# 9. MATHEMATICAL METHODS IN ECONOMY

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# INNOVATION DEVELOPMENT OF UKRAINIAN REGIONS: COMPARATIVE AND CLUSTER ANALYSIS

*The rating Ukrainian regions by the level of innovative development has been developed on the basis ten indicators of innovation activity in industrial and of implementation of innovation products and processes in 2014. Among the Ukrainian regions are clusters with high, medium and low value of innovation development indicator have been detected. Regions of Ukraine have been attributed to the two clusters: with high and low levels of implementation innovations, rationalization proposals, intellectual property rights and advanced technology*

***Key words***: *innovation development, Ukraine, region, ranking, cluster analysis, Kohonen self-organizing maps.*

**Introduction.** Innovation is complex process from the inception of an innovative idea to its realization and perception of innovations the real economy [1]. The economic outputs of countries are closely related to the level of their innovative development. Innovative development is viewed as a process of economic growth based on the assimilation of the results of innovative activity. Difficult socio-economic situation in Ukraine is both a signal about the need to increase the level of innovative development, and at the same time the factor that prevents the enhancement of innovation activity.

The purpose of research is a comparative analysis of the level of innovative development of regions in Ukraine. The object of research is the system of innovative development indicators at the regional level in Ukraine.

The empirical base for the research was the official statistical information about scientific and innovative activity in regions of Ukraine [2-4].

The level of development of the regional innovation system was evaluated on basis of such indicators: 1) the share of innovation-active enterprises in industrial, %; 2) innovation expenditure in industrial, mln. grn.; 3) the share of sales of innovative products in industrial, %; 4) the number of enterprises that implemented innovations, units; 5) the created advanced technologies, units; 6) the number of enterprises implementing intellectual property rights, units; 7) the use of rationalization proposals, units; 8) the number of enterprises who have used rationalization proposals, units; 9) acquiring advanced technology, units; 10) the number of sold advanced technology, units.

As methods of research have been used the methods of ranking, cluster analysis (with software "Deductor Studio Academic").

## 1. Ranking of regions

The ranking Ukrainian regions have been made on the basis the quantitative values of indicators from 1) to 10). The official data about scientific and innovative activity of Autonomous Republic of Crimea in 2014 is not available. The results of ranking Ukrainian regions in 2014 except Crimea are presented in table. 1.

## 2. The clustering of Ukrainian regions by the level of innovation development in the Kohonen self-organizing maps

The clustering of Ukrainian regions according to 10 ranking was performed in "Deductor Studio Academic" by two methods: a) Kohonen self-organizing maps; b) k-means. Ukrainian regions are grouped into 3 cluster in the Kohonen self-organizing maps.

Table 1

## The ranking Ukrainian regions by the level of innovative development*

| Rank by | Kharkiv region | Kiev city | Ivano-Frankivsk region | Dnepropetrovsk region | Zaporizhzhya region | Lviv region | Poltava region | Sumy region | Donetsk region** | Mykolaiv region | Vinnytsia region | Kyiv region |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| the share of innovation-active enterprises in industrial | 4 | 5 | 3 | 16 | 2 | 10 | 24 | 7 | 14 | 6 | 15 | 20 |
| the innovation expenditure in industrial | 4 | 1 | 16 | 2 | 9 | 11 | 8 | 6 | 7 | 5 | 3 | 14 |
| the share of sales of innovative products in industrial | 5 | 13 | 5 | 24 | 15 | 12 | 2 | 1 | 15 | 19 | 10 | 11 |
| the number of enterprises that implemented innovations | 1 | 2 | 5 | 6 | 4 | 3 | 17 | 16 | 17 | 12 | 10 | 7 |
| the created advanced technologies | 2 | 1 | 7 | 3 | 12 | 11 | 6 | 19 | 4 | 4 | 10 | 7 |
| the number of enterprises implementing intellectual property rights | 1 | 2 | 9 | 3 | 8 | 6 | 4 | 15 | 5 | 11 | 11 | 6 |
| the use of rationalization proposals | 5 | 4 | 9 | 1 | 11 | 6 | 7 | 13 | 2 | 17 | 12 | 10 |
| the number of enterprises who have used rationalization proposals | 2 | 3 | 6 | 1 | 6 | 9 | 5 | 9 | 6 | 14 | 14 | 9 |
| the acquiring advanced technology | 3 | 4 | 5 | 17 | 7 | 11 | 10 | 1 | 17 | 2 | 8 | 12 |
| the sold advanced technology | 2 | 1 | 6 | 4 | 6 | 3 | 6 | 5 | 6 | 6 | 6 | 6 |
| SUM of ranks | 29 | 36 | 71 | 77 | 80 | 82 | 89 | 92 | 93 | 96 | 99 | 102 |

*Source: calculated by the author based on official data [2-4]*
*** excluding the territory not controlled by Ukraine*

The continuation of the Table 1

| Rank by | Odessa region | Zhytomyr region | Kherson region | Kirovograd region | Ternopil region | Rivne region | Volyn region | Chernivtsi region | Chernihiv region | Cherkasy region | Transcarpathian region | Khmelnytskyi region | Lugansk region** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 |
| the share of innovation-active enterprises in industrial | 9 | 18 | 1 | 8 | 12 | 12 | 22 | 11 | 17 | 23 | 25 | 21 | 19 |
| the innovation expenditure in industrial | 10 | 20 | 18 | 17 | 21 | 25 | 12 | 19 | 15 | 23 | 24 | 13 | 22 |
| the share of sales of innovative products in industrial | 9 | 20 | 4 | 7 | 15 | 23 | 8 | 13 | 21 | 18 | 3 | 22 | 25 |
| the number of enterprises that implemented innovations | 9 | 14 | 20 | 14 | 21 | 8 | 19 | 22 | 23 | 11 | 24 | 12 | 25 |
| the created advanced technologies | 20 | 9 | 15 | 18 | 12 | 20 | 15 | 20 | 14 | 20 | 20 | 20 | 15 |
| the number of enterprises implementing intellectual property rights | 9 | 11 | 15 | 21 | 17 | 18 | 23 | 23 | 18 | 18 | 14 | 25 | 21 |
| the use of rationalization proposals | 3 | 8 | 21 | 15 | 14 | 16 | 21 | 19 | 18 | 20 | 21 | 21 | 21 |
| the number of enterprises who have used rationalization proposals | 9 | 4 | 21 | 17 | 13 | 17 | 21 | 17 | 14 | 17 | 21 | 21 | 21 |
| the acquiring advanced technology | 21 | 5 | 9 | 19 | 14 | 16 | 14 | 13 | 20 | 23 | 21 | 23 | 23 |
| the sold advanced technology | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| SUM of ranks | 105 | 115 | 130 | 142 | 145 | 161 | 161 | 163 | 166 | 179 | 179 | 184 | 198 |

*Source: calculated by the author based on official data [2-4]*
*** - excluding the territory not controlled by Ukraine*

The Kohonen self-organizing map has been recognized more than 54% of the objects of the training sample. The significance of the 7 indicators 100%, 1 indicator (rank according to the

acquiring advanced technology) is 99.7%, and two (rank according to share of innovation-active enterprises in industrial and the share of sales of innovative products in industrial) less than 75%.

Kharkiv region is the nearest to the center of cluster 0, and generally has the lowest sum of ranks on all indicators of innovation development, that are considered. So, Kharkiv region was the leader of innovation development in Ukraine in 2014.

Cluster 1 consists of ten Ukrainian regions, cluster 2 – 11 (see table 2).

Table 2

**The composition of the clusters according to level of innovation development in Ukraine (in the Kohonen self-organizing maps)\***

| Cluster 0 | Cluster 1 | Cluster 2 |
|---|---|---|
| The regions with the highest value on indicators of innovative development | The regions with the average value on indicators of innovative development | The regions with the indicators of innovation development in value below the average |
| Kharkiv region<br>Lviv region<br>Dnipropetrovsk region<br>Kyiv city | Mykolaiv region<br>Donetsk region<br>Poltava region<br>Ivano-Frankivsk region.<br>Kiev region<br>Zhytomyr region<br>Vinnytsia region<br>Zaporozhye region<br>Sumy region<br>Odessa region | Kherson region<br>Kirovohrad region<br>Chernivtsi region<br>Rivne region<br>The Ternopil region.<br>Chernihiv region<br>Luhansk region.<br>Khmelnitsky region.<br>Volyn region<br>Cherkasy region<br>Transcarpathian region |

*\* Source: derived by the author based on the analysis of data in "Deductor Studio Academic"*

The mean of the ranks does not exceed 11.5 for each region from the cluster 1– so regions from this cluster are ranked higher than the national average in the ratings of innovation development.

The mean of the ranks above 13 for each regions from the cluster 2, therefore, the representatives of this cluster are ranked below the national average in the ratings of innovation development.

Lugansk region (excluding the territory not controlled by Ukraine) has the highest sum of ranks on all indicators of innovative development in 2014.

**3. The clustering of Ukrainian regions by the level of innovation development by the k-means.**

The results of clusterization of Ukrainian regions (3 clusters) by the method of K-means coincided with the results of the clustering are shown in table. 2.

The matrix is a pairwise comparison of the clusters shows that cluster 0 and cluster 1 are quite similar, while clusters 0 and 2, 2 and 1 – not at all like (see Fig. 1). This may indicate that the gap between the values of indicators of innovation development cluster 0 and cluster 1 small.

|   | 0 | 1 | 2 |
|---|---|---|---|
| 0 | 100,00% | 73,41% | 0,06% |
| 1 | 73,41% | 100,00% | 8,96% |
| 2 | 0,06% | 8,96% | 100,00% |

**Fig. 1 The matrix is a pairwise comparison of the clusters 0, 1 and 2**

**4. The clustering of Ukrainian regions by the level implementation of innovative products and processes**

Additionally have been analyzed according to Ukrainian regions differ in the level of implementation of innovation product and process in enterprises: namely, intellectual property rights, innovations, rationalization proposals and advanced technology (technical achievements). Clustering is performed based on the values of ranks of the regions according to four indicators: the

number of enterprises that implemented innovations; the number of enterprises implementing intellectual property rights; the use of rationalization proposals; acquiring advanced technology.

As a result of the attempts of clustering in Kohonen self-organizing maps, the best option was to allocate two clusters (cluster A and cluster B). The significance of this clustering was not less than 99.9%. Cluster A unites 14 regions, cluster B – 11 regions of Ukraine. The composition of the clusters is presented in Table 3.

Table 3

**The composition of the clusters according to level of implementation of innovation products and processes (in the Kohonen self-organizing maps)\***

| Cluster A | Cluster B |
|---|---|
| Regions with high rates of implementation innovations, rationalization proposals, IPR and advanced technology | Regions with below average rates of implementation innovations, rationalization proposals, IPR and advanced technology |
| Kharkiv region<br>Lviv region<br>Dnipropetrovsk region<br>Kyiv city<br>Mykolaiv region<br>Donetsk region<br>Poltava region<br>Ivano-Frankivsk region<br>Kiev region<br>Zhytomyr region<br>Vinnytsia region<br>Zaporozhye region<br>Sumy region<br>Odessa region | Kherson region<br>Kirovohrad region<br>Chernivtsi region<br>Rivne region<br>Ternopil region<br>Chernihiv region<br>Luhansk region.<br>Khmelnitsky region<br>Volyn region<br>Cherkasy region<br>Transcarpathian region |

*\* Source: derived by the author based on the analysis of data in Deductor Studio Academic*

It should be noted that the cluster A includes all regions from Cluster 0 and Cluster 1 in clustering of Ukrainian regions by the level of innovation development.

The average ranks of regions from cluster A does not exceed 9 and above the national average. On the contrary, the regions in cluster B have an average rank for each indicator is not less than 17, which is significantly below the average rank for the country. Thus, the formed clusters of Ukrainian regions by the level implementation of innovation products and processes are very different (see matrix is a pairwise comparison on Fig. 2).
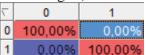
| ⊼ | 0 | 1 |
|---|---|---|
| 0 | 100,00% | 0,00% |
| 1 | 0,00% | 100,00% |

**Fig. 2 The matrix is a pairwise comparison of the clusters A and B**

**Conclusion.** The rating Ukrainian regions by the level of innovative development has been developed on the basis ten indicators of innovation activity in industrial and of implementation of innovation products and processes in 2014. It was implemented three variants of clusterization of Ukrainian regions. Conclusions on the three cluster analyses are the same: 1) Kharkiv region was the leader of innovation development in Ukraine in 2014; 2) Lugansk region (excluding the territory not controlled by Ukraine) was the outsider of innovation development in Ukraine in 2014; 3) Kharkiv region, Kyiv city, Dnipropetrovsk region and Lviv region are the regions with the highest value on indicators of innovative development; 4) The regions with the highest and middle value on indicators of innovative development (14 regions) are also leaders of implementation innovations, rationalization proposals, intellectual property rights and advanced technology; 5) There was a big difference between the average values of implementation of innovation products and processes for 14 regions-leaders and other 11 regions.

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# PAIR CORRELATIONS IN ECONOMIC AND MATHEMATICAL METHODS

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## ПАРНАЯ КОРРЕЛЯЦИЯ В ЭКОНОМИКО-МАТЕМАТИЧЕСКИХ МЕТОДАХ

*The article deals with modern economic-mathematical methods. The economic system presented in the form of series-connected elements. Shows the dependence for the calculation of the probability of occurrence of economic events in the system serially connected elements according to the degree of correlation. Proposed the power function definitions for series-connected elements of the probability of absence of event (phenomenon) the economic system of the two elements, with the coefficient of pair correlation.*

*Keywords: coefficient of correlation, assessing of projects, coefficient of generalized covariance, economic system, probability, event*

*В статье рассмотрены современные экономико-математические методы. Экономическая система представлена в виде последовательно соединенных элементов. Приведена зависимость для расчета вероятности появления экономических событий в системе последовательно соединенных элементов с учетом степени корреляционной связи. Предложена степенная функция определения для последовательно соединенных элементов вероятности появления (отсутствия) события (явления) экономической системы двух элементов с учетом коэффициента парной корреляции.*

*Ключевые слова: коэффициент корреляции, коэффициент обобщенной ковариации, экономическая система, вероятность, событие*

Существующие модели условно можно разделить на два класса – модели материальные и модели абстрактные. В данном исследовании мы рассмотрим один из видов абстрактных моделей, а именно, математические в разрезе . анализа различных явлений и процессов, имеющих экономические закономерности. Согласно [1] применение математических методов существенно расширяет возможности экономического анализа, позволяет сформулировать новые постановки экономических задач, повышает качество принимаемых управленческих решений. Математические модели экономики, отражая с помощью математических соотношений основные свойства экономических процессов и явлений, представляют собой эффективный инструмент исследования сложных экономических проблем. В современной научно-технической деятельности математические модели являются важнейшей формой моделирования, а в экономических исследованиях и практике планирования и управления – доминирующей формой.

Рассматривая математические модели экономических процессов и явлений многие экономисты используют их упрощенные формальные описания, называемые экономическими моделями [2]. Примерами экономических моделей являются модели потребительского выбора, модели фирмы, модели экономического роста, модели равновесия на товарных, факторных и финансовых рынках и многие другие.