

Shkolnik I. O.

*Doctor of Economic Sciences, Professor,
Head of the Department of banking, finance and insurance Sumy State University Sumy,
Ukraine; e-mail: y.shkolnyk@uabs.sumdu.edu.ua*

Bukhtiarova A. G.

*PhD in Economics, Senior Lecturer of the Department of banking,
finance and insurance Sumy State University Sumy;
Ukraine; e-mail: a.bukhtiarova@uabs.sumdu.edu.ua*

Semenog A. U.

*PhD in Economics, Assistant professor of the Department of banking,
finance and insurance Sumy State University Sumy;
Ukraine; e-mail: a.semenoh@uabs.sumdu.edu.ua*

ECONOMIC MODELING OF ASSESSMENT OF UKRAINIAN BANKING SYSTEM

Abstract. The investigation presents scientific and methodological approach of evaluation of efficiency of the banking system through a generalized Harrington function (desirable function) that allows to determine the current state of the banking system and to predict the perspectives of its development. In the simulation of assessment of the banking system were used data from 49 banks operating in Ukraine for 2003–2016 and 15 financial indicators, which provide formation of input variables of the model. The method of data processing is implemented in the package Viscovery SOMine. The approach is based on the analysis of the dynamics of patterns of banks and building self-organizing Kohonen maps which enables to determine the trajectory of activity of individual bank. This approach enables forecasting of individual bank crisis and the potential crisis of banking system of a country. Conducted trend forecast of the Harrington function suggests potential of improving of Ukrainian banking system over the next 3 years.

Keywords: banks, banking system, economic modeling, Harrington desirability function, cluster analysis, self-organizing Kohonen map

JEL Classification: C38, G17, G21, G33

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Школьник І. О.

*д.е.н., професор, завідувач кафедри фінансів, банківської справи та страхування,
Сумський державний університет м. Суми,
Україна; e-mail: y.shkolnyk@uabs.sumdu.edu.ua*

Бухтіярова А. Г.

*к.е.н., старший викладач кафедри фінансів, банківської справи та страхування,
Сумський державний університет м. Суми;
Україна; e-mail: a.bukhtiarova@uabs.sumdu.edu.ua*

Семенов А. Ю.

*к.е.н., доцент кафедри фінансів, банківської справи та страхування,
Сумський державний університет м. Суми,
Україна; e-mail: a.semenoh@uabs.sumdu.edu.ua*

ЕКОНОМІКО–МАТЕМАТИЧНЕ МОДЕЛЮВАННЯ ОЦІНКИ ФУНКЦІОНУВАННЯ УКРАЇНСЬКОЇ БАНКІВСЬКОЇ СИСТЕМИ

Анотація. У дослідженні представлено науково–методичні засади оцінювання ефективності функціонування банківської системи України за допомогою узагальненої функції Харрінгтона (функції бажаності). Запропонований науково–методичний підхід, що ґрунтується на аналізі динаміки патернів банків та побудові самоорганізуючих карт Кохонена, дозволяє визначити траєкторію розвитку окремого банку та спрогнозувати кризовий фінансовий стан як окремого банку так і банківської системи країни в цілому.

Ключові слова: банки, банківська система, економіко–математичне моделювання, функція бажаності Харрінгтона, кластерний аналіз, самоорганізуючі карти Кохонена.
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Школьник И. А.

*д.э.н., профессор, заведующий кафедрой финансов, банковского дела и страхования
Сумской государственной университет г. Сумы,
Украина; e-mail: y.shkolnyk@uabs.sumdu.edu.ua*

Бухтиярова А. Г.

*к.э.н., старший преподаватель кафедры финансов, банковского дела и страхования
Сумской государственной университет г. Сумы,
Украина; e-mail: a.bukhtiyarova@uabs.sumdu.edu.ua*

Семенов А. Ю.

*к.э.н., доцент кафедры финансов, банковского дела и страхования
Сумской государственной университет г. Сумы,
Украина; e-mail: a.semenoh@uabs.sumdu.edu.ua*

ЭКОНОМИКО–МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ ОЦЕНКИ ФУНКЦИОНИРОВАНИЯ УКРАИНСКОЙ БАНКОВСКОЙ СИСТЕМЫ

Аннотация. В исследовании представлены научно–методические основы оценки эффективности функционирования банковской системы с помощью обобщенной функции Харрінгтона (функции желательности), что дает возможность определить текущее состояние банковской системы и спрогнозировать перспективы ее развития. При моделировании оценки функционирования банковской системы были использованы данные 49 банков, действующих в Украине в 2003–2016 гг. В модели было использовано 15 финансовых показателей, обеспечивающих формирование входных переменных модели. Предложенный научно–методический подход, основанный на анализе динамики паттернов банков и построении самоорганизующихся карт Кохонена позволяет определить траекторию развития отдельного банка. Также на основе данного подхода возможно прогнозирование кризисного финансового состояния как отдельного банка, так и банковской системы страны в целом.

Ключевые слова: банки, банковская система, экономико–математическое моделирование, функция желательности Харрінгтона, кластерный анализ, самоорганизующиеся карты Кохонена.

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Introduction. In the context of globalization for each country exacerbated the problem of sustainable economic development, which largely depends on the stability of the banking system. Under these conditions, methods for early diagnosis of possible crisis in the banking system and the choice of statistical methods for forecasting future state of the banking system are particularly important. These will enable a timely manner to prevent the emergence of problems in the banking activities.

In an unstable economic situation in the banking system of Ukraine research and financial analysis of this segment of the financial market and individual banks is a priority task as for researchers and for practitioners.

Literature review and the problem statement. Almost every country has its own method of assessing the financial condition of banks allowing for the national economy. In the world, there are several early response (notification) systems and developed number of models such as: CAMEL (Capital adequacy – Asset quality – Management – Earnings – Liquidity), CAMELS (CAMEL + Sensitivity to market risk), CAEL (Capital adequacy – Asset quality – Earnings – Liquidity), SCOR (Statistical CAMELS off–site rating), FIMS (financial institutions monitoring system), SEER (system for estimating examination ratings), SAABA (Support System for Banking Analysis), BAKIS (BAKred Information System) [1, 2, 3]. All these models are applied in practice and

through them conducted a qualitative analysis of the dynamic of the banking system in many countries, but each of them has its advantages and disadvantages. In our opinion analysis of common and distinctive features of banks and assessment of the banking system the most appropriate for research is the use of cluster analysis. Kohonen self-organizing maps consist of components called nodes or neurons. The number of such components manually enters by researcher. Each node can be described by two lines (vectors). The first vector describing the weight m and is characterized by a corresponding dimension input. Another vector r is the coordinate data specific host on the general Kohonen map. The resulting map can be represented by the elements (cells) that had rectangular or hexagonal shape. It should be noted that the most common form is hexagonal because it provides greater visualization of maps and the distance between the centers of adjacent cells are the same.

As for the structure of input data, most researchers thought the same, so according to O.P. Zarutskya [4], the most significant are the final (quality) parameters, quantitative (structural) parameters of balance proportion of banks and profile of performed operations, financial indicators characterizing the market sector, where is bank's profit are formed. Construction of clusters based on the similarity among banks in the environment of indicators / factors selected for the study. Group of indicators that characterizing a single cluster called a pattern. In practice, each cluster has its own unique pattern, which it describes. Changing of dynamics of patterns may indicate a change in the strategic objectives of the bank. The study of the dynamics of patterns and their temporal characteristics can be a tool to assess the evolution of the bank and will predict individual indicators of the bank in the future. We consider that the trajectory of the evolution of the bank can be defined ordered set of patterns, each of which describes the activities of the bank at a time. The more range of indicators of the efficiency of the bank, the more accurate will be conducted cluster analysis, as an effective mechanism for building patterns prerequisite is a large amount of input data. Method of clustering using of Kohonen maps considers the totality of the indicators [5, 6]. The study aims to develop a model that will determine the trajectory of a single commercial bank and the banking system and will enable to predict beforehand the potential banking crisis.

Research results. The algorithm of assessment of the banking system is represented as follows:

- I. The analysis of the patterns of banks in Ukraine includes 5 stages.
 - Stage 1. Defining the system of indicators on which the clusters map is based.
 - Gradual collection of necessary input data (financial statements of banks);
 - Formation databases, i.e. forming matrix input X .

$$X = \begin{bmatrix} X_{11} & \dots & X_{1m} \\ \dots & \dots & \dots \\ X_{n1} & \dots & X_{nm} \end{bmatrix} \quad (1)$$

- m – number of financial indicators;
- n – number of banks participating in the analysis;
- X_{nm} – value of m indicator for the n bank

Stage 2. Normalization of input data of the model.

As the chosen indicators have different measurement scale, for their unique comparison it is necessary to make the normalization.

The method of bringing information dimensionless to the normalized form is based on the concept of "ideal" quality strategies as a vector.

$$E^{\text{ideal}} = (e_1^{\text{ideal}}, \dots, e_Q^{\text{ideal}}) \quad (2)$$

Using a component ideal column vector estimates (on q test) is reduced to normalized form:

$$E(e_q) \xrightarrow{NORM} E^H(e_q), q=1, \dots, Q \quad (3)$$

$$e_q^H(s_k) = \frac{e_q(s_k)}{e_q^{ideal}}, k=1, \dots, m \quad (4)$$

A successful solution to the problem of normalization depends largely on proper and objective definition of the "ideal" quality strategies. Method of determining the ideal vector method determines the relative normalization.

As an ideal vector, can be used, for example, a vector whose components are the maximum possible value of local criteria:

$$e_q^{ideal} = ((\max_{S_i \in S} e_1(s_i); \dots; (\max_{S_i \in S} e_q(s_i); \dots; (\max_{S_i \in S} e_Q(s_i))) \quad (5)$$

Stage 3. Optimizing of input data using the Harrington desirability function.

Generalized Harrington function (the desirability function) is quantitative, unambiguous, unique and universal indicator of the quality of the object, but if you add qualities such as adequacy, effectiveness and statistical sensitivity, it becomes clear that it can be used as a criterion for optimization. To use the Harrington scale, we need all the studied parameters lead to dimensionless form per the horizontal axis and calculate the value of partial Harrington functions.

$$G_i = \sqrt[n]{\prod_{k=1}^n d_k} \quad (6)$$

$$d_k = \exp(-\exp(-\bar{x}_k)) \quad (7)$$

- k – number of indicators used to assess the desirability function;
- d_k – partial function which is defined per the Harrington scale;
- \bar{x}_k – rate in dimensionless form.
- n – the number of investigated objects;

Particle coefficients calculated in generalized coefficients systems allow us with almost mathematical precision determine their advantages and disadvantages. If the ratio of the desirability of system is in the lower area features of Harrington function, for satisfactory results of functioning of the bank will need to "pull" almost all the parameters of the system to an acceptable level (due to the high cost of time and effort to be correctly estimate (Table. 1).

Table 1

Harrington function scale

Desirability	Assessment
Very good	[0,80–1,00]
Good	[0,63–0,80)
Satisfactory	[0,37–0,63)
Bad	[0,20–0,37)
Very bad	[0,00–0,20)

Analyzing partial coefficients of desirability of specific parameters, we can assess opportunities and ways of upgrading of individual bank.

Stage 4. Process data by means of software Viscovery SOMine.

The method of data processing is implemented in the package Viscovery SOMine. Using the proposed method of grouping large volumes we can receive more information about the real state and trends of each object by comparison with the totality of objects and generalize of similar features.

a) Setting priorities of clustering features (efficiency of banks) by Fishburne method.

In multi decision-making tasks the local criteria have different importance for the person who decides. This should be considered to select the optimal strategy, giving preference to a more important criteria information or situations.

We check the balance of the distribution of weights for which we use a formula to sum arithmetic progression of m parameters with strict descending order of priority. Further we normalized weights and conducted weight coefficients calculated by Fishburne rule:

$$W_i = \frac{2(N - n + 1)}{N(N + 1)} \quad (8)$$

W_i – weight coefficient of i indicator;

n – weight of indicator;

N – total number of indicators.

The amount of weighting coefficients should equal 1.

b) Setting up the training of Kohonen maps.

Installed the number of neurons of Kohonen maps (Number of nodes=1000) is conditioned by the size of the target population of banks. The value of tension parameter set at 0.3 level to increase the sensitivity of artificial neural network. For more accurate results, choose "Accurate" schedule.

c) construction of maps of clusters investigated banks;

d) analysis of the results of the model based on the Harrington desirability function scale;

d) distribution points for groups of banks in clusters;

f) evaluation of banks by groups within clusters.

5 stage. Assessment of the adequacy of the model.

To test the adequacy of the model we will input to model two conventional banks “The good bank” and “The bad bank” (with maximum and minimum value of synthesizing function). Reaction of model will allow to conclude correct response of model of diametrically different value of indicators.

The conceptual model of dynamic analysis of patterns of banks in the banking system presented as:

$$\chi = \{G_1; G_2; G_3; G_4\} \rightarrow \max$$

$$\left\{ \begin{array}{l} G_i = \sqrt[n]{\prod_{k=1}^n d_k} \\ d_k = \exp(-\exp(-\bar{x}_k)) \\ n = 1 \dots N \\ k = 1 \dots K \\ G_i \in [0;1] \\ \chi \in [1;4] \end{array} \right. \quad (9)$$

We use methodical approach to analyze the dynamics of patterns of banks in the banking system of Ukraine. To construct the model was chosen 49 banks of Ukraine. For clarity of the results were taken representatives of each of the 4 groups of banks. The choice of banks for research

was conducted based on the Decision of the National Bank of Ukraine "About distribution of banks in the group" [7, 8, 9, 10]. **Ошибка! Источник ссылки не найден.**

Defining the metrics on which the clusters map is based. In the model we proposed using 15 indicators that provide formation of input variables of models.

We propose to use a relative approach to normalization of parameters used in mathematical statistics.

$$e_q^H(s_k) = \frac{e_q(s_k)}{\max_{s_i \in S} e_1(s_i)}, q = 1, \dots, Q; k = 1, \dots, m \quad (10)$$

Next stage is optimizing of input data using the Harrington desirability function. We consider the significance of the 15 indicators and conduct convolution. This study investigates banks in the following areas: a group of indicators characterizing the state of bank deposits (4 indicators); group of indicators characterizing the state of the bank's assets (5 indicators); group of indicators characterizing the state of the bank's capital (3 indicators); group of indicators characterizing the state of bank loans (3 indicators). We find the weight of each group of indicators. To apply this, we use Fishburne rule. We find the weight of each group of indicators. To apply this, we use Fishburne rule.

The process of data processing by means of software Viscovery SOMine.

We have set of Kohonen maps for selected groups of indicators and borders for partitioning the clusters. Based on the presentation of colors we can determine the distance between elements of the samples. You can also use Kohonen maps of the scale to determine the values of the cells, their comparison and analysis.

Thus, data processing was obtained 6 clusters. General Kohonen map is presented in Figure 2.

For the interpretation of the results we can generate the trajectory of banks during 2003–2015.

The formation of ranks of clusters are presented in Table 2.

Table 2

Forming ranks clusters

Cluster	Share	Synthesizing function				Distribution				Rank	Group of banks
		G ₁	G ₂	G ₃	G ₄	G ₁	G ₂	G ₃	G ₄		
S ₁	52,61%	0,4923	0,5455	0,4616	0,5179	3	3	3	3	2**	Stable banks
S ₂	22,39%	0,4739	0,4993	0,4779	0,5282	3	3	3	3	3**	Problem banks
S ₃	10,28%	0,3845	0,5339	0,3181	0,5112	3	2	3	3	5	Banks in crisis
S ₄	9,66%	0,4556	0,4277	0,4930	0,5431	3	3	3	3	4**	Problem banks
S ₅	2,15%	0,0042	0,5174	0,0587	0,4990	3	1	3	1	6	Banks at the stage of bankruptcy
S ₆	2,91%	0,5643	0,6447	0,4684	0,5201	4	3	3	3	1	Strong banks

** To set the rank for clusters S₁, S₂, and S₃, the average rate of synthesizing function was used

To assess the efficiency of the individual banks, we conditionally divide clusters into groups. Based on the model results the group of strong banks include (Cluster S₆ – pink cluster): PJSC Imeksbank (in 2012), JSC Oschadbank (2003–2008) and PJSC PrivatBank (2003–2015). Crisis Group banks in 2015 include 5 banks (Cluster S₃ – yellow cluster): PJSC Zemelny Capital, JSC Oschadbank, PJSC FUIB, JSC Ukreximbank, PJSC Ukrsotsbank (UniCredit Bank).

Group Banks at the stage of bankruptcy in 2015 include 2 banks (Cluster S₅ – violet cluster): PJSC Universal Bank and PJSC Prominvestbank.

Banks included in the last 2 groups are requiring special supervision by the state banking supervisors. Specific sanctions for Ukrainian and international banking legislation should be applied to these banks.

To test the adequacy of the model we introduce to the model two conventional banks “The good bank” and “The bad bank”.

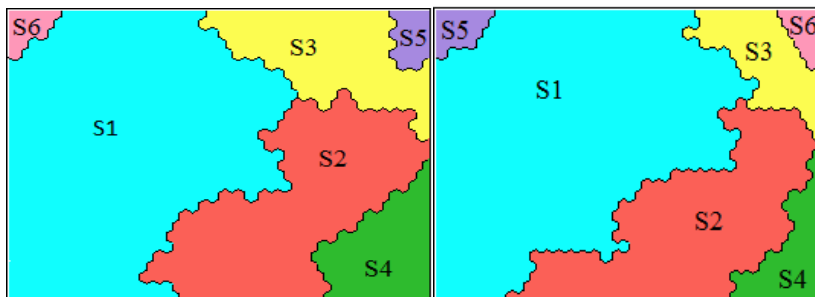


Figure 1. Kohonen map of Ukrainian banking system and New Kohonen map with conventional banks

In the upper left corner, there is a violet cluster S_5 indicators which show the best financial reporting data and in the upper right corner there is a pink cluster S_6 that contrast worst. Based on the results we can conclude that “The bad bank” with low financial performance thus was added in the worst pattern, while the “The good bank” on the general Kohonen map goes to the best pattern that confirming the adequacy of the proposed model. Normalization of data on the Savage basis. The choice of normalization explained that Savage normalization is the most common among researchers, economists and simultaneously combines 2 operations: changing indicator of the effectiveness $(E(e_q))^{\pm} \xrightarrow{NORM} (E^H(e_q))^m$ and natural method of normalization. After that data should be optimized on Harrington function.

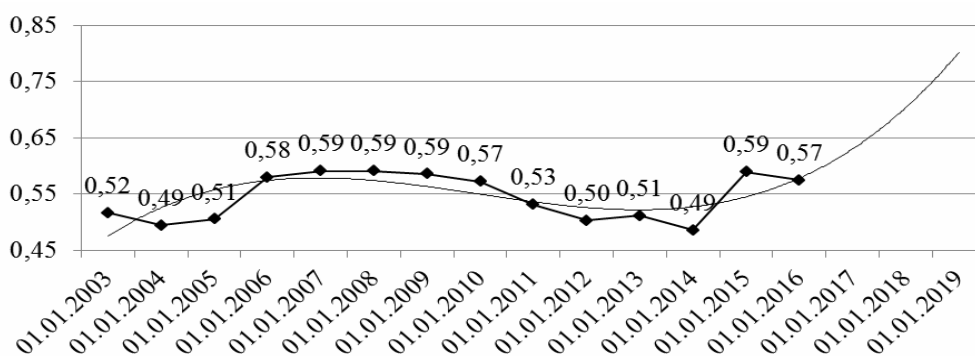


Figure 2. Assessment of functioning of the banking system of Ukraine

Calculating of the integral index, we considered belonging of individual bank to the group of banks, according to the National Bank of Ukraine classification of banks by assets. Balance between groups of banks were allocated on the Fishburne basis.

Analysis of evaluation of the banking system based on scale of assessment of the Harrington desirability function. Construction of the third-degree polynomial trend to identify general trends in the banking system during the period.

Trend forecasting of developing the banking system for 3 future periods.

Results of the evaluation of the banking system of Ukraine is shown in Figure 3.

Conclusions. Thus, the following conclusions can be made. The activity of the Ukrainian banking system underwent some fluctuations during the investigated period, but remained at a satisfactory level in accordance with the values obtained by Harrington function. During 2003–2004, the value of generalized Harrington function was at 0,52–0,49 points, but the following years showed a significant improvement of Ukrainian banking system in 2005–2009 when it consistent the level of 0,58–0,60 points.

During 2010–2012, the Ukrainian banking system has experienced great upheaval that accordingly affected the indicator of Harrington function whose value decreased to 0.5 in 2012. At the beginning of 2013 we can notice a slight recovery of the system, however, in the following 2 years, the situation in the banking system again deteriorated. At the beginning of 2016 integral assessment of the Ukrainian banking system is 0.57 points that corresponding to a satisfactory level of desirability.

Conducted trend forecast of the Harrington function suggests potential of improving of Ukrainian banking system over the next 3 years. Based on the results of the model we see the need to search resources to further improvement and reforming of the banking system of Ukraine.

It should be noted that obtained model can be expanded with additional indicators and parameters that will not influence on its effectiveness. This model can also be used for the simulation of other financial processes and systems.

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Бухтіарова А. Г., Семенов А. Ю.

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Semenov A. U.