

Assessment of bank's financial security levels based on a comprehensive index using information technology

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Abstract. The article considers the issues of assessing the level of financial security of the bank. An analysis of existing approaches to solving this problem. A scientific and methodological approach based on the application of comprehensive assessment technology is proposed. The computational algorithm is presented in the form of a four-stage procedure, which contains the identification of the initial data set, their normalization, calculation of the partial composite indexes, and a comprehensive index of financial security. Results have interpretation. Determining the levels of financial security and the limits of the relevant integrated indicator is based on the analysis of the configuration of objects in the two-scale space of partial composite indexes, which is based on the division of the set of initial indicators by content characteristics. The results of the grouping generally coincided with the results of the banks ranking according to the rating assessment of their stability, presented in official statistics. The article presents the practical implementation of the proposed computational procedure. To automate calculations and the possibility of scenario modeling, an electronic form of a spreadsheet was created with the help of form controls. The obtained results allowed us to identify the number of levels of financial security and their boundaries.

Keywords: financial security, bank, composite index, information technology, convolution, scale of financial security levels.

1 Introduction

1.1 Problem description

The financial sector has a leading role in the modern economy, providing financial intermediation between the various actors in the financial market and creating the basic preconditions for social reproduction. A sound and efficient financial sector encourage

productive investment, thus supporting innovation and economic growth. Bank credit is also used to finance the needs of households, in particular, to balance the structure of consumption and further investment for future self-sufficiency, sustainability, and development.

The high level of financial security of the banking system determines not only the efficiency of its functioning and economic stability of society but also the financial strength and national security of the state as a whole.

Great Financial Crisis of 2007–09, which accompanied by the emergence of the crisis conditions in the banking system in many countries of the world, challenged the reliability of the entire financial system, caused a real bank bankruptcy. The current trends in the development of bank activity in the countries of the world testify to the intensification of processes that provoke general global instability. The profound, structural nature of these changes shows that the transformation of the world banking system, as well as national banking ones, is an inevitable process with indeterminate consequences. According to the official statistics of the National Bank of Ukraine, the number of banking institutions of domestic owners in Ukraine has halved for the period from 2014 to 2018 [28], which testifies to the ineffectiveness of management work and the inability to withstand financial threats.

The Covid-19 pandemic has become a new challenge for the world economy in general and all its subsystems, including banking one [35]. As has been noted in paper [3], the size, scope, and influence of the Covid-19 crisis are comparable to those of the Great Financial Crisis of 2007–09. As a consequence, long-term rating forecasts have been revised to negative for many banks, especially those with low profitability.

Therefore, currently, the main task of banks is to play their role in stabilizing the economic situation as soon as possible. To do this, they must, above all, have sufficient financial resources to immediately provide companies with the necessary financial support and ensure their survival.

Report of the National Bank of Ukraine on Financial Stability, dated June 2020 [27], states, that the Ukrainian banking sector entered the crisis caused by the pandemic in good shape and with a sufficient margin of safety. Due to the clean-up of the banking sector, the introduction of internationally recognized capital and liquidity requirements, regular stress testing, and other measures to improve the reliability of the sector, the new crisis has not led to disruptions in the banking system. The capital adequacy of banks significantly exceeded the minimum level. Banks can now use its surplus to absorb credit losses and for further lending. Financial institutions have become highly efficient and profitable, so in the end, they generate capital themselves.

The funding structure is also favorable – more than 90% of liabilities are raised in the domestic market. The banking sector today does not depend on the situation on international capital markets. The liquidity of financial institutions is high both in hryvnia and in foreign currencies. At the same time, due to the growth compared to the previous year, allocations to reserves significantly reduced the profitability of the banking sector. There are also losses from the decline in the quality of the loan portfolio, but estimates of their volume can be made only at the end of the year. The report also notes that the current crisis could lead to a breach of the fixed or regulatory capital adequacy ratios of nine banks, which account for 30% of the sector's assets, of which

25% are two state-owned banks. In two financial institutions, the capital may become negative. These are all institutions that have shown negative results of stress testing in the past but have not taken sufficient measures to address the accumulated issues.

We agree with the statement of the study [7] that the key challenge over the coming period is to keep credit flowing amidst deteriorating credit quality and rising defaults. Critical to supporting this activity are banks' continued ability to raise funds and willingness to provide credit, which in turn would depend on market perceptions of their and their borrowers' solvency.

Under such conditions, the urgent task of the future banking system is to ensure its stability, which is the dominant condition for its steady development and ensuring the stable functioning of the national economy.

Financial security, as a functional part of the bank's economic security, provides an appropriate level of stability of its financial state, which ensures the safety of priority financial interests associated with the implementation of the adopted development strategy and the meet the target competitive positions in the conditions of external and internal threats. Therefore, the banking system faces the challenge of achieving the financial stability of each bank and guaranteeing the financial security of the entire system. The high dynamism of social development in the conditions of the growing openness of the national economy and its integration into the world economy increases the threats and influence of destabilizing factors of the internal and external environment, deepening the financial markets competition prevent the process of realization of strategic directions of banks development in terms of profitability and minimization of risks. This determines the urgency of solving the problem of ensuring the financial security of banks, which will enable them to carry out preventive actions and minimize the negative effects of the crisis in the national banking system.

At present, there are no common approaches among scholars to the definition of the nature and characteristics of the financial security of banks, as well as to the procedures and mechanisms for its quantitative assessment and identification of security level. We agree with the views of scholars [26], according to which the financial security of the bank is considered as it state is characterized by the protection of its financial interests, sufficient volume of resources, the presence of stable growth dynamics of main indicators in the current and prospective periods, which is achieved by using a sound financial strategy, flexibility in the adoption of financial decisions, timely response to the external and internal dangers and threats. Ensuring the financial security of banks should be aimed at neutralizing the structural imbalances in their development and the negative impact of destabilizing internal and external disturbances. The state and level of bank security may have some variability in time, but if the fluctuation of such fluctuations is insignificant, its development is not subject to significant changes. Effective managing the bank's activities necessitate the use of modern tools for identification of bank financial security level and analyzing its dynamics. This allows as objective as possible to describe the current state of security and promptly signal about threats to the bank's financial security depending on the purpose, objectives, and interests of all stakeholders.

1.2 Literature review

The analysis and assessment of the financial security system have long been the subject of research by researchers. Traditionally, these issues were considered within the framework of diagnosing crisis phenomena and assessing the bankruptcy probability. However, recently they have been distinguished in a separate field and it can be stated that the number of scholar's publications and practical developments in this area is increasing. The key issue that arises in assessing financial security is to establish its criterion like a benchmark that can be quantitatively measured by a certain set of initial indicators of the bank's activity. It allows us to conclude about the state or level of bank financial security. As these criteria we may use performance indicators, indicators of the financial condition, including financial viability, minimizing risks, maximizing the cost of equity capital, etc. Additionally, issues of identifying a set of defining indicators that characterize the financial security state are also studied.

An important condition for ensuring the bank's financial security is its financial stability. It is a system category that reflects the prospects for its development. It can be interpreted differently but is always based on indicators that reflect the qualitative and quantitative state of the bank's capital base, the level of liquidity, the quality of assets and liabilities, profitability, and quality of bank management. Financial stability acts both as a prerequisite and as a result of ensuring the financial security of the bank. The issue of assessing financial stability on the example of banks around the world using a variety of tools, in particular, correlation and regression analysis, comprehensive assessment technology, financial analysis, are presented in [2; 8; 12; 14; 29; 40].

The stability of a bank is largely ensured by indicators of liquidity and profitability. They are key components for ensuring the continuity of banking activities, characterize the bank's capacity, especially in times of crisis. On the one hand, they are components of a system of indicators that are used to assess both the banks' financial stability and financial security. On the other hand, many scholars attach special importance to them, considering them both as determinants and as result indicators in the procedures for evaluating the performance of the banking sector. Appropriate approaches are presented in studies [6; 18; 22; 23; 30; 34; 39; 43]. Note that many authors of the presented works paid attention to the evaluation by using the comprehensive assessment technology to design indicators of the bank's financial stability.

Consider the characteristics of the main approaches that focus on assessing the banks' financial security as a separate characteristic of the bank's operation.

At the national level, the methodology presented by the Ministry of Economic Development and Trade of Ukraine [24] is used. It provides a series of indicators of the state of banking security in Ukraine: overdue loan arrears in the total volume of loans of Ukrainian banks; the ratio of bank loans and deposits in foreign currency; the share of foreign capital in the total amount of bank's capital; the ratio of long-term loans and others. An approach based on the use of normative values as the main criteria for assessing financial security is quite common, in particular, in the papers [13; 19; 31; 41]. In our opinion, the disadvantage of this approach is that it does not allow us to establish the level of financial security, but only to state the degree of its provision for

individual components. Also, the normative values of bank's effectiveness indicators are designed for some idealized banks and can't objectively reflect the state of real bank's financial security.

The mentioned disadvantages are eliminated in the methods, which use the tools of economics and mathematical modeling to assess the level and state of financial security. In particular, O. A. Sergienko with co-authors [9; 36; 37; 38] considers a set of models that allow to analyze the state and trends of financial market development, to evaluate and analyze the structural elements of bank financial security, to investigate the degree of influence local indicators to the overall financial security level. The result is scenarios for ensuring bank financial security. In our opinion, the given models require rather considerable volumes of the initial data, and the results are based on complicated calculations, which is limited to their practical application. Also, it must be taken into account that ratings are ordinal by their origins, and allow them to use very limited mathematical tools for their correct processing.

Scoring models for assessing the financial security level are given in the papers [32; 44; 46]. The advantages of such models are the simplicity of calculations and the clarity of results interpretation. However, the provision of scores for each characteristic always has some subjectivity, which makes the final evaluation results less reliable. Also, it is indirectly necessary to justify forming an expert group, to carry out agreeing expert views, etc. Among the methods of financial security modeling, of particular note is an approach based on comprehensive assessment technology [1; 4; 15; 16; 17; 20; 21; 25; 45]. Assessment methods presented in these papers differ in the set of indicators, the rules for calculating the final result, and the choice of weight coefficients of the composite index components. An important problem in assessing the financial security level is the choice and justification of the scale, which allows you to identify this level. These issues are highlighted in [16; 20; 25; 36]. However, it should be noted that the author's proposals don't always sufficiently substantiate the number of financial security levels and the boundaries of these.

In the presented researches, procedures of an estimation of financial security differ on the quantity of the initial indicators selected for calculations, ways of data normalization, and their integration into a final indicator of financial security. Although in most cases the technical side of the calculations usually does not require much effort, it should be noted that current issues related to the use of information technology, including specialized software in solving problems of assessing the level of financial security in the scientific literature are covered not enough. The use of such technologies will determine the impact of individual partial indicators on the final result, structuring of the studied objects by the values of the integrated indicator, simplify the recalculation of the result when changing the number of partial indicators, grouping, rules of their normalization, method of convolution into the final result, choice of weight values for initial indicators, etc.

The purpose of this article is to improve the methodology for assessing the level of financial security with the construction and justification of the appropriate scale of levels and their boundaries, as well as a description of the possible use of information technology to automate calculations in this field.

2 Research methodology

2.1 Description of an approach to assess the level of financial security

The basis of the proposed approach is the technology of comprehensive index assessment. The main idea underlying the approach, that is presented in paper [16], is that for determining the classification of the object under study, they are pictured in some multidimensional space of partial composite indexes, calculated by the subset of the aggregate of initial indicators and reflect a certain characteristic of the bank's activities. The number of such composite indexes is determined based on features of the set of initial bank indicators. The constructed structure of the studied objects is aimed at identifying their grouping by the distinguishing characteristics. To quantify the financial security level, a comprehensive index is used, designed by the totality of initial indicators. The number of financial security levels and their boundaries are determined based on the objects' classification obtained.

The calculating procedure for the proposed approach consists of the following steps. At the first stage, a set of initial indicators is shaped, which will be used to assess the financial security level. To simplify calculations, it is recommended to select indicators that can be obtained from the open-access banks' financial statements or that can be obtained based on such information. Also, shaping a training sample for the calculations is carried out in this step. The initial collection is divided into groups of indicators according to certain rules, in particular, based on their content characteristics. The number of groups is determined by the objectives of the study and the characteristics of the indicators.

The second stage carries out the grouping of initial indicators for the essential characteristics. Next, the procedures for data normalization and establishment of weighting factors within each group are executed. Each group can have its own rules for normalization based on the origins and essence of the indicators selected. Typically, this procedure is based on the selected sample taking into account the maximal and minimal values for each indicator.

In this stage, the procedure of data normalization is carried out normalizing with the transformation of their values into an interval from 0 to 1. For each indicator can be selected its own rules of normalization, based on the nature of the selected indicators. Usually, the rationing is carried out according to the formed sample taking into account the largest and smallest values for each indicator (scaling of their values):

$$u_{ij} = 1 - \frac{|x_{ij} - x_j^*|}{x_{jmax} - x_{jmin}}, \quad (1)$$

where u_{ij} are normalized values of indicators, x_{ij} – initial values of indicators, $x_{jmin} = \min_i x_{ij}$, $x_{jmax} = \max_i x_{ij}$, $i=1, \dots, m$, $j=1, \dots, n$, m – number of objects observed (banks), n – number of initial indicators.

Values x_j^* are identified by the formula:

$$x_j^* = \begin{cases} x_{jmax}, & \text{when } j \text{ is a incentive;} \\ x_{jmin}, & \text{when } j \text{ is a disincentive.} \end{cases} \quad (2)$$

This approach has the disadvantage that changing the sample can lead to a change in its largest and smallest values, and, as a consequence, a change in the sample of normalized values, which can affect the final result.

There are also other approaches to the normalization of indicators by scaling them, in particular, presented in [10]. Provided that there are normative or recommended values that can be used as the best (optimal), the normalization procedure has such form:

a) when x_{ij} is incentive:

$$u_{ij} = \begin{cases} 0, & x_{ij} < 0; \\ \frac{x_{ij}}{x_j^*}, & 0 \leq x_{ij} \leq x_j^*; \\ 1, & x_{ij} > x_j^*; \end{cases} \quad (3)$$

b) when x_{ij} is disincentive:

$$u_{ij} = \begin{cases} 0, & x_{ij} \leq 0; \\ \frac{x_j^*}{x_{ij}}, & x_{ij} \geq x_j^*; \\ 1, & 0 < x_{ij} < x_j^*; \end{cases} \quad (4)$$

where x_j^* is regulatory (normative) or recommended value selected as an optimal one.

This way of normalization does not depend on the sample but has the disadvantage that not all indicators have such optimal values x_j^* .

Some approaches perform nonlinear normalization of data based on functional dependencies, that are presented, in particular, in [11; 42]. However, they are also focused on the use of optimal values of indicators, which reduces their practical application. Another procedure performed at this stage is to determine the weight of indicators both within each group and for groups. Usually, the weights are either chosen equal or set based on substantive considerations, expert evaluation. Also, quite common is the use of methods of multidimensional statistics, in particular, factor analysis.

In the third stage, the calculation of partial composite indexes for each group and the identification of the grouping of the studied set of objects in the space of new scales. As integration procedure there is usually used additive (formula (5)), multiplicative (formulas (6) and (7)) convolutions or convolutions by the method of distances (formula (8)):

$$Q_A = \sum_{j=1}^n w_j u_{ij} \quad (5)$$

$$Q_{M1} = \prod_{j=1}^n u_{ij}^{w_j}, \quad (6)$$

$$Q_{M2} = -1 + \prod_{j=1}^n (1 + u_{ij}^{w_j}), \quad (7)$$

$$Q_D = 1 - \sqrt{\sum_{j=1}^n w_j (1 - u_{ij})^2} \quad (8)$$

where Q_A , Q_{M1} , Q_{M2} , Q_D , are the values of the composite index for additive, multiplicative (formulas (6) and (7)) convolutions or convolutions by the method of distances appropriately, $i=1, \dots, m$; w_j – weighted coefficients of indicators, $j=1, \dots, n$. In this case, weighted coefficients should meet the condition:

$$\sum_{j=1}^n w_j = 1. \quad (9)$$

At the fourth stage, the calculation of the comprehensive indicator of financial security is carried out for the whole set of initial indicators. One of the convolutions (5) – (8) is also used for this purpose. After that, taking into account the typology obtained at the previous stage, the number of levels of financial security is determined and their quantitative limits are calculated.

The given procedure contains certain universalism and admits adaptation under the application of specific situations. In particular, this concerns the formation of a training sample, the choice of the initial set of banks indicators, their distribution by essential characteristics, the choice of convolution and weighting coefficients to calculate partial composite indexes and a comprehensive index, the definition of the number of financial security levels and their boundaries. In our view, some of these issues are not significant, such as the choice of grouping form for the initial set of indicators or the convolution form to design both composite and convolution indexes. Solving other issues should be in line with the results obtained by other methods, in particular the identifying financial security level for a selected sample of banks.

We can also use traditional methods of multidimensional statistical analysis, such as factor or component analysis, clustering technology to group banks. However, for the first specified group of methods, there may be difficulties in meaningful interpretation of the latent characteristics obtained. To group objects using cluster analysis technology, there are problems with the interpretation of clusters. We recommend using these methods to reconcile the results obtained by the proposed procedure.

2.2 Using information technology for providing calculations

Consider the possibility of automating calculations by means of spreadsheets. In order to create a user-friendly interface to manage initial data and calculation algorithm, it is advisable to use form controls like Spin Buttons, Scroll Bars, Check Boxes, Option Button, List Box, Combo Box.

In particular, to manage the inclusion of the indicator into the calculations, we can use the form control Check Box. To select the individual components of the calculation algorithm, in particular, the method of data normalization, the method of convolution of partial indicators, it is advisable to use form controls like List Box or Combo Box. In this case, it is necessary to provide for the formation of appropriate lists of elements in any cells of the spreadsheet to their inclusion into the body of List Box or Combo Box. Management of separate values (for example, weights) it is expedient to carry out with using Spin Buttons.

Managing by data and formulas for their processing can be performed using scenario managing tools like what-If analysis. It allows you to create, store, and substitute

different sets of values for the output, as well as automatically generate reports on the results of calculations. Such tools are useful in modeling procedures for assessing the level of financial security to change the rules of data processing including their normalization, convolution, etc. and determine the most practical result.

3 Results and discussions

Let us consider the practical use of the approach proposed. To rich this aim, we select a set of initial indicators and shape a training data sample. The information source is the official data of the National Bank of Ukraine [28].

So, for analysis we were selected the following set of indicators: X_1 – index of assets coverage by equity; X_2 – index of assets coverage by authorized capital; X_3 – the share of current deposits in the bank’s deposit base, %; X_4 – the share of retail deposits of in the bank’s liabilities, %; X_5 – ratio of loans and deposits; X_6 – loan reserve ratio; X_7 – the ratio of assets coverage to liquid assets; X_8 – coefficient of coverage of attracted resources by liquid assets; X_9 – the ratio of liabilities coverage to liquid assets; X_{10} – ROA, %; X_{11} – ROE, %; X_{12} – net interest margin, X_{13} – the ratio of interest expenses to interest income.

The indicators $X_1 - X_6$ reflect the effectiveness of shaping the competitive capacity of banks, the rest of the indicators $X_7 - X_{13}$ – the effectiveness of banks’ operational and financial activities.

The selection of two groups of indicators, in this case, has the advantage that the results of grouping can be reflected graphically in a form that is convenient for perception, and therefore subject to a clear and understandable interpretation.

The analysis of the scientific publications showed that for some of the indicators we can determine the optimal (normative or recommended) values. In particular, the author of [5] recommends the following values, presented in table 1.

Table 1. Optimal (recommended value) for indicators.

Indicator	Optimal (recommended value)
X_1 – index of assets coverage by equity	10%
X_5 – ratio of loans and deposits	70%
X_7 – the ratio of assets coverage to liquid assets	30%
X_{10} – ROA	4%
X_{11} – ROE	20%
X_{12} –net interest margin	45%
X_{13} –ratio of interest expenses to interest income	80%

The training sample was made by such Ukraine’s banks, that are presented in the table 2. For calculations, we choose the data period from 2017 to 2019. The values of the relevant partial indicators, selected for calculations and distributed by groups, are presented in tables 3-8.

To provide calculations, we create an electronic form using form controls. it contains, in addition to the initial data, form controls Check Boxes to include indicators in the calculations. The Combo Boxes are used to distribute the initial partial indicators

between groups; choosing the method of specifying weights for partial indicators and groups (equal or user-defined); the type of baseline indicators (incentive or disincentive), as well as the method of data normalization.

Table 2. Sample of banks.

Code	Name of Bank
C_1	Public Joint-Stock Company “Commercial Bank Privatbank” (PJSC CB Privatbank);
C_2	Public Joint-Stock Company “State Savings Bank of Ukraine” (PJSC Oshcadbank);
C_3	Joint Stock Company “The State Export-Import Bank of Ukraine” (JSC Ukreximbank);
C_4	Public Joint-Stock Company “Joint Stock Bank “Ukrgazbank”;
C_5	Joint-Stock Company “Raiffeisen Bank Aval”;
C_6	Joint-Stock Company “First Ukrainian International Bank” (FUIB);
C_7	Joint-Stock Company “Alfa-Bank Ukraine”;
C_8	Joint-Stock Company “Ukrsibbank”;
C_9	Public Joint Stock Company “Joint-Stock Commercial Industrial Investment Bank” (PJSC Prominvestbank);
C_10	Public Joint-Stock Company ‘Commercial Bank ‘Financial Initiative’
C_11	Joint-Stock Company “Megabank”
C_12	Joint-Stock Company ‘Credit Agricole Bank’
C_13	Joint Stock Company OTP Bank’
C_14	Joint Stock Company ‘Procredit Bank’
C_15	Joint Stock Company ‘Tascombank’
C_16	Joint Stock Company ‘Universal Bank’
C_17	Joint Stock Company ‘ING Bank Ukraine’
C_18	Joint-Stock Company ‘Accent-Bank’ (JSC ‘A-Bank’)
C_19	Joint-Stock Company ‘Idea Bank’
C_20	Pravex Bank’ Joint-Stock Company
C_21	Public Joint-Stock Company ‘Joint Stock Commercial Bank Industrialbank’

Table 3. The first group of indicators' data for 2017.

Code	Indicators' values					
	X_1	X_2	X_3	X_4	X_5	X_6
C_1	9.9	79.5	37.4	72.0	18.3	610.4
C_2	13.5	18.7	34.4	42.7	50.2	82.7
C_3	8.5	22.6	63.3	16.0	76.3	79.7
C_4	8.1	19.2	52.0	26.3	55.4	32.2
C_5	15.1	8.5	79.6	35.4	72.3	18.9
C_6	10.5	7.1	51.8	37.5	69.1	31.8
C_7	8.0	24.6	35.6	51.8	68.2	30.0
C_8	12.0	10.9	92.4	32.0	62.1	29.1
C_9	30.6	253.4	44.2	29.7	141.3	256.0
C_10	-29.3	21.1	52.7	8.1	537.4	124.9
C_11	11.7	6.8	24.6	40.6	99.4	8.4
C_12	10.5	4.0	62.3	23.0	77.6	12.3
C_13	11.8	20.7	84.6	38.2	68.9	35.0
C_14	11.9	6.5	55.1	32.3	104.9	4.3
C_15	6.7	4.4	17.3	46.6	94.2	7.6
C_16	14.9	49.8	23.1	39.1	76.2	27.3
C_17	37.6	7.3	34.5	0.3	138.4	8.4
C_18	15.3	7.2	16.3	89.0	90.8	28.7
C_19	11.8	8.3	18.7	70.4	87.9	29.2
C_20	19.8	18.5	83.5	32.3	19.3	5.0
C_21	29.6	14.0	34.6	59.0	80.1	17.3

Table 4. The second group of indicators' data for 2017.

Code	Indicators' values						
	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}
C_1	7.6	9.4	8.4	-9.6	-120.0	2.8	79.8
C_2	5.2	7.8	6.1	0.3	2.4	3.0	72.1
C_3	4.0	7.6	4.4	0.6	9.4	2.3	72.7
C_4	3.5	3.8	3.8	1.0	11.7	4.2	66.0
C_5	12.9	17.3	15.2	7.0	42.6	11.9	17.9
C_6	5.8	7.1	6.4	1.7	17.6	7.4	41.6
C_7	2.5	2.9	2.7	1.5	18.0	7.5	49.2
C_8	10.0	12.9	11.3	3.2	30.3	10.9	12.8
C_9	2.6	5.6	3.7	-28.1	-135.5	4.5	52.4
C_10	0.9	5.4	0.7	-11.3	-12.4	12.7	38.1
C_11	5.0	6.9	5.7	0.8	8.0	2.1	80.1
C_12	6.8	8.5	7.6	3.6	38.7	9.6	28.8
C_13	7.3	8.6	8.3	3.4	30.2	8.2	35.8
C_14	5.3	7.2	6.0	3.4	29.8	7.4	48.1
C_15	3.9	4.5	4.1	1.4	19.3	8.9	52.1
C_16	5.5	6.6	6.5	1.8	11.6	7.3	37.2
C_17	0.9	1.5	1.5	1.5	5.3	7.4	25.8
C_18	3.3	4.0	3.9	7.7	55.3	20.7	37.9
C_19	6.0	7.2	6.8	4.0	39.3	26.5	34.9
C_20	7.4	9.9	9.3	-2.3	-10.2	5.3	38.9
C_21	7.1	10.4	10.1	0.2	0.5	8.1	38.7

Table 5. The first group of indicators' data for 2018.

Code	Indicators' values					
	X_1	X_2	X_3	X_4	X_5	X_6
C_1	11.2	73.1	45.7	70.8	23.1	464.9
C_2	8.4	22.7	32.6	47.5	44.6	94.2
C_3	5.3	23.9	52.1	17.1	90.7	89.4
C_4	7.0	16.2	43.9	27.5	69.3	18.5
C_5	14.7	7.8	75.0	34.7	81.8	8.9
C_6	12.7	6.6	55.1	39.8	67.7	34.3
C_7	8.3	20.2	41.3	58.0	62.0	28.1
C_8	12.8	9.6	86.5	33.1	64.4	13.7
C_9	20.0	368.8	44.9	28.6	146.7	415.7
C_10	-123.6	38.1	53.6	8.4	269.9	297.2
C_11	10.1	6.3	25.7	43.8	95.0	9.2
C_12	12.8	3.7	66.8	23.5	81.8	10.5
C_13	16.0	18.8	84.2	40.8	83.0	25.9
C_14	14.2	5.2	53.5	30.8	136.4	3.0
C_15	12.1	6.5	17.5	51.0	94.0	7.7
C_16	10.5	37.0	32.8	57.6	71.7	40.8
C_17	37.3	6.7	50.5	0.0	153.6	8.2
C_18	20.8	6.5	16.5	78.0	98.9	13.8
C_19	17.1	7.1	18.5	71.4	102.3	45.0
C_20	44.5	21.8	80.6	51.5	51.7	4.6
C_21	25.1	17.0	56.5	43.2	60.2	16.6

Table 6. The second group of indicators' data for 2018

Code	Indicators' values						
	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}
C_1	7.9	9.9	8.9	4.3	40.9	7.5	45.5
C_2	4.9	6.7	5.3	0.1	0.5	2.7	71.8
C_3	2.6	5.1	2.7	0.6	8.3	1.5	81.4
C_4	4.4	5.2	4.7	1.0	13.5	4.6	61.8
C_5	12.7	17.1	14.9	6.7	45.2	12.3	20.5
C_6	5.4	6.5	6.2	4.2	36.3	9.6	37.3
C_7	3.5	4.0	3.8	2.3	28.1	7.8	45.0
C_8	9.9	12.8	11.3	5.4	43.2	9.4	15.4
C_9	4.0	8.1	5.0	-20.0	-76.1	12.2	24.3
C_10	2.0	6.9	0.9	-50.2	96.8	0.7	-27.1
C_11	5.7	7.5	6.3	0.4	3.5	2.5	77.3
C_12	6.5	8.0	7.4	4.6	39.2	8.0	37.8
C_13	7.1	8.8	8.4	6.3	45.0	10.4	29.7
C_14	2.8	4.7	3.2	3.5	26.5	5.9	51.9
C_15	5.3	6.5	6.1	2.7	27.8	7.7	51.0
C_16	4.8	5.9	5.4	1.2	10.0	7.6	45.5
C_17	1.5	2.5	2.5	4.9	13.0	9.9	29.2
C_18	3.6	4.9	4.6	13.1	72.0	29.2	26.1
C_19	3.9	5.1	4.7	8.6	58.9	36.1	23.1
C_20	14.5	27.7	26.2	-2.8	-9.0	10.7	20.5
C_21	7.1	9.7	9.5	0.4	1.6	7.5	36.5

Table 7. The first group of indicators' data for 2019.

Code	Indicators' values					
	X_1	X_2	X_3	X_4	X_5	X_6
C_1	13.5	73.4	49.7	73.1	26.1	419.3
C_2	8.3	22.7	37.2	50.2	40.1	94.0
C_3	5.3	25.5	49.8	18.2	81.4	95.7
C_4	7.2	15.9	42.9	29.7	58.2	20.3
C_5	12.9	7.6	73.9	36.2	76.6	7.1
C_6	15.2	6.6	56.7	43.0	72.2	32.9
C_7	9.5	19.4	40.5	60.3	58.9	28.8
C_8	10.9	9.7	89.1	36.5	51.6	15.1
C_9	33.0	475.4	69.2	14.9	201.0	584.1
C_10	-168.3	52.0	50.5	9.4	291.4	296.3
C_11	10.4	6.8	19.4	46.5	101.9	11.7
C_12	11.1	3.2	63.2	21.3	80.2	8.6
C_13	17.8	16.8	84.1	41.7	84.6	21.4
C_14	15.4	6.6	53.7	32.4	134.1	3.4
C_15	12.6	6.4	22.5	52.2	94.4	8.2
C_16	9.4	25.8	34.2	65.0	68.9	28.2
C_17	36.9	6.8	52.8	0.0	99.5	11.4
C_18	15.7	6.1	14.2	80.9	95.3	27.5
C_19	14.4	6.0	20.5	71.6	96.6	52.2
C_20	41.1	20.3	78.1	52.2	31.8	1.7
C_21	28.2	18.9	50.0	46.8	67.2	16.7

Table 8. The second group of indicators' data for 2019.

Code	Indicators' values						
	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}
C_1	8.3	10.6	9.5	8.4	69.9	8.7	41.2
C_2	8.0	10.2	8.7	0.1	1.0	3.5	70.4
C_3	4.9	8.8	5.1	0.7	13.7	1.5	83.9
C_4	6.8	7.7	7.3	1.0	14.3	4.3	68.8
C_5	12.2	15.6	14.0	6.1	47.7	12.0	26.5
C_6	6.8	8.4	8.1	4.5	34.6	10.5	31.8
C_7	5.7	6.6	6.3	3.2	35.3	8.4	50.2
C_8	8.3	10.4	9.3	5.9	52.7	10.5	19.0
C_9	3.5	10.7	5.3	-16.2	-48.7	12.8	29.7
C_10	0.4	1.0	0.1	-23.3	-20.4	-8.8	89.7
C_11	3.6	5.0	4.0	0.5	5.1	2.5	83.6
C_12	6.2	7.4	7.0	4.3	38.7	7.7	41.6
C_13	7.8	10.1	9.5	6.9	42.2	11.8	29.5
C_14	4.2	7.0	5.0	3.3	23.9	5.9	53.7
C_15	5.4	6.6	6.2	2.1	20.7	8.6	50.3
C_16	5.8	6.9	6.4	3.4	30.2	9.6	47.2
C_17	3.6	5.9	5.7	6.4	17.2	10.8	31.9
C_18	4.5	5.6	5.4	13.0	79.0	30.0	31.0
C_19	4.9	6.2	5.8	7.2	48.9	37.5	23.8
C_20	11.3	20.7	19.2	-3.0	-7.1	11.6	26.5
C_21	6.0	8.7	8.3	0.5	1.8	8.7	40.2

Note, that for some indicators, we have provided the recommended values as optimal for them. To select the values of weights (in case they are set by the user) we use Spin Buttons. A fragment of the electronic form for data for 2019 is shown in figure 1. In this case, we included all indicators in the calculations but took into account different ways of their normalization.

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	Calculation for 2019														
2	Initial data	Code	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13
3		C_1	13,5	73,4	49,7	73,1	26,1	419,3	8,3	10,6	9,5	8,4	69,9	8,7	41,2
4		C_2	8,3	22,7	37,2	50,2	40,1	94,0	8,0	10,2	8,7	0,1	1,0	3,5	70,4
5		C_3	5,3	25,5	49,8	18,2	81,4	95,7	4,9	8,8	5,1	0,7	13,7	1,5	83,9
6		C_4	7,2	15,9	42,9	29,7	58,2	20,3	6,8	7,7	7,3	1,0	14,3	4,3	68,8
7		C_5	12,9	7,6	73,9	36,2	76,6	7,1	12,2	15,6	14,0	6,1	47,7	12,0	26,5
8		C_6	15,2	6,6	56,7	43,0	72,2	32,9	6,8	8,4	8,1	4,5	34,6	10,5	31,8
9		C_7	9,5	19,4	40,5	60,3	58,9	28,8	5,7	6,6	6,3	3,2	35,3	8,4	50,2
10		C_8	10,9	9,7	89,1	36,5	51,6	15,1	8,3	10,4	9,3	5,9	52,7	10,5	19,0
11		C_9	33,0	475,4	69,2	14,9	201,0	584,1	3,5	10,7	5,3	-16,2	-48,7	12,8	29,7
12		C_10	-168,3	52,0	50,5	9,4	291,4	296,3	0,4	1,0	0,1	-23,3	-20,4	-8,8	89,7
13		C_11	10,4	6,8	19,4	46,5	101,9	11,7	3,6	5,0	4,0	0,5	5,1	2,5	83,6
14		C_12	11,1	3,2	63,2	21,3	80,2	8,6	6,2	7,4	7,0	4,3	38,7	7,7	41,6
15		C_13	17,8	16,8	84,1	41,7	84,6	21,4	7,8	10,1	9,5	6,9	42,2	11,8	29,5
16		C_14	15,4	6,6	53,7	32,4	134,1	3,4	4,2	7,0	5,0	3,3	23,9	5,9	53,7
17		C_15	12,6	6,4	22,5	52,2	94,4	8,2	5,4	6,6	6,2	2,1	20,7	8,6	50,3
18		C_16	9,4	25,8	34,2	65,0	68,9	28,2	5,8	6,9	6,4	3,4	30,2	9,6	47,2
19		C_17	36,9	6,8	52,8	0,0	99,5	11,4	3,6	5,9	5,7	6,4	17,2	10,8	31,9
20		C_18	15,7	6,1	14,2	80,9	95,3	27,5	4,5	5,6	5,4	13,0	79,0	30,0	31,0
21		C_19	14,4	6,0	20,5	71,6	96,6	52,2	4,9	6,2	5,8	7,2	48,9	37,5	23,8
22		C_20	41,1	20,3	78,1	52,2	31,8	1,7	11,3	20,7	19,2	-3,0	-7,1	11,6	26,5
23		C_21	28,2	18,9	50,0	46,8	67,2	16,7	6,0	8,7	8,3	0,5	1,8	8,7	40,2
24	Include index for calculation														
25	Select a group		1	1	1	1	1	1	2	2	2	2	2	2	2
26	Set weight coefficients for first group	equal													
27	Set weight coefficients for second group	equal													
28	Change weight coefficients by user		0,17	0,17	0,17	0,17	0,17	0,17	0,14	0,14	0,14	0,14	0,14	0,14	0,14
29	Weight coefficients' values		10,0				70,0		30,0			4,0	20,0	45,0	80,0
30	regulatory values (if any)														
31	Kind of index		incenti	incenti	incenti	incenti	incenti	incenti	incenti	incenti	incenti	incenti	incenti	incenti	disincenti
32	Normalization Method		by reg	by scal	by scal	by scal	by reg	by scal	by reg	by scal	by scal	by reg	by reg	by scal	by reg
34	Set weight coefficients for groups	by user	group #1	group #2											
35	Change weight coefficients by user		6	7											
36	Weight coefficients' values		0,46	0,54											
37															

Fig. 1. The electronic form for calculation.

Let us conduct the calculation by to data normalization formulas like (1), (3), and (4) depending on the availability of the recommended values of indicators and their type. The weights for all partial indicators within the group are set the same, and for groups – in proportion to the number of indicators in the group ($w_{g1}=6/13$, $w_{g2}=7/13$). Convolution of partial indicators for each group is carried out according to formula (5). The results of the calculation of partial indicators I_1 , I_2 , and the financial security comprehensive index I_{COM} , also calculated by the formula (5), are shown in table 9.

The graphical configuration of banks in the space of partial indicators is presented in figures 2, 3, 4.

Analyzing the consolidated results of the calculations we can observe the following trends.

Regarding the composite index I_1 , according to the data of 2017, its highest values were achieved by two banking institutions: PJSC Prominvestbank (C_9) and PJSC CB Privatbank (C_1), their index's values are 0.69 and 0.61, respectively, the remaining banks were characterized by indicators that in the vast majority were within 0.40-0.60. In 2018, the highest levels of indicators of the effectiveness of the formation of competitive potential also showed C_1 and C_9, but C_9 managed to maximize the indicator I_1 to 0.78 against the nearest value of 0.64. Regarding the dominant trend, we

can observe an overall improvement in the indicators among the surveyed banks, although the range of values of the indicator has not changed. In 2019, there is a further increase in the values of this indicator with an increase in the bottom for most banks to 0.49. Thus, based on the results of calculations, it can be concluded that the efficiency of the formation of the competitive potential of banks, in general, has tended to increase.

Table 9. Values of partial indicators I_1 , I_2 , and the financial security comprehensive index I_{COM} .

Code	2017			2018			2019		
	I_1	I_2	I_{COM}	I_1	I_2	I_{COM}	I_1	I_2	I_{COM}
C_1	0.61	0.33	0.46	0.64	0.58	0.61	0.60	0.66	0.63
C_2	0.44	0.31	0.37	0.43	0.23	0.32	0.42	0.36	0.39
C_3	0.47	0.34	0.40	0.42	0.26	0.33	0.41	0.41	0.41
C_4	0.41	0.34	0.37	0.42	0.35	0.38	0.39	0.46	0.43
C_5	0.54	0.83	0.70	0.55	0.70	0.63	0.54	0.76	0.66
C_6	0.49	0.49	0.49	0.52	0.54	0.53	0.53	0.63	0.58
C_7	0.46	0.40	0.43	0.49	0.44	0.46	0.49	0.57	0.53
C_8	0.55	0.71	0.64	0.56	0.63	0.60	0.54	0.66	0.61
C_9	0.69	0.24	0.44	0.78	0.26	0.50	0.82	0.34	0.56
C_10	0.31	0.24	0.27	0.39	0.32	0.35	0.37	0.13	0.24
C_11	0.43	0.35	0.39	0.45	0.28	0.36	0.44	0.30	0.37
C_12	0.48	0.62	0.56	0.51	0.56	0.53	0.49	0.61	0.55
C_13	0.57	0.62	0.60	0.60	0.58	0.59	0.59	0.67	0.63
C_14	0.48	0.57	0.53	0.49	0.47	0.48	0.49	0.55	0.52
C_15	0.37	0.45	0.41	0.45	0.49	0.47	0.46	0.53	0.50
C_16	0.46	0.45	0.45	0.52	0.35	0.43	0.51	0.58	0.55
C_17	0.38	0.28	0.32	0.42	0.43	0.43	0.42	0.56	0.50
C_18	0.51	0.61	0.56	0.51	0.60	0.55	0.51	0.64	0.58
C_19	0.48	0.71	0.60	0.51	0.63	0.57	0.51	0.68	0.60
C_20	0.43	0.36	0.39	0.56	0.54	0.55	0.50	0.55	0.52
C_21	0.49	0.40	0.44	0.51	0.32	0.41	0.51	0.37	0.44

Summarizing the results of the calculation for indicator I_2 , which characterizes the efficiency of the operational and financial activities of banks, we can conclude that they differ in the range of values of the main group of banking institutions, and extremal values. In particular, when most of the values obtained in 2017 are in the range of 0.31-0.62, we observe a value of 0.83 for JSC Raiffeisen Bank Aval (C_5) and 0.71 for JSC Ukrsibbank (C_8) and JSC Idea Bank (C_19), while the minimum level was recorded at 0.24 for PJSC Prominvestbank (C_9) and PJSC Commercial Bank 'Financial Initiative' (C_10). According to the data of 2018, there are no stable trends to change indicators, and the changes themselves are multifaceted. Thus, the value of indicator I_2 for C_5 decreased to 0.70, and for JSC Pravex Bank (C_20) its value increased to 0.54. Compared to 2019, the analytical generalization of the obtained results indicates an overall improvement in the situation and an increase in the levels of I_2 for the sample banks, as a result of which the range for the predominant group of banking institutions shifted to 0.43-0.74. However, a sharp deterioration of the situation is observed for

C₁₀, as a result of which the level of I_2 was minimal among the whole set of values obtained and amounted to only 0.13.

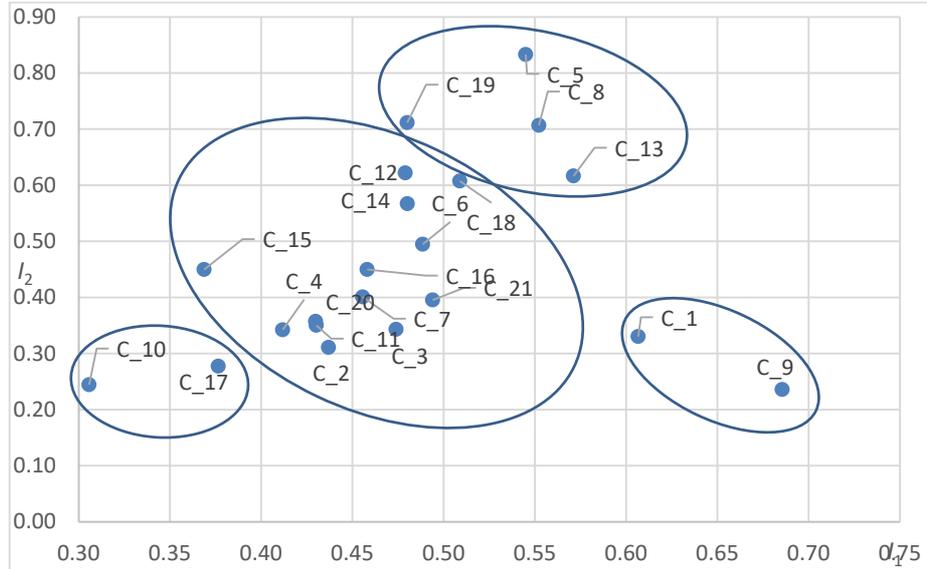


Fig. 2. Imaging banks for data of 2017.

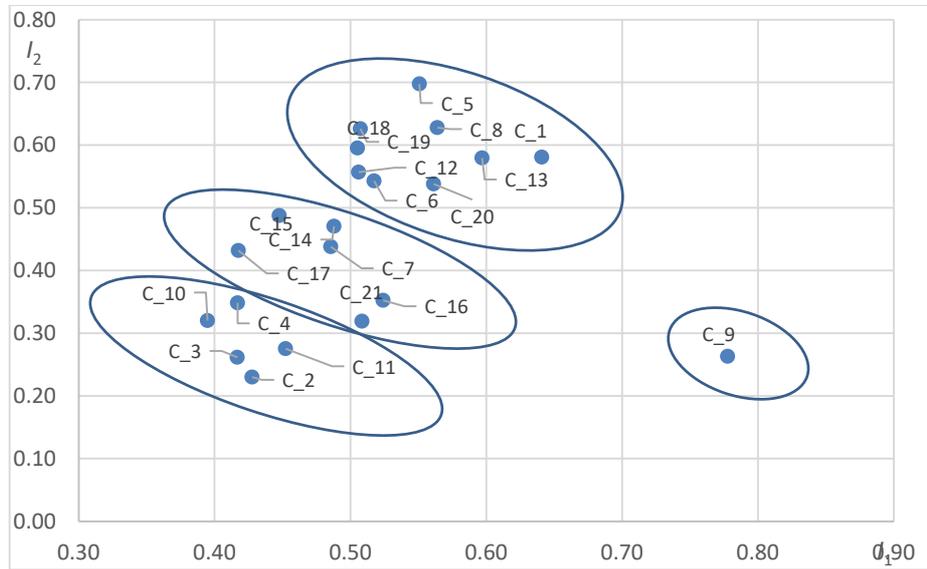


Fig. 3. Imaging banks for data of 2018.

Due to the influence of these partial indicators on the formation of the level of bank's financial security comprehensive index (I_{COM}), we note, that in 2017 the minimum level

of the indicator was recorded for PJSC Commercial Bank “Financial Initiative” (C_10) and was 0.27, with a predominant overall range of 0.37 -0.56. According to the results of processing the performance of banks in 2018, we can conclude that the minimum value of the indicator increased to 0.32, and the lower limit of the main data set also increased and amounted to 0.41. As for 2019, we can note a slight improvement in most banks. An increase in the negative trend of changes in the overall level of financial security is observed only for C_10, which during 2017-2019 had the lowest values of the generalized I_{COM} indicator during the study period for this sample of banks.

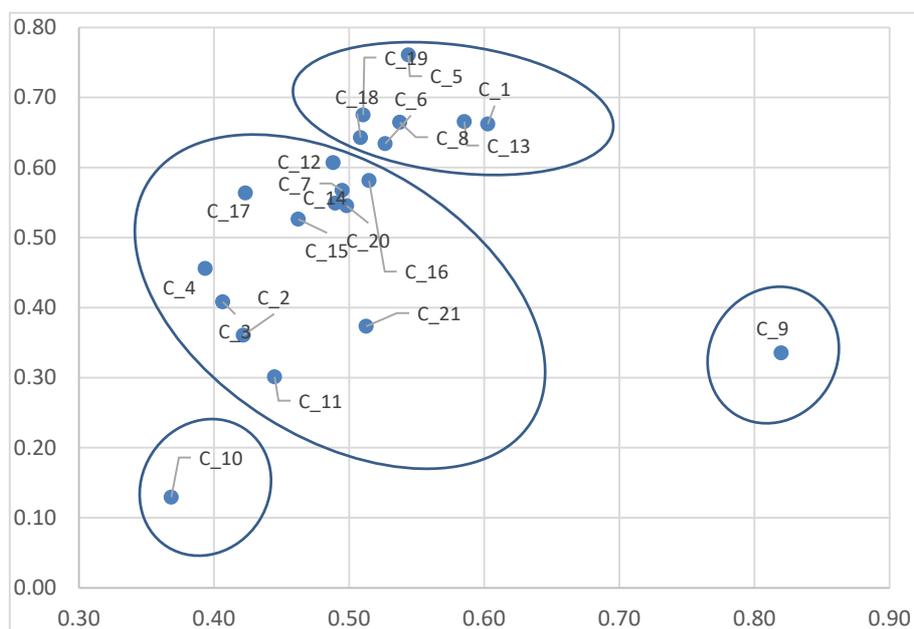


Fig. 4. Imaging banks for data of 2019.

As a result, we can state that in the realities of the existing domestic financial space, the studied stable banks show a satisfactory and sufficient level of financial security (according to the developed level's gradation). When forming the financial security comprehensive index, the composite index I_2 , which characterizes the liquidity and profitability of banks, has a more significant positive effect, while the basic components of financial security, in terms of capitalization and funding (composite index I_1) mostly need improvement.

In general, only systematic work to improve competitiveness, by providing a strong resource base and a balanced formation of assets and liabilities, and sound financial management of strategic, tactical, and operational levels will ensure the overall efficiency of operational and financial activities of the bank in a dynamic environment, with existing and potential threats to the financial security of the banking institution in the short and long term.

Analysis of graphs (fig. 2-4) shows that in general for all banks there is a fairly dense grouping of them in the space of partial composite indexes. But PJSC Prominvestbank is located as a separate object, first of all, due to high values on the scale I_1 . It is one of the first banks in Ukraine, founded in 1992, it is one of the twenty banks of Ukraine in volumes of assets. However, accumulated losses affecting the level of indicators of the effectiveness of the bank's operational and financial activities are the signal of the deterioration of financial security with the established basis of competitive capacity due to the factors of capitalization, funding, and asset quality. The bank's ineffective management policy related to the ownership of its bank capital is a destabilizing factor in the bank's activities on the market.

At the same time, relatively low values on the scale of indicator I_2 are compensated by high values on the scale of indicator I_1 , which allows us to position this bank quite high on the result indicator I_{COM} .

Comparison of the results of the ranking of banks on the I_{COM} scale, with the rating of their stability, presented according to the results of their comprehensive assessment on the Minfin portal [33] in general showed a coincidence of results, which indicates in favor of the proposed assessment methodology.

The next step is to determine the levels of financial security based on the values of the obtained generalized integrated indicator. Analyzing the presented in the table 9 values and graph imaging of banks in the space of partial composite indexes indicators, we can conclude that it is appropriate in this case to allocate three levels: sufficient, satisfactory, and low.

According to the results obtained in [16], to identify the boundaries of intervals for each financial security level we use the formula:

$$l_i = (\alpha_{i+1} + \beta_i)/2, \quad (10)$$

where l_i is a right bound for i -th interval, $i=1..k-1$, k – number of intervals; α_{i+1} – minimal value of comprehensive index, which corresponds to $(i+1)$ -th financial security level; β_i – maximal value of comprehensive index, which corresponds to i -th financial security level. Paper [16] proposed the following boundaries for levels:

- for sufficient level: $I_{COM} \geq 0,51$;
- for satisfactory level: $0,36 \leq I_{COM} < 0,51$;
- for low level: $I_{COM} < 0,36$.

Note that the first interval, which corresponds to a sufficient level, has very wide boundaries. But in this case, using the results of calculations in table 9 and the results of grouping banks according to the levels of financial security, given above, we propose to change the low boundary for the first financial security level, leaving the ranges for other levels unchanged. Therefore, in this case, the intervals have a form:

- for sufficient level: $I_{COM} \geq 0,57$;
- for satisfactory level: $0,36 \leq I_{COM} < 0,51$;
- for low level: $I_{COM} < 0,36$.

We used the iterative procedure, given in [10], to clarify the values of the boundaries of the corresponding intervals. The results of the calculations show that for these samples there was no change in the values of the limits of the intervals of financial security levels. Therefore, the obtained generalized indicator of financial security and the corresponding scale can be used to identify the level of financial security of other banks.

4 Conclusions

An important condition for the efficient use of financial resources is the ability of the banking system to respond on time to changes in the environment and to resist external and internal threats. Therefore, it is important to assess the level of a bank's financial security, which will timely identify problem situations and develop adequate management decisions to neutralize them. The article proposes further development of the application of the technology of complex integrated assessment to determine the levels of financial security of banks. The evaluation is carried out using the procedure of the block-convolution of partial indicators. The presented evaluation tools are aimed at maximal taken into account the real state of financial institutions, are accessible and intuitive to use and provide for the data processing that has a clear quantitative dimension, are freely available on the websites of specialized institutions, or can be easily calculated from such data. The positioning of banks in the space of partial composite indexes was carried out, which allowed justifying the number of levels of financial security and their limits. The results of the calculations showed that in the realities of the existing domestic financial space the studied banks are stably functioning and show a satisfactory and sufficient level of financial security (according to the developed gradation of levels). To automate the calculations and provide the ability to model different evaluation scenarios, it is proposed to use an electronic form created in a spreadsheet using form controls. A comparison of the results of assessing the level of financial security of banks with the rating of their financial stability, presented by the Ministry of Finance, generally showed a coincidence of results. The subject of further research is the improvement of the procedure for assessing the level of bank's financial security, aimed at taking into account non-metric indicators, in particular, expert assessments; establishing and substantiating the importance of the components of the integrated indicator of financial security; improving the scale for assessing the level of financial security by identifying and justifying its high level.

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