

ЕКОНОМІКА ТА УПРАВЛІННЯ НАЦІОНАЛЬНИМ ГОСПОДАРСТВОМ

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**NEUROMODELLING
OF FINANCIAL AND ECONOMIC
SECURITY OF THE REGION**

**НЕЙРОМОДЕЛЮВАННЯ
ФІНАНСОВО-ЕКОНОМІЧНОЇ
БЕЗПЕКИ РЕГІОНУ**

Urgency of the research. In the light of changes in the global security system, the problem of an adequate assessment of economic security in a regional context is acute. Existing methods provide for the calculation of a complex indicator or system of indicators for assessing economic security. Instead, the realities of today require a revision of the conceptual approach to the definition of "economic security", which will take into account the impact of the processes of interpenetration and the integration of economic systems of individual regions.

Target setting. The problem of finding and testing new methods to assess the economic security of regions arises.

Actual scientific researches and issues analysis. A considerable amount of research is devoted to the quantitative and qualitative assessment of the country's economic security. The classic approach to assessing economic security involves calculating the integral index and does not take into account the integration of individual regions and the country as a whole into world markets.

Uninvestigated parts of general matters defining. The need to change the angle of view on the monitoring of regional economic security arose in connection with: an increase in the scale and acceleration of the processes of globalization; difficult geopolitical situation in the country.

The research objective. The purpose of this study is to assess the feasibility of combining theoretical approach and indicative of the theory of open systems to assess the level of economic security of the region.

The statement of basic materials. In this work an algorithm for using the apparatus of the theory of neural networks for the estimation of the economic system of the regions is developed. The obtained economic-mathematical model allows to perform clusterization of territorial units according to selected indicators of economic security. Testing of the developed algorithm is conducted on the basis of data on the state of economic development of the regions of Ukraine.

Conclusions. The result of the simulation is a cluster structure that divided the totality of regions of Ukraine into four clusters according to selected classification characteristics. The results obtained have a clear economic interpretation.

Keywords: economic security; region; neural network; clusterization; indicative approach.

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Актуальність теми дослідження. У світлі зміни системи глобальної світової безпеки, гостро постає проблема адекватної оцінки економічної безпеки в регіональному розрізі. Існуючі методика передбачають розрахунок комплексного показника або системи показників для оцінки економічної безпеки. Натомість реалії сьогодення вимагають перегляду концептуального підходу до визначення поняття «економічна безпека», що врахує вплив процесів взаємопроникнення та інтеграції економічних систем окремих регіонів.

Постановка проблеми. Постає задача пошуку та тестування нових методів щодо оцінки економічної безпеки регіонів.

Аналіз останніх досліджень і публікацій. Проблематиці кількісної та якісної оцінки економічної безпеки країни присвячена значна кількість досліджень. Класичний підхід до оцінки економічної безпеки передбачає обчислення інтегрального індексу та не враховує інтеграцію окремих регіонів та країни в цілому у світові ринки.

Виділення недосліджених частин загальної проблеми. Необхідність зміни кута зору на проблематику моніторингу регіональної економічної безпеки виникла у зв'язку з: збільшенням масштабів та пришвидшенням процесів глобалізації; складною геополітичною ситуацією в середині країни.

Постановка завдання. Метою даного дослідження є теоретична оцінка можливості поєднання індикативного підходу та положень теорії відкритих систем до оцінки рівня економічної безпеки регіону.

Викладення основного матеріалу. В роботі розроблено алгоритм використання апарату теорії нейронних мереж для оцінки економічної системи регіонів. Отримана економіко-математична модель дозволяє виконувати кластеризацію територіальних одиниць за обраними індикаторами економічної безпеки. Тестування розробленого алгоритму проведено на основі даних про стан економічного розвитку регіонів України.

Висновки. Результатом моделювання стала кластерна структура, що розподілила сукупність регіонів України на чотири кластери відповідно до відібраних класифікаційних характеристик. Отримані результати мають чітку економічну інтерпретацію.

Ключові слова: економічна безпека; регіон; нейронна мережа; кластеризація; індикативний підхід.

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Urgency of the research. In relation to the global world security system changes, the revision of economic, social and political ties between countries is particularly acute in the issue of an adequate assessment of economic security in a regional context. Existing methods ensure the complex indicator or system of indicators calculation for assessing economic security. Instead, the modern realities require a revision of the conceptual approach to defining the term "economic security", which will take into account the impact of the interpenetration and integration of economic systems processes of individual regions.

Target setting. The purpose of this study is to work out existing developments in the quantitative assessment of Ukraine's economic security, identify their weaknesses in terms of the international economic relations transformation, and provide the theoretical assessment of the possibility to combine the indicative approach and the provisions of the open system theory with the economic security level assessment in the region.

Actual scientific researches and issues analysis. A considerable part of the research is devoted to the quantitative and qualitative assessment of the country's economic security. Among the founders of this direction are: L. Abalkin, Y. Altukhov, V. Abramov, V. Andriychuk, G. Androschuk, I. Binko, A. Baranovsky, B. Bogomolov, A. Blinov, S. Varnal, G. Viachkanov, O. Vlasyuk, V. Gorotkin, A. Galchinsky, V. Heyets, T. Gladchenko, O. Goncharenko, A. Gorbunov, V. Spirit, A. Draga, M. Yermoshenko, A. Kachinsky, V. Kirilenko, T. Klebanova, T. Kovalchuk, A. Kozachenko, M. Kozoriz, P. Krainov, B. Kravchenko, D. Lyapin, I. Mazur, O. Malinovska, V. Muntiyany, G. Pasternak-Taranushenko, N. Reverchuk, V. Senchagov, A. Sukhorukov, T. Hailova, V. Shlemko and others.

The country's economic security is defined as a set of conditions and factors that ensure the national economy independence, stability and sustainability, the ability to continuously update, confront external threats and development. This necessitates a generalized assessment and a systematic approach to regulating the state economic security level.

In order to determine the dynamics of the economic security integral index and its components, an appropriate methodology that can provide adequate diagnostics with the possibility of comparison with the integral threshold (optimal) values is required. Solving this problem is a necessary condition but not sufficient to develop a strategy to ensure the desired level of state economic security. Therefore, the development of scientific approaches in order to justify the necessary values of the economic security components and their indicators, which ensure the economic security level in a favourable or specified zone, is essential [1].

Uninvestigated parts of general matters defining. The need to change the angle of view on the issue of regional economic security monitoring has arisen in connection with:

- increase of the scale and acceleration of globalization processes in the world;
- a complex geopolitical situation in the middle of the country, when the unplanned change in the status of certain parts of the industrial and recreational regions has led to the actual alienation of large enterprises of various functional purposes, the termination of production cycles, and the significant migration of the population.

The research objective. This study aims to determine the possibility, prospects and outline the benefits of using the conceptual foundations of the open system theory in order to assess the regional economy security level.

The statement of basic materials. The classic approach to assessing the national economy vulnerability is indicative. The algorithm foresees the preliminary calculation of the indicators set and further comparison with the limit values. It is assumed that beyond these values the economic system becomes vulnerable to internal and external factors and loses the ability to self-development, competitiveness, and national wealth accumulation [1]. Thus, the task of optimal economic regulation is to periodically monitor a certain system of indicators and formulate appropriate corrective actions.

The resulting assessment of the country's economic security can be carried out in two directions:

1. complex estimation calculation on the basis of pre-calculated sub-indicators in the context of the basic social, economic and political processes and the subsequent comparison with boundary norms or reference values;
2. the calculation of the sub-indicators number corresponding to the normative values, and the ap-

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pointment of the country's economic security status (optimal, dangerous, critical, etc.) according to their share in the total number.

Currently, at the legislative level in Ukraine, the methodological recommendations for calculating the country's economic security level are fixed, which essentially implement the indicative approach in assessing the national economy vulnerability and ultimately provide the calculation of the integral estimation [2]. Compared with the abolished methodology from 2007, the new development has a number of advantages, namely:

- definition of the boundary values vector of integral indicators;
- setting of weight coefficients for calculating the contribution of each subindex to the integral index by the main components method;
- substantiation of the factor axes rotation method.

This methodology has several methodological and technical issues in determining the economic security integral index.

The economy openness at the national and regional levels, on the one hand, provides ample opportunities for the economic competition development and the country welfare through international trade. The interdependence that arises during internal or external financial and economic integration, in terms of sharp economy deterioration in one of the partner countries, the economic crisis, or worsen political relationships at the highest level create, at times, higher risks for the national economy than any indicative value of an integral or sub-integral indicator of economic security that goes beyond the boundaries. This is primarily due to the impossibility for the government or the president to unilaterally quickly extinguish the negative effects of such changes and the lack of a methodological basis for the permanent assessment of such risks.

In this regard, the author proposes to form a methodology for assessing the economic security of the region using the conceptual apparatus of the open system theory [3]. Accordingly, the economy is seen as an open system that shares resources (material, energy, and information) with the environment. Through the resources exchange with the environment, the system is constantly evolving. The resources coming from the outside go for life support, streamline and maintain system stability. Closed systems degrade and collapse. As an example of closed systems researches in this field distinguish tribal, collectivist and socialist society.

The use of preliminary studies in the field of open system modelling makes it possible, when assessing national security, to take into account the impact of external factors, including unexpected shocks, economic volatility and manipulations of partner governments.

In this case, the trajectory of economic development can be described using the nonlinear differential equation of Fischer-Kolmogorov-Petrovskii-Piskunov [4-5], which is the basic equation for the theory of active media and the theory of systems that are self-organized:

$$\frac{\partial X(R, t)}{\partial t} = F[X(R, t)] + \frac{\partial}{\partial R_i} \left[D_{ij}(X) \frac{\partial X}{\partial R_j} \right], \quad (1)$$

where $X(R, t)$ is the set (vector) of functions characterizing the economic system; $F(X)$ is the nonlinear functions, which are determined by the structure of the system being studied. For example, for a single-product open economy, consisting of bistable elements, it may look like a polynomial [6]:

$$F(X) = (a - bX^2)X \text{ for } b > 0, \quad (2)$$

and the corresponding dynamic equation for calculating a separate element of the system will look like:

$$\frac{\partial X}{\partial T} = (a - bX^2)X, \text{ for } b > 0, \quad (3)$$

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where parameter a defines the bifurcation point of the economic system, for $a < 0$ there is a state of rest, for $a > 0$ it is a bistable state of the economic system with $X \pm \sqrt{\frac{a}{b}}$; D is the coefficient of spatial diffusion of an open system elements; R is the radius vector of points of the medium. The concept of α control parameter (or set of control parameters) is introduced and determines the ordering degree of the open economic system conditions. The control parameter determines the direction and speed of the controlled system in the phase plane (abstract space with the number of measurements, equal to the number of time dependent variables that characterize the state of the system being studied). For a random system, the recovered attractor in the phase plane will have the shape of a cloud for any dimension of the attachment (Fig. 1). In the case of correct selection of the characteristics of the phase plane, there will be a random attractor of a completely different shape (for example, Fig. 2).

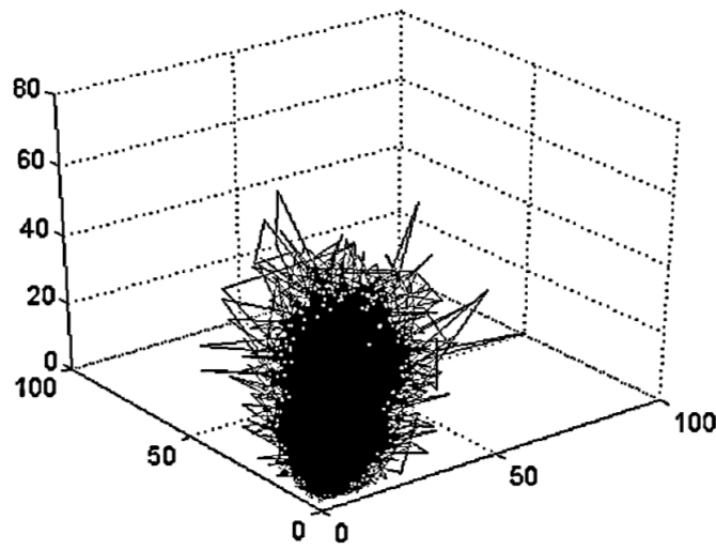


Fig. 1. Recovered attractor of a random system for the embedding dimension of three

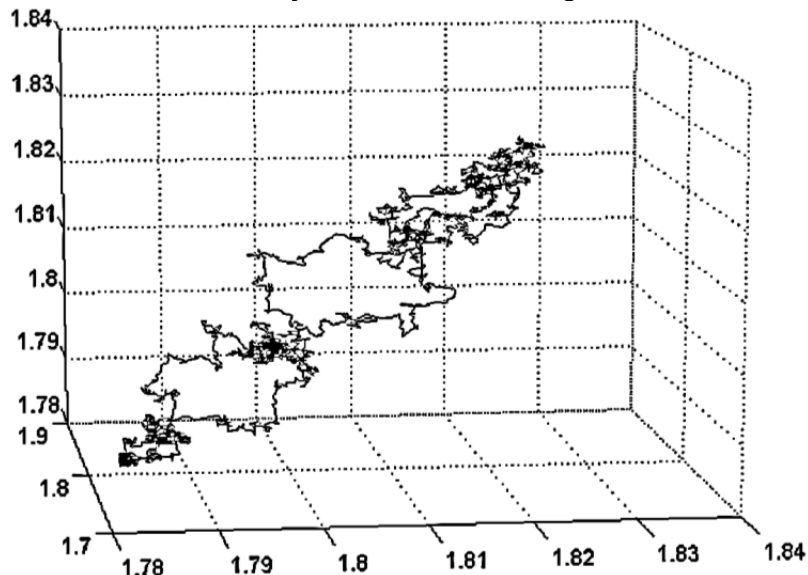


Fig. 2. Recovered attractor of the dynamic exchange rate system of British Pound/US dollar for the embedding dimension of three

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Therefore, the task of determining the optimal trajectory of economic development is to select a set of control parameters that will ensure the transition from one equilibrium state of the system to another.

According to the classic indicative approach, optimal management of economic security includes: periodic monitoring and calculation of sub-indices in the context of basic social and economic processes (production, demographic, energy, foreign economic, investment-innovation, macroeconomic, food, social, financial); comparing them with the limit values and developing such managerial influences that will ensure the calculated indicators are located within safe limits.

Considering the economic security of the region in terms of open systems concept described above, the process of approaching the trajectory of the economic system movement to the critical value of one of the indicators of its functioning on the phase plane is not characterized as catastrophic. Particular attention in the context of this concept requires a set of values of the economic system characteristics, in which it approaches the point of bifurcation.

In accordance with the nature of the object of study, the point of bifurcation will in the future be called the critical state of the regional economic system, which leads to a stability violation of its established operation mode and the emergence of bifurcation point of the whole spectrum of alternative virtual evolution scenarios. Due to the economic stability system loss at the point of bifurcation, minor changes in the environment can lead to significant qualitative changes in the structure of the economic system and the further trajectory of its development. From the point of view of the mathematical description of this process, the bifurcation signifies the solutions ramification of the nonlinear differential equation (1) [4].

According to the synergetics theory, the sensitivity of the regional economy to external fluctuations and changes will be the higher the less diversified its structure is. This conclusion is explainable, because the economy is oriented, for example, only on the energy resources export or a narrow range of industrial goods in the conditions of sharp changes in the market, and will lead to a corresponding budget revenues reduction and deterioration of the population welfare. The reorientation will require considerable resources and time.

Similarly, the resistance to external fluctuations depends on the region: the larger it is, the less its sensitivity. Nevertheless, both links are nonlinear and constrain the transition to another state of the economic system only to some extent. Over time, the accumulation of external stimuli that has not found the appropriate response will lead to the system bifurcation, and the presence of an extensive internal structure and large territory will make the country less manageable and reduce its vulnerability to fluctuations.

For an adequate description of the economic system dynamics and the safety assessment in terms of its trajectory approximation in the phase space to the bifurcation time, it is necessary to select an appropriate system of basic indicators. Such system ought to include, in addition to the generally accepted quantitative characteristics of the economy efficiency assessment, specific criteria. In particular, for modelling and assessing the financial and economic security of the region, it is suggested using the following indicators:

The first group is the generally accepted quantitative characteristics, calculated in accordance with the State Committee of Statistics methodology.

1. The growth rate of gross regional product, calculated on the basis of statistical indicator of growth rate:

$$R_{growth}^{GRP} = \frac{GRP_t}{GRP_0}, \quad (4)$$

where R_{growth}^{GRP} is the growth rate, GRP_t is the gross regional product at the time t , GRP_0 is the gross regional product at the basic moment of time.

2. The unemployment rate growth of the region's population:

$$R_{growth}^{UR} = \frac{UR_t}{UR_0}, \quad (5)$$

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where R_{growth}^{UR} is the growth rate, UR_t is the unemployment rate at the time t , UR_0 is the unemployment rate at the basic moment of time.

3. The index of accrued real wage that characterizes the change in the purchasing power of wages in the reporting period compared with the base one. It is determined by dividing the net nominal wage index into the consumer price index for the same period:

$$I^{CRW} = \frac{I_{t,0}^{NW}}{I_{t,0}^{CP}}, \tag{6}$$

where I^{CRW} is the index of the calculated real wage, $I_{t,0}^{NW}$ is the index of accrued nominal "net" wages of the current period in comparison with the base one, $I_{t,0}^{CP}$ is the consumer price index of the current period in comparison with the base one.

4. The index of agricultural products reflects the relative level of total physical quantities of agricultural products produced for any periods of time chosen for comparison. For its calculation, the Laspeyres formula is chosen, i.e. [7]:

$$I_t^{AP} = \frac{\sum_{i=1}^n q_t^i \cdot p_0^i}{\sum_{i=1}^n q_0^i \cdot p_0^i}, \tag{7}$$

where q^i is the volume of production of a particular product type in kind; p_0^i is the comparable price for a particular type of i product; $t, 0$ are time periods (base and reporting) selected for comparison.

5. The index of industrial products is the weighted average, the basis of the weight structure of which is the data on the added gross value distribution between industrial activities, from the corresponding individual indices for each product [8]:

$$I_t^{AP} = \frac{\sum_{i=1}^n q_t^i \cdot p_0^i}{\sum_{i=1}^n q_0^i \cdot p_0^i}, \tag{8}$$

where q^i is the volume of i production of a particular kind of industrial products in kind; p_0^i is the comparable price for a specific type of i industrial product; $t, 0$ are time periods (base and reporting) selected for comparison.

6. The index of construction products is the sum of the weighted average of the indices of buildings and other structures construction, calculated as the ratio of the number of worked man-hours in the reporting month to the average monthly value of the number of hours worked in the base year. The share of building materials components for each type of construction product is chosen as weight. The index is adjusted in accordance with the productivity factor and the calendar amendment [8]:

$$I^{CP} = \left(\left(\frac{N_t^{HWCC}}{N_0^{HWCC}} \right) \cdot \Delta_0^{CC} + \left(\frac{N_t^{HWES}}{N_0^{HWES}} \right) \cdot \Delta_0^{EC} \right) \cdot C \cdot I^{LP}, \tag{9}$$

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where I^{CP} is the construction products index; N_t^{HWCC} is the number of man-hours worked on objects of capital construction in the current month; \bar{N}_0^{HWCC} is the average monthly number of hours worked in the base year at the objects of capital construction; Δ_0^{CC} is the share of capital construction volume of all products in the base year; N_t^{HWES} is the number of man-hours spent in the current month on objects of engineering structures; \bar{N}_0^{HWES} is the average monthly number of hours worked in the base year on the objects of engineering structures; Δ_0^{EC} is the share of the volume of engineering structures in the base year; C is the coefficient of calendar changes to the average monthly value of the base year; I^{LP} is the index of labour productivity in the previous reporting year to the base one.

7. The capital investment index is defined as the ratio of the assets value invested in a particular quarter, adjusted for the corresponding price indices, to the average value of the assets invested in the base year:

$$I^{CI} = \frac{\sum_{j=1}^m (V_t^j \div i_{t/0}^j)}{\sum_{j=1}^m \bar{V}_0^j}, \tag{10}$$

where I^{CI} is the capital investment index; V_t^j is the capital investments volume by j type of asset in the reporting period; $i_{t/0}^j$ is the index of capital investment prices by type of assets j in the reporting period t to the average of the base year; \bar{V}_0^j is the average quarterly capital investment by type of asset j in the base year.

8. The consumer price index is an indicator that characterizes changes in the time of the general level of prices for goods and services purchased by the population for non-productive consumption. It is an indicator of the change in the value of a fixed set of consumer goods and services in the current period compared with the base one.

The second group is specific criteria reflecting the consequences of globalization and the integration of certain areas for economic security. In particular, the so-called indicators of economy openness (adapted to the terminology of the regional economy):

1. Export quota:

$$EQ = \frac{EV}{GRP} \cdot 100\%, \tag{11}$$

where EQ is the export quota, EV is the export value for a specified period, GRP is the value of the gross regional product.

2. Import quota:

$$IQ = \frac{IV}{GRP} \cdot 100\%, \tag{12}$$

where IQ is the import quota, IV is the import value for a specified period.

3. Import share:

$$IS = \frac{IV}{GRP + IV - IE} \cdot 100\%, \tag{13}$$

where IS is the import share.

4. Indicator of capital movements:

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$$ICM = \frac{FDI}{NI}, \tag{14}$$

where *ICM* is the indicator of capital movements, *FDI* is the foreign direct investments, *NI* is the number of inhabitants.

Therefore, the proposed list of quantitative indicators will allow taking into account the impact of interregional and international integration processes in assessing economic security.

In order to avoid the contradictions accompanying the algorithm for estimating the integral index of national economic security, it is proposed to use the mathematical apparatus of the neural networks theory to assess the level of economic security of the Ukrainian regions (oblasts).

It is necessary to assess the level of economic security of the regions with the help of a neural network like the Kohonen-type map. The input sample has been divided out of 24 territorial units characterized by a set of two types of indicators in the total number of 12. There is an input sample size of the $24 \times 12 = 288$ elements. Clustering is done separately for each year. The study period is seven years from January 1st, 2011, to January 1st, 2017.

The optimal number of neural network clusters is determined from the empirical relation [9]:

$$N_{nt} > \frac{N}{\%e}, \tag{15}$$

where N_{nt} is the number of the training sample ($N_{nt} = 24$); $\%e$ is the percentage of training error. If the value of training error equals $\%e = 0,2$, based on formula (15) it is possible to determine the maximum possible number of clusters $\max(N) = 4$.

An example of original sample for clustering for 2016 is given in Tab. 1.

Table 1

Output data for the distribution process modelling of oblasts in the country by economic security level

Oblast	Indicator											
	Rate of GDP growth, %	Rate of unemployment growth, %	Index of accrued real wages, %	Index of agricultural products, %	Index of industrial output, %	Index of construction products, %	Index of capital investments, %	Consumer price index, %	Export quota, %	Imported quota, %	Share of imports, %	Capital flow rate, UAH
1	2	3	4	5	6	7	8	9	10	11	12	13
Vinnitsa	104.9	108.99	87.90	117.50	97.60	136.40	102.50	110.00	42.69	13.00	18.49	4874.77
Volyn	109.0	117.35	86.60	102.10	95.30	100.00	97.50	111.80	50.20	92.78	65.07	5745.54
Dnipropetrovsk	99.5	109.72	82.60	100.20	98.70	81.00	115.50	112.70	70.86	41.60	58.81	9500.52
Donetsk	101.8	102.17	78.40	106.30	97.20	72.40	145.10	111.60	77.56	25.11	52.81	2532.51
Zhytomyr	104.5	99.12	85.40	115.70	91.50	79.00	127.50	112.60	32.80	22.78	25.32	4160.85
Zakarpattia	96.1	108.70	86.90	95.90	79.90	111.50	93.90	111.70	108.83	101.78	109.50	2955.84
Zaporozhye	98.1	103.09	87.70	98.40	93.30	76.40	131.30	112.30	66.93	29.15	46.85	5836.14
Ivano-Frankivsk	101.2	104.76	86.80	101.50	87.90	118.30	65.30	110.90	32.53	23.02	25.44	4752.37
Kievskaya	101.8	106.25	91.00	110.00	105.60	135.90	124.80	112.20	42.62	73.77	56.25	17918.2
Kirovograd	108.7	108.77	84.80	109.30	113.00	88.20	147.00	112.30	28.91	12.44	14.90	6344.09
Lugansk	53.0	102.56	87.10	118.70	96.00	138.00	146.40	110.70	47.50	38.96	42.60	1322.73



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Continuation of Table 1

1	2	3	4	5	6	7	8	9	10	11	12	13
Lviv	99.3	93.90	88.20	102.00	92.40	121.90	130.70	111.90	35.02	46.66	41.80	6696.97
Nikolaev	104.0	108.99	84.10	108.40	116.30	290.70	147.60	112.20	89.90	37.00	78.55	7921.68
Odessa	106.2	104.62	89.10	111.40	96.80	118.40	163.40	113.60	39.63	32.09	34.71	6275.25
Poltava	100.3	104.13	84.20	103.10	99.90	67.60	132.20	114.20	38.95	22.86	27.24	7675.76
Rivne	98.5	107.07	83.90	105.00	94.50	175.20	91.20	112.30	23.47	18.81	19.73	3516.05
Sumy	97.1	92.08	82.00	104.30	83.90	55.60	135.40	114.20	33.92	27.33	29.26	4678.96
Ternopil	97.1	97.46	84.90	104.40	95.70	86.50	117.20	111.60	28.70	26.81	27.33	4234.85
Kharkiv	103.7	90.14	86.00	106.50	97.10	103.20	135.90	114.10	21.41	31.02	28.30	5793.68
Kherson	100.3	109.80	86.30	101.70	96.30	128.80	135.80	112.80	19.90	13.43	14.35	4094.81
Khmelnitsky	101.3	92.16	84.80	107.50	97.50	72.20	123.40	111.40	20.17	21.00	20.83	6799.50
Cherkassy	103.6	106.12	86.30	102.10	97.50	99.70	135.00	112.70	24.26	14.89	16.43	4951.90
Chernivtsi	100.3	93.55	86.50	101.00	96.70	118.80	85.90	111.00	16.76	13.45	13.91	2689.66
Chernihiv	103.0	105.61	86.30	104.40	112.90	60.10	132.50	112.80	30.44	33.33	32.40	4791.28

Source: author's own calculations and State Committee of Statistics [Electronic resource] - <http://www.ukrstat.gov.ua/>

Although the output information given in Tab. 1 is presented as relative values, for the regions clustering and the neural network construction, it should be reduced to a scale with a maximum value of 1 and a minimum of 0. It is necessary to do the preliminary data valuation in accordance with the formula:

$$x'_{ij} = \frac{(\max - \min) \cdot (x_{ij} - x_{\min i})}{(x_{\max i} - x_{\min i})} + \min, \tag{16}$$

where x'_{ij} is the the j 's value of i 's row of standardized data array; $x_{\min i}$ is the minimum value per row i ; $x_{\max i}$ is the maximum value per row i ; $\max = 1$; $\min = -1$.

With the help of MatLab software, the following neo-neural network of Kohonen-type map was obtained, which divided twenty four areas into four groups according to definite indicators.

Figures 3-4 depict the general and detailed structure of the constructed neural network.

As a result of the simulation, a trained neural network has been obtained that distributes Ukrainian oblasts to clusters according to the financial and economic security level. An example of such structure for data of 2016 is shown in Fig. 5.

It is necessary to consider the oblasts included in each cluster on the modelling basis in more detail.

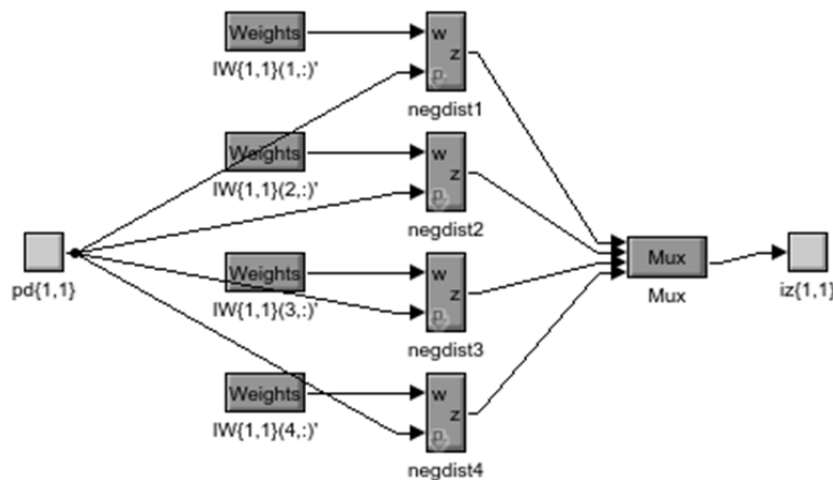


Fig. 3. The detailed structure of the "Self-organizing map construction" block

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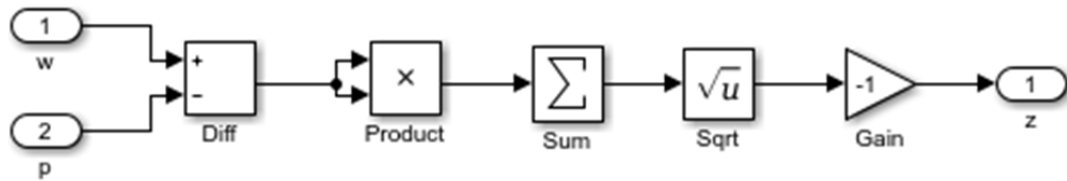


Fig. 4. The expanded internal algorithm structure, which implements the calculation of weights for each neuron

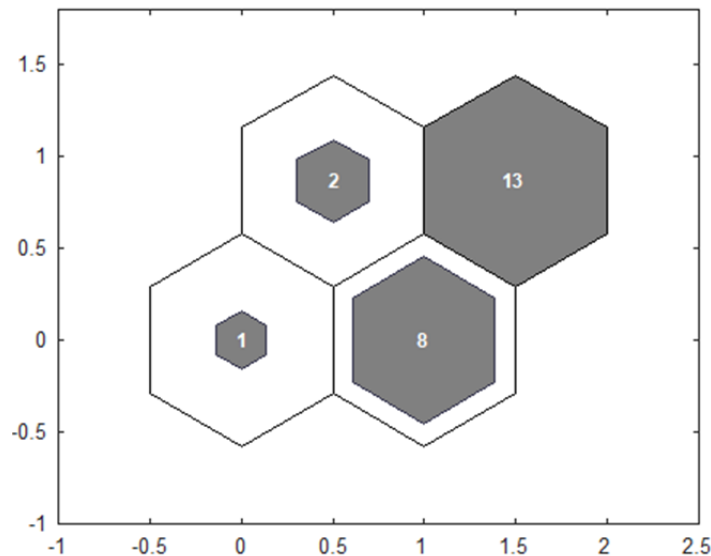


Fig. 5. Clusterization of oblasts' economies in terms of financial and economic security

The first cluster: the Kiev oblast.

The second cluster: Vinnytsia, Zhytomyr, Ivano-Frankivsk, Lugansk, Rivne, Ternopil, Khmelnytsky, Chernivtsi oblasts.

Third cluster: Volyn, Zakarpattia oblasts.

The fourth cluster: Dnipropetrovsk, Donetsk, Zaporozhye, Kirovograd, Lviv, Nikolaev, Odessa, Poltava, Sumy, Kharkiv, Kherson, Cherkasy, Cherkassy oblasts.

The average values of absolute values, which are the classification characteristics of clusterization, have been analyzed.

According to the results obtained, it can be concluded that the highest level of financial and economic security in 2016 was typical to the oblasts included in the first and fourth clusters.

It ought to be noted that as a result of clusterization, only the Kiev oblast was included into the first cluster. This special position in the cluster structure is logical. The first cluster is characterized by maximum values of five out of twelve classification characteristics; 50% of the classification characteristics are at the second level on the strength of all the evidence. Thus, the Kyiv oblast has the highest level of financial and economic security.

The oblasts included in the fourth cluster account for more than 50% of the total sample: these are 13 oblasts including the Dnipropetrovsk one. This cluster is characterized by the highest average rate of GDP growth, capital investment index and consumer price index. The core of the cluster is historically formed industrial oblasts of Ukraine (for example, Dnipropetrovsk, Donetsk, Kharkiv, Mykolaiv, Zaporozhye, Odessa oblasts). The level of financial and economic security of the oblasts' included in the cluster number four can be characterized as steady.

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The highest average rate of unemployment growth, import quota and the smallest average values of such classification characteristics as the agricultural product index, industrial production index, capital investment index are typical for the oblasts included in the third cluster (Volyn and Zakarpattia oblasts). The lack of industrial potential and the peculiarities of the geographical location determine the peculiarities of the GRP structure formation and the high share of transboundary movement of goods and services. On the whole, the level of financial and economic security of the oblasts included in the third cluster should be classified as marginal or inadequate.

The level of financial and economic security for the second cluster can be considered as the edge or sufficient one. It is the second largest in the cluster structure and includes eight oblasts. The values of the classification features in the group take the second or third place on the strength of all the evidence.

Conclusions. Acceleration and increase of the globalization processes scale requires a of the conceptual approach revision to assessing the level of economic security. The classic indicative approach that is used by governments of most countries allows assessing the security of an equilibrium economic system and taking into account the slight changes in the external environment. However, in terms of recent world events, it becomes clear that adequate security management of the regional economy is impossible without taking into account the risks of significant fluctuations in the policies and economies of partner countries. In this regard, in the study, an analysis of the possibility of using the conceptual apparatus of open systems theory for the economic security determination has been made. The construction of an adequate nonlinear model implies the definition of acceptable characteristics, which will uniquely determine the regional economic system state at any given time. In addition to the generally accepted macroindicators, it is proposed to use the characteristics associated with integration processes inside the country and outside its borders.

In order to construct an adequate model of financial and economic security assessment at the regional level, a neural network of self-organized map type is used.

The simulation result has been a cluster structure that has divided the set of oblasts in Ukraine into four clusters according to selected classification characteristics. Each cluster corresponds to a certain level of financial and economic security, which was characterized as: high, stable, sufficient and marginal or insufficient.

The obtained results have a clear economic interpretation.

Therefore, the conclusion can be made on the promising use of this approach to assessing the financial and economic security level.

References

1. Kharazishvili, M. Yu., Sukhorukov, A. I., Krupelnitska, T. P. (2013). Shchodo vdoskonalennia metodolohii intehrlnoho otsiniuvannia rivnia ekonomichnoi bezpeky Ukrainy: Analitichna zapyska [Concerning the improvement of the methodology of the integrated assessment of the level of economic security in Ukraine: An analytical note]. *www.niss.gov.ua*. Retrieved from: <http://www.niss.gov.ua/articles/1358/> [in Ukrainian].
2. Nakaz Pro zatverdzhennia Metodychnykh rekomendatsii shchodo rozrakhunku rivnia ekonomichnoi bezpeky Ukrainy: vid 29 zhovtnia 2013 r., № 1277 [Order on Approval of Methodological Recommendations for Calculating the Level of Economic Security of Ukraine: from October 29 2013 r., № 1277]. *search.ligazakon.ua*. Retrieved from http://search.ligazakon.ua/l_doc2.nsf/link1/ME131588.html [in Ukrainian].
3. Klimontovich, Yu. L. (1995). *Statisticheskaya teoriya otкрыtykh sistem [The statistical theory of open systems]*. Moscow: Yanus [in Russian].
4. Kolmogorov, A. N., Petrovskiy, N. G., Piskunov, N. S. (1937). Issledovanie uravneniya diffuzii, soedinennoy s vozrastaniem veshchestva, i ego primenenie k odnoy biologicheskoy probleme [Investigation of the diffusion equation connected with the increase of matter and its

Література

1. Харазішвілі, Ю. М. Щодо вдосконалення методології інтегрального оцінювання рівня економічної безпеки України: Аналітична записка / Ю. М. Харазішвілі, А. І. Сухоруков, Т. П. Крупельницька. – НІСД, вересень 2013 р. – Режим доступу: <http://www.niss.gov.ua/articles/1358/>.
2. Про затвердження Методичних рекомендацій щодо розрахунку рівня економічної безпеки України № 1277 від 29.10.2013 р. – Режим доступу: http://search.ligazakon.ua/l_doc2.nsf/link1/ME131588.html.
3. Климонтович, Ю. Л. Статистическая теория открытых систем / Ю. Л. Климонтович. - М. : ТОО Янус, 1995. – 624 с.
4. Колмогоров, А. Н. Исследование уравнения диффузии, соединенной с возрастанием вещества, и его применение к одной биологической проблеме / А. Н. Колмогоров, Н. Г. Петровский, Н. С. Пискунов // Бюл. МГУ. Сер. А. Математика и Механика, 1937. – Т. 1, - № 6. – С. 1-16.
5. Fisher, R. A. The wave of advance of advantageous genes / R. A. Fisher // *Annual Eugenics*. – 1937. – Vol. 7. – P. 355-369.
6. Арнольд, В. И. Теория бифуркаций / В. И. Арнольд, В. С. Афраймович, Ю. С. Ильясенко, Л. П. Шильников //

ЕКОНОМІКА ТА УПРАВЛІННЯ НАЦІОНАЛЬНИМ ГОСПОДАРСТВОМ

application to a single biological problem]. *Bulletin of Moscow State University. Series: Mathematics and Mechanics*, 6, 1-16 [in Russian].

5. Fisher R. A. (1937). The wave of advance of advantageous genes. *Annual Eugenics*, 7, 355-369 [in English].

6. Arnold, V. I., Afraimovich, V. S., Ilyashenko, Yu. S., Shilnikov, L. P. (1986). Teoriya bifurkatsiy [Theory of bifurcations]. *Dinamicheskie sistemy. Itogi nauki i tekhniki. Sovremennye problemy matematiki. Fundamentalnye napravleniya – The results of science and technology. Modern problems of mathematics. Fundamental directions*. (Vols. 5), (pp. 5-218). Moscow: VINITI [in Russian].

7. Nakaz Derzhavnoho komitetu statystyky Ukrainy pro Metodyku rozrakhunku indeksu obsiahu silskohospodarskoho vyrobnytstva: vid 06 veresnia 2009 r., № 53 [Order of the State Statistics Committee of Ukraine on the Methodology for calculating the agricultural production index from September 6, 2009, № 53]. *ukrstat.org*. Retrieved from https://ukrstat.org/uk/metod_polog/metod_doc/2009/53/metod.htm [in Ukrainian].

8. Nakaz Derzhavnoho komitetu statystyky Ukrainy pro Metodyku rozrakhunku intehrlnoho indeksu vyrobnytstva (vrakhovuiuchy indeksy promyslovoi ta budivelnoi produktsii) vid 02 serpnia 2005 r., № 224 [Order of the State Statistics Committee of Ukraine on the Methodology for calculating the integral production index (taking into account indices of industrial and construction products): from August 2 2005, № 244]. *consultant.parus.ua*. Retrieved from <http://consultant.parus.ua/?doc=07SNB80C2B> [in Ukrainian].

9. Hush, D., Horne, B. (1993). Progress in supervised neural network. *IEEE Signal Processing Magazine*, 10.1, 8-39 [in English].

Динамические системы – Итоги науки и техники. Современные проблемы математики. Фундаментальные направления. – М.: ВИНТИ, 1986. – Т. 5. – С. 5-218.

7. Методика розрахунку індексу обсягу сільськогосподарського виробництва / Наказ Державного комітету статистики України № 53 від 06 вересня 2009 р. – Режим доступу : https://ukrstat.org/uk/metod_polog/metod_doc/2009/53/metod.htm.

8. Методика розрахунку інтегрального індексу виробництва (враховуючи індекси промислової та будівельної продукції) / Наказ Державного комітету статистики України №224 від 02 серпня 2005 р. (у редакції наказу Держкомстату №201 від 05 серпня 2011 р.) – Режим доступу: <http://consultant.parus.ua/?doc=07SNB80C2B>.

9. Hush, D. Progress in supervised neural network / D. Hush, B. Horne // *IEEE Signal Processing Magazine*. – 1993. – No. 10. – Vol. 1. – P. 8-39.

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