products items, units | 21,171 | 3 | 2,829 | 21 | 52,388 | 0,000 |

The smaller the value of the intracluster dispersion and the greater the value of the intercluster dispersion, the better the characteristic characterizes the object's belonging to the cluster and the better the clustering (Erina A.M, 2014). The values of the *F* and *p-level* also characterize the contribution of the trait to the distribution of objects by the cluster. The higher the clustering quality, the higher the *F* value and the lower the *p-level.* The results of the analysis of variance confirm the significance of the intercluster differences ($p < 0.05$).

The graph of the given mean values by clusters is presented in Figure 1.3, the geographical visualization is shown in Figure 1.4.

To summarize the above-mentioned, the highest innovation activity is observed in the Kyiv city and Kharkiv region (cluster 3). Lviv, Zaporizhzhia, and Sumy regions were also quite positive in terms of innovative activity. According to the indicator of the number of employees involved in the implementation of research and development, in 2017, Dnipropetrovsk, Zaporizhzhia, Kyiv (including the Kyiv city), Lviv and Kharkiv regions have the best results. The largest number of innovative products was sold in Kharkiv and Kyiv regions. Kharkiv, Sumy, Zaporizhzhia, Dnipropetrovsk, Chernihiv regions and Kyiv have the best performance in terms of the number of new technological processes implemented at industrial enterprises. The research reveals a certain unevenness of innovative activity of Ukrainian regions. Thus, regions with low rates of the innovative activity include Khmelnytsk, Ternopil, Rivne, and others (cluster 2).

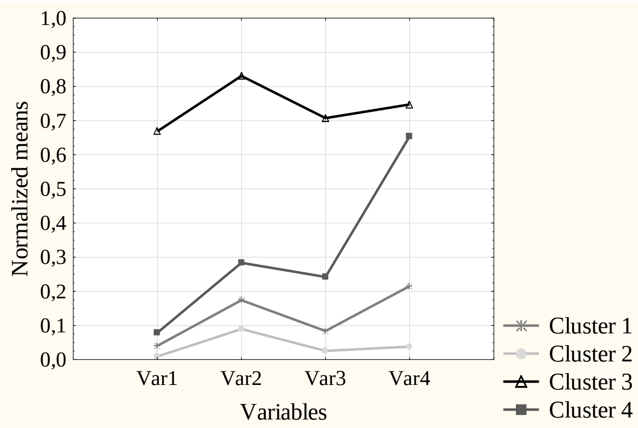


**Figure 1.3 Graph of the averaged values by cluster**


**Figure 1.4 Clustering of regions of Ukraine by the innovative activity**

It is worth noting that the division of multidimensional space into clusters (in our case, the division of regions in terms of innovative activity) makes it possible to simplify further data processing and decision making by applying a specific method of analysis to each cluster. However, there is no best option for clustering. Any primary set of objects can be divided into a specific, predefined number of clusters in different ways and get different results (Erina A. M, 2014). The division of a set of objects into clusters is related to a selection criterion (for example: to select observations that maximize the initial intercluster distances; to randomly select *k* observations; to select the first *k* observations).

The formation of indicators of innovative activity of the region is influenced by various factors, such as population, income level, availability of a wide range of different creative activities and, accordingly, talented employees, as well as the availability of enterprises and organizations capable of implementing the innovative activity.

Increase in the level of innovative activity of Ukrainian regions can be achieved under the following conditions:

– attracting highly educated and talented employees to help to increase the indicators of innovative development, the economic growth rate and the level of competitiveness of the region increase accordingly;

– stimulation of innovative activity strategies of enterprises and organizations by the bodies of public administration and self-government;

– intensification and funding of R&D (private-public ratio);

– increase in gross domestic expenditures on business-funded R&D;

– ensuring effective implementation of regional scientific and technological development programs;

– ensuring political stability and security;

– efficient use of labor, energy, and trade;

– development of innovative strategies for regional development;

– increasing the level of scientific and technical publications, the number of researchers;

– ensuring the export of information and communication technologies;

– promotion of import and export of creative goods and high technologies;

– stimulation of increase of patent and intellectual indicators of the country;

– encouraging start-ups and investments in innovative development and research;

– continuous improvements in research and education;

– establishing cooperation between the business sector and universities.

Thus, to increase the level of innovative activity of regions and the country as a whole, it is necessary to develop and implement an appropriate long-term strategy for the innovative development of regions, considering the features of the territories from a particular cluster. The priorities of the innovative strategy should include the following: update of outdated technologies, increase in the volume of investment in innovation, balance of innovative supply and demand, introduction of material, energy and resource-saving technologies in all sectors of the economy, support of research in priority areas of development of science, technology, etc.

**Acknowledgements**

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