“Systemic risk in the banking system: measuring and interpreting the results”

AUTHORS	Olena Bezrodna http://orcid.org/0000-0002-9480-0898 Zoia Ivanova https://orcid.org/0000-0002-3233-8212 Yulia Onyshchenko https://orcid.org/0000-0002-3114-4504 Volodymyr Lypchanskyi https://orcid.org/0000-0002-8525-512X Serhii Rymar https://orcid.org/0000-0001-7102-3443
ARTICLE INFO	Olena Bezrodna, Zoia Ivanova, Yulia Onyshchenko, Volodymyr Lypchanskyi and Serhii Rymar (2019). Systemic risk in the banking system: measuring and interpreting the results. *Banks and Bank Systems*, *14*(3), 34-47. doi:10.21511/bbs.14(3).2019.04
DOI	http://dx.doi.org/10.21511/bbs.14(3).2019.04
RELEASED ON	Wednesday, 07 August 2019
RECEIVED ON	Monday, 17 June 2019
ACCEPTED ON	Monday, 22 July 2019

JOURNAL	"Banks and Bank Systems"
ISSN PRINT	1816-7403
ISSN ONLINE	1991-7074
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
45	3	4

BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine

www.businessperspectives.org

Received on: 17th of June, 2019
Accepted on: 22nd of July, 2019

Olena Bezrodna, Ph.D., Senior Lecturer, Department of Banking, Simon Kuznets Kharkiv National University of Economics, Ukraine.

Zoia Ivanova, Ph.D., Senior Lecturer, Department of Marketing and Business Management, National University of "Kyiv-Mohyla Academy", Ukraine.

Yulia Onyshchenko, Ph.D., Associate Professor, Department of Banking, Odesa National Economic University, Ukraine.

Volodymyr Lypchanskyi, Ph.D., Associate Professor, Department of Economy, Management and Commercial Activity, Central-Ukrainian National Technical University, Ukraine.

Serhii Rymar, Senior Lecturer, Department of Pubic Science, Information and Archival Affairs, Central-Ukrainian National Technical University, Ukraine.

Olena Bezrodna (Ukraine), **Zoia Ivanova** (Ukraine), **Yulia Onyshchenko** (Ukraine), **Volodymyr Lypchanskyi** (Ukraine), **Serhii Rymar** (Ukraine)

SYSTEMIC RISK IN THE BANKING SYSTEM: MEASURING AND INTERPRETING THE RESULTS

Abstract

Highly concentrated banking system risks and the cumulative effect due to their accumulation act as a driver for improving the macro-prudential policy implemented by central banks. For this reason, an effectively and comprehensively assessed systemic risk in the banking system is declared an express condition for the early detection of its production sources and blocking of potential spreading channels, reducing the possible implementation. In light of this, the article develops an approach to the aggregated systemic risk assessment and interpretation of its results. The proposed approach is based on the considered influence exerted by financial risks of systemically important banks on the destabilized banking system and interconnections between banks in the context of the possible crisis impulse spreading. The following steps should be accomplished to form an aggregated systemic risk indicator in the banking system. Firstly, the differentiation of systemically important banks by the degree of their systemic importance; secondly, an integral assessment of the bank operation riskiness within certain bank groups; thirdly, the cumulative composition of the corresponding integral indicators, taking into account their weighting coefficients based on two criteria, namely values of the systemic importance indicator differentiating the bank groups, and the correlation of their risks. Interpreting the quantitative measurement results with regard to the systemic risk in the banking system is followed by the recommendations below: the systemic risk grading into high, medium and low levels and the respective definition of the threshold aggregated systemic risk indicator value which informs about the possible systemic crisis when approached; justification of the selected supervision regime types (strengthened, moderate or weakened) for systemically important banks, depending on the riskiness level specific for their operation and the systemic importance degree. The developed approach to measuring the systemic risk by means of constructing an aggregated indicator and interpreting the obtained results was being tested considering the financial risk indicators of the systemically important banks in Ukraine during 2009–2018.

Keywords systemic risk, banking system, systemically important banks (SIBs), financial risks, macro-prudential policy

JEL Classification G01, G28

INTRODUCTION

Naturally, the banking system, as well as the entire financial system, are prone to producing risks that spread rapidly to other economy sectors. Consequently, the cyclical banking crisis nature, as well as the banking system impact on the payment status, money turnover and real economy financing, determine the urgency to ensure its stability through the early detected and neutralized systemic crisis processes. This issue is solved today within the macro-prudential policy implemented by central banks, which is focused on assessing the systemic risks for financial stability and developing measures aimed to neutralize them.

Maintaining the banking system stability is relevant and represents a severe issue for Ukraine as well, since the country is one of the top

http://dx.doi.org/10.21511/bbs.14(3).2019.04

three world leaders with regard to the intensity of the systemic banking crisis occurrence (International Monetary Fund, 2018). Moreover, the state invested a lot in overcoming the recent banking crisis; its expenditures amounted to 15.8% of GDP, according to the National Bank of Ukraine (in 2014 – 2.4%, in 2015 – 4.5%, in 2016 – 5.7%, and in 2017 – 3.2%).

Despite the fact that the Ukrainian banking system has been refreshed and cleared of troubled banks in view of the most recent years resulting in certain positive changes, the banking system remains highly vulnerable. This is confirmed by the NBU's published results of the stress testing targeted at the major banks, which took place in 2018. In total, 13 out of 24 stress-tested banks accounting for more than 94% of banking system assets were declared requiring additional capitalization (in the amount of UAH 42.1 billion), which indicates their inability to stay afloat while being influenced by factors destabilizing their activity and the possible systemic risk accumulation. In light of this, stabilizing the banking system condition and ensuring financial stability as a whole represent the target priorities of the NBU's activity, as announced in the National Bank Strategy and the Macro-Prudential Policy Strategy.

Therefore, this article is intended to develop the approach to quantitative systemic risk measurement in the banking system and interpretation of the assessment results for further consideration while implementing the macro-prudential policy.

1. LITERATURE REVIEW

Recently, the modern economic scientific literature has paid increasing attention to the systemic risk concept and its measurement issues. In this respect, unlike with other concepts, there is almost no confrontation on the term "systemic risk" among scholars and economists, as well as no significant disputes have occurred regarding its interpretation. This is evidenced by the existing substantially similar concepts of "systemic risk", including in particular the following: the risk or likelihood of the systemic failures (Kaufman & Scott, 2003); the risk of the entire financial system collapse (Borri et al., 2012); the possibility that the financial system may become unstable (Murphy, 2012); the risk of failures incurred by financial institutions or the capital market freezing (Acharya et al., 2009); the risk of financial service disturbance (IMF, 2009), etc. And when it comes to the systemic risk causes and consequences, then the firms belief is that the systemic risk is most often caused by failures in the operation of large interconnected financial institutions, which not only destabilizes the financial system, but also negatively affects the real economy. Therefore, the key systemic risk concept aspects are reasonably reflected in the chain "infectious agents – mechanisms and channels of their spread – the scale of consequences". From this perspective, the systemic risk in the banking system can be defined as the risk of its destabilization arising from the growing financial vulnerability of banks (typically, this refers to systemically important banks or SIBs), which in turn catalyzes the processes of crisis impulse spreading to other banking institutions (the infection develops through the credit and financial ties among banks resulting from their financial relations and gains strength with the panic spreading through information flows) and consequently leads the banking system to inability to fully perform its functions. However, it is fair to note that, in addition to the negative consequences resulting from the systemic risk materialization, positive effects are also possible, though they hardly ever occur. For instance, De Bandt and Hartmann (2000) point at this fact. In their view, some financial crises are able to simply eliminate inefficient system players, particularly when asymmetric information prevents the market mechanism from performing its activities.

As for the systemic risk measurement, researchers deal with this issue more actively. In particular, scholars suggest systematizing the assessment methods, taking into account their common features, test and analyze the results through empirical research, improvement, and communicate the advantages and disadvantages of certain ones. For instance, Borri et al. (2012) summarize the existing literature on the systemic risk assessment in the banking system in two directions: a network analysis and a micro-evidence approach being developed by researchers, which proceeds from specific bank variables and is meant to quantitatively determinate their contributions to the systemic risk. Gerlach (2009) and Cerutti et al. (2012) identify three approaches to the systemic risk assessment. Thus, as follows from Gerlach (2009), the appropriate approaches include: monitoring of aggregated indicators of solvency or financial stability; measuring bank interconnections; and analyzing changes in financial asset prices. Cerutti et al. (2012) emphasize the approaches to assessing the systemic risk based on the bank balance interconnectivity (affecting the spreading shocks), as well as approaches to assessing the systemic risk premium and shock interconnections (using the market information on credit spreads and share prices or other assets). Furthermore, the authors outline a long-term approach as a third approach based on modeling (simulation and scenario analysis methods) and that allows for better understanding of how specific shock types can provoke system-level events. Di Cesare and Picco (2018) provide recommendations similar to the previously discussed ones aimed at comparing the systemic risk assessment methods. Thus, the authors differentiate the expected loss in case of failures in the operation of financial institutions (banks), indicators of their possible default, indicators that illustrate the specific infection mechanisms and indicators of the general "disaster" level in the system based on the main systemic risk features, which can cover the basic indicators. In addition, Di Cesare and Picco (2018) suggest comparing the appropriate methods and other criteria, namely: availability (with regard to the ability to predict system events, implementation simplicity, etc.); theoretical foundations taken into account and analytical methods used.

The outlined suggestions in respect to grouping the systemic risk assessment approaches have both common features and differences. The first point is related to certain aspects defined as the main ones in the classification division of the existing assessment methods, and the second point refers to the extent of the researchers' coverage of their various quantities. However, introduction into the peculiarities of the methodological support implementation as for measuring the systemic risk also allows us to conclude that when certain criteria are distinguished with the aim to group the methods, some scholars put aside their intercrossing. In particular, this includes combining both bank balance sheets and market data, as well as taking into account possible defaults of banking institutions. Considering the above, it is advisable to review three approaches from the perspective of summarizing the key aspects for the systemic risk assessment in the banking system and the differentiation of its methods:

- the first approach is aimed at determining the banking system losses (damages);
- the second approach evaluates the influence of banks' interconnections on the spreading shocks (the infection effect); and
- the third approach defines the aggregated indicators that demonstrate the stress level and the imbalance accumulation in the banking system.

The methods that are combined within the first approach to the systemic risk measurement and are considered by modern researchers include: conditional value at risk or CoVar (Adrian & Brunnermeier, 2011; Borri et al., 2012; Karimalis & Nomikos, 2014; Huang et al., 2015; Teply & Kvapilikova, 2017, etc.); systemic expected shortfall or SES (Acharya et al., 2010); marginal expected shortfall or MES (Acharya et al., 2010; Brownlees & Engle, 2012; Yun & Moon, 2014; Huang et al., 2015; etc.); systemic contingent claims analysis or Systemic CCA (Capera et al., 2011); distress insurance premium or DIP (Huang et al., 2009), and SRISK (Brownlees & Engle, 2017; Foggitt et al., 2017).

It should be noted that Adrian and Brunnermeier (2011) suggested fundamentals for the development and use of CoVaR. With allowance for their findings, CoVaR is defined as value at risk (VaR) in the financial system influenced by financial institutions that are in the critical condition. In this context, CoVaR, namely the contribution made by an institution to the systemic risk, is evaluated as the difference between the conditional CoVaR for the institution being in the critical condition and CoVaR for the same institution being in the "median" condition. Borri et al. (2012) and Karkowska

http://dx.doi.org/10.21511/bbs.14(3).2019.04

(2015) emphasize the advantages peculiar for this method (in particular, the possibility to identify the recapitalization need for the banking system and banks' contributions to the systemic risk) in the context of the analytical study implementation with regard to the systemic risk assessment in the European banking area. Karimalis and Nomikos (2014), Teply and Kvapilikova (2017) also review the feasibility of using CoVaR to measure the systemic risk in the banking system, and determine the need to improve this method using the copula functions (Karimalis & Nomikos, 2014) and wavelet analysis (Teply & Kvapilikova, 2017).

Acharya et al. (2010) proposed a systemic expected shortfall (SES) to measure the systemic risk and predict losses during the financial crisis, generalizing the insufficient capitalization tendency under the system recession conditions shown by financial institutions. It is important to note that a marginal expected shortfall (MES) is used when calculating SES. At the same time, MES is also considered by Acharya et al. (2010), Brownlees and Engle (2012) and other researchers as an individual systemic risk measure. In particular, MES is considered in the Yun and Moon (2014) study in the context of practical use while assessing the systemic risk in the Korean banking system. In compliance with the economic interpretation of the Yun and Moon (2014) study results, the systemic risk indicator reflects the marginal expected revenue shortfall on the stock portfolio of individual banks in conditions where market yields are lower than a certain threshold. There is an approach based on the distress insurance premium definition, which is similar to the MES according to the logic of use while measuring the systemic risk (presented in Huang et al., 2009). As specified in the method outlined by Huang et al. (2009), determining the systemic risk level includes forming a hypothetical portfolio composed of debt instruments issued by the analyzed banks, weighted by the size of their liabilities. Accordingly, the systemic risk indicator reflects the theoretical insurance premium (the cost of insurance against financial difficulties), which protects against the problem losses of this portfolio in the next 12 weeks. When measuring the systemic risk, Huang et al. (2009) take into consideration the possible default of individual banks and the predicted data on asset return correlations.

The SRISK and systemic contingent claims analysis also relate to the first group of approaches to the systemic risk measurement in the banking system and have much in common with the methods discussed above. For instance, SRISK (as proposed by Brownlees and Engle (2017) and used by Foggitt et al. (2017) to measure the systemic risk in the banking system of South Africa) also generalizes the banks' insufficient capitalization tendency (defines a capital shortage in a system event) and is determined relying on both MES and SES. In turn, according to Capera et al. (2011), the systemic contingent claims analysis is a more flexible and comprehensive tool for measuring the systemic risk in the banking system when compared with CoVaR, SES and DIP. The Capera et al. (2011) study (the proposals for the systemic risk assessment were tested relying on the sampled data of the four major banks of Colombia) represents a conclusion within the corresponding approach relating to the practicability of determining the losses incurred by banks considering their possible default and determining the distance-to-default.

The methods for assessing the systemic risk in the banking system, which are most often referred to the second approach, include: a network analysis, a risk correlation-based approach (a co-risk model), distress dependence matrix design, a default intensity model approach, etc. (IMF Global Financial Stability Report, 2009; Gerlach, 2009; Di Cesare & Picco, 2018). At the same time, the network analysis, which involves the banking network design following on from the identified ties among banks (including, but not limited to the interbank credit market) and allows for predicting the consequences of possible stress events, is the most common in the researchers' articles dealing with this approach to the systemic risk measurement (in particular, Cont et al., 2010; Hu et al., 2012; Gudelytė & Navickienė, 2013; Fan et al., 2018, etc.). Meanwhile, Gudelytė and Navickienė (2013) emphasize not only the advantages but also the disadvantages of the network analysis. Thus, among its advantages the authors mention the easy interpreted usage results; the banking sector structure reflection; the identified systemic risk sources and assessment of the possibly implementing the infection effect of banking institutions; the shaped possible scenario of the banking system collapse. As for the disadvantages, the unclear reasons for the bank default are named (according to the researchers, they should be determined upon a fundamental analysis of the bank balance structure and assessment of macroeconomic conditions in which these banks operate). Report to the G-20 Finance Ministers and Central Bank Governors (IMF, 2009), in which the network analysis, along with portfolio models of risk and stress testing, are considered as approaches to the identification of systemically important banks, also highlights the network analysis difficulties. In particular, the document indicates the possibility of cross-sectoral institutional influences, as well as the likelihood of a rapid change in actual ties (illustrating the fact that the analysis results may be limited in effect).

As previously noted, the third distinguished approach to the systemic risk assessment involves determining its aggregated level based on financial imbalance data in the banking system. Proposals made by the researchers below represent the examples of implementing this approach to the systemic risk measurement within the entire financial system: Holl'o et al. (2012) – calculating the composite indicator of systemic stress (CISS); Ivanets (2017) – evaluating the systemic risk index as an integrated financial stability indicator; Dumičić (2016) – formation of the accumulation and consequence (or materialization) indexes of the systemic risk and their aggregation into the overall systemic risk index; Dungey et al. (2018) – developing the dynamic systemic risk index, taking into account the links among the risks faced by financial institutions. In turn, Hartmann et al. (2005), Sum (2015), Van Oordt and Zhou (2015) etc. may be mentioned among the researchers who study the systemic risk issue in the banking system and, therefore, put forward suggestions on its measurement using the methods that are in line with the third approach. For example, Hartmann et al. (2005) suggest assessing the systemic risk in two directions. The first direction is based on recognizing the spillovers in the banking system (the infection risk, that is, the risk spreading from one bank to the other ones), and the second direction takes into account the influence exerted by banks on systemic shocks. Van Oordt and Zhou (2015) also summarize two components while introducing the systemic risk assessment proposals: the first one reflects the bank risk level, and the second one refers to the strength of the bank's connection with the banking system in the financial stress context. Sum (2015) emphasizes the possibility of measuring the systemic risk by applying a z-score method, which illustrates the reduced revenue level of the banking system leading to its insolvency. The author notes that this approach does not cover the bank interconnections, which represents its disadvantage. However, according to Sum (2015), the z-score enables assessing the overall banking system reliability and, therefore, may serve as a measure for the tendency toward the systemic risk occurrence.

It should be noted that the methods considered within the three generalized approaches to measuring the systemic risk in the banking system do not contradict each other, but may provide different results if applied. In particular, Huang et al. (2015) confirm this upon reviewing four methods for measuring the systemic risk (CoVaR, MES, and two indices identified according to the extreme value theory framework that show a link between the possible bank defaults). When comparing the results of these methods, Huang et al. (2015) revealed discrepancies in the obtained bank ratings formed according to their systemic risk contributions. It is also worth bringing a focus on the existing restrictions related to the use of certain methods (in particular, the complexity of calculations using estimated parameters and market data at different development levels of financial markets) and the shortcomings typical for some of them (while ignoring certain aspects), which in turn requires developing more versatile and complex approaches to measuring the systemic risks. For this reason, scholars have been trying to improve and compile the existing methods in recent years. However, the complexity issue in this context is not the only one that requires a solution. The interpretation of the systemic risk assessment results needs to be enhanced, as, for example, it is mostly reduced to the determination of bank contributions to the systemic risk (through their contributions to the banking system losses under certain stressful conditions and to the relationships between banking institutions respectively) within the scope of the first and second approaches.

http://dx.doi.org/10.21511/bbs.14(3).2019.04

2. METHODS

The conclusions drawn from the analyzed scientific literature provide a consecutive sequential approach to designing the aggregated systemic risk indicator in the banking system and interpreting the obtained results. According to the proposed approach, the analytical process, which requires the quantitative measurement of the systemic risk level in the banking system by designing the aggregated indicator, is based on two positions. As follows from the first position, the systemic risk is produced when the systemically important banks are destabilized. Pursuant to the second position, interconnected SIBs catalyze the exacerbation and deployment of crisis phenomena in the banking system (the so-called "domino effect" implementation).

Based on the first position, the systemic risk may be measured quantitatively by summarizing the information on the operation riskiness levels of the systemically important banks. Among other factors, one can focus on assessing the financial risks that highlight the disturbance of banks and reflect their tendency toward default. The below set of indicators was proposed to assess the financial risks of systemically important banks (Kuznyetsova & Pogorelenko, 2018): an immediate liquidity ratio (a liquidity risk); a share of foreign currency deposits in bank liabilities (a currency risk); a net interest margin (an interest risk); a share of credit impairment provisions in the credit portfolio (a credit risk); a share of security impairment provisions in the security portfolio (an investment risk); a resource base instability ratio (a resource base stability risk).

Given that, in order to substantiate the requirements for the SIB operation, the international practice has determined the practicability of their differentiation according to the degree of systemic importance (in particular, this is highlighted in the method identifying global systemically important banks, the G-SIBs; the Basel Committee on Banking Supervision, 2018), the aggregated banking system systemic risk indicator (*BSSRI*) may be determined as follows:

$$BSSRI = \sum_{i=1}^{n} a_i \cdot IRSIB_i, \qquad (1)$$

where $IRSIB_i$ – integral operation riskiness indicators for each SIBs group that are differentiated according to their degree of systemic importance; a_i – weighting coefficients for the *BSSRI* components; n – the number of SIBs groups.

IRSIB is calculated as the arithmetic average of integral operation riskiness indicators for systemically important banks that belong to the same group. In turn, the riskiness of each systemically important bank is assessed integrally using the entropy method (introduced by Kizim & Geymn, 2008), according to which the integral indicator (I_j as a generalization characteristic for a j object) is determined by the following formula:

$$I_j = \sum_{l=1}^{m} E_l \cdot z_{lj}, \qquad (2)$$

where E_l – entropy for the l characteristic; z_{lj} – a normalized value of the l characteristic for the j object; m – the number of characteristics used for the assessment.

Justifying the weighting coefficients (a_i) for the *BSSRI* components requires their ranking based on the degree of systemic importance of each bank group and their interconnectivity that affects the infection spread (according to the second position providing background for the developed approach to the systemic risk measurement). From this perspective, the weighting coefficients are clarified in three stages. At the first stage, the ranking depends on the degree of systemic importance of bank groups. The second stage stipulates ranking based on the summed up coefficients of pair correlations between the integral indicator values of the bank operation riskiness (that is, between the $IRSIB_i$ values) calculated for each bank group. When the first and second stages are completed, the $IRSIB_i$ weighting coefficients are determined by Fishburn's criterion (Fishburn, 1970), and the third stage includes averaging of the weighting coefficients obtained through two rankings (the a_i sum should be equal to 1).

It is worth noting that approaches to the systemically important bank identification are being improved on a regular basis and come with different sets of criteria. At the same time, the bank asset volume continues to represent the key criterion for their classification as systemically important banks (Capera et al., 2011; Haubrich & DeKoning, 2017). Moreover, Report to the G-20 Finance Ministers and Central Bank Governors (IMF, 2009), Acharya et al. (2010), Borri et al. (2012), Yun and Moon (2014) point out that the size of banks significantly affects their contribution to the systemic risk. Therefore, within this approach to measuring the systemic risk in the banking system, SIBs are determined with regard to the recommendations specified in Bezrodna and Lesik (2017), stating that a bank is considered systemically important if the share of its assets in the total assets of the banking sector (a bank's size index) is equal to or greater than 3.5%. In view of this, the bank's size index is regarded as a parameter for assessing the bank systemic importance level.

The number of identified SIBs in different national banking systems may vary significantly. In this light, the identification of a large number of systemically important bank groups is inappropriate in relation to the proposals for the quantitatively measured systemic risk and further interpretation of the assessment results. Accordingly, banks are differentiated upon determining their relation to one of three groups – SIBs of first-order systemic importance (SIB_1), SIBs of second-order systemic importance (SIB_2) and SIBs of third-order systemic importance (SIB_3). The arithmetic average of the systemic importance indicator for the identified systemically important banks is used to specify the requirements for grouping banks as a separation point (a differentiation criterion) (Bezrodna & Lesik, 2017). The banks with a systemic importance indicator higher than the arithmetic average should be attributed to the banks of first-order systemic importance. On the other hand, the banks with a systemic importance level lower than the arithmetic average are re-differentiated by the average level of the systemic importance indicator (applicable for these banks). In other words, the distribution is iterated for the second time and the list of banks with the 2nd- and 3rd-order systemic importance is substantiated similarly to identifying banks with the 1st-order systemic importance.

In regard to interpreting the systemic risk measurement results in the banking system, it is appropriate to distinguish two blocks that will cover the following guidelines. Firstly, grading the aggregated indicator values of the systemic risk and its components through correlation with qualitative levels (low, medium and high). Secondly, justifying the bank supervision regime types based on the identified qualitative levels of operation riskiness for individual SIBs, and taking into account the degree of their systemic importance.

As a result, an interval scale is formed by the three-sigma method within the first block, following on from the statistical characteristics (namely, the arithmetic average ($\overline{X}$), the mean squared deviation (σ), the median (*Me*) and the mode (*Mo*), the asymmetry ratio (*As*)) of the distributed $IRSIB_i$ and *BSSRI* values. The features of defining the interval scale boundaries with symmetric (or close to normal) and asymmetric distribution of the analyzed indicator values are given in formulas (3)-(5).

Scale interval justification in the context of symmetric or close to normal data distribution (if the asymmetry ratio is less than 0.5 modulus):

$$\overline{X}-3\sigma; \qquad \overline{X}+3\sigma. \tag{3}$$

Scale interval justification in the context of significant left-hand data asymmetry (the asymmetry ratio is greater than 0.5 and its value is negative):

$$Me-3\sigma\left(k+1\right); \qquad Me+3\sigma k. \tag{4}$$

Scale interval justification in the context of significant right-hand data asymmetry (the asymmetry ratio is greater than 0.5 and its value is positive):

$$Me-3\sigma k; \qquad Me+3\sigma\left(k+1\right). \tag{5}$$

As one can see, in contrast to formula (3), formulas (4) and (5), firstly use the median instead of the arithmetic average; and secondly, they use the corrective coefficient (*k*) proposed by Zinchenko (2007).

The supervision regime types (differing in the frequency of on-site bank inspections) are to be determined using the matrix approach (Figure 1) within the second block of proposals for interpreting the systemic risk measurement results in the banking system. This stipulates using a 9-quadrant matrix (a modified McKinsey's matrix), which is formed by the ratio of the operation riski-

SIB operation riskiness level		Degree of the SIB systemic importance		
		1 st-order	2nd-order	3rd-order
	High	**Quadrant 1** Strengthened supervision regime	**Quadrant 2** Strengthened supervision regime	**Quadrant 4** Moderate supervision regime
	Medium	**Quadrant 3** Strengthened supervision regime	**Quadrant 5** Moderate supervision regime	**Quadrant 7** Weakened supervision regime
	Low	**Quadrant 6** Moderate supervision regime	**Quadrant 8** Weakened supervision regime	**Quadrant 9** Weakened supervision regime

Figure 1. Matrix of the selected supervision regime types for systemically important banks

ness level (low, medium, high) for the systemically important bank and the degree of its systemic importance (the first-, the second- and the third-order systemic importance).

The interpretation below is given in accordance with the defined positioning of SIBs in the shaped matrix. When banks are placed in quadrants 1-3 (meaning a high probability of the banking system collapse), it is proposed to strengthen the supervision regime over their operation (on-site inspections are organized every three months). On the other hand, when banks fall into quadrants 4-6 and 7-9, it is advisable to introduce moderate and weakened supervision regimes, respectively. At the same time, the inspection frequency for the moderate regime is every six months, and for the weakened regime – once a year.

3. EMPIRICAL RESULTS

The developed approach to measuring the systemic risk in the banking system and interpreting the assessment results has been tested considering the financial risk indicators of the systemically important banks in Ukraine (for the period of 2009–2018). Table 1 illustrates the conditions under which SIBs are distributed by degree of their systemic importance. The list of systemically important banks as well as their asset share in total assets of the banking sector were determined annually as of January 1 (according to the NBU's statistical reporting). The data presented in Table 1 have been justified using a 2-stage iterative procedure for determining the average group asset share of SIBs.

Table 1. Criteria for determining the relation of Ukrainian systemically important banks to three groups depending on the degree of their systemic importance

Years	Asset share (*Ai*,%) of SIBs in total assets of the banking sector	Criteria for determining the relation of SIBs to groups depending on the degree of their systemic importance		
		SIBs with the 1st-order systemic importance	SIBs with the 2nd-order systemic importance	SIBs with the 3rd-order systemic importance
2009	45.7	$A_1 \geq 5.7$ %	5.7% > $A_2 \geq$ 4.4%	4.4% > $A_3 \geq$ 3.5%
2010	43.3	$A_1 \geq 6.2$ %	6.2% > $A_2 \geq$ 4.6%	4.6% > $A_3 \geq$ 3.5%
2011	48.4	$A_1 \geq 6.1$ %	6.1% > $A_2 \geq$ 4.5%	4.5% > $A_3 \geq$ 3.5%
2012	43.7	$A_1 \geq 6.2$ %	6.2% > $A_2 \geq$ 4.0%	4.0% > $A_3 \geq$ 3.5%
2013	38.6	$A_1 \geq 7.7$ %	7.7% > $A_2 \geq$ 5.2%	5.2% > $A_3 \geq$ 3.5%
2014	40.1	$A_1 \geq 8.0$ %	8.0% > $A_2 \geq$ 5.1%	5.1% > $A_3 \geq$ 3.5%
2015	54.2	$A_1 \geq 6.8$ %	6.8% > $A_2 \geq$ 3.9%	3.9% > $A_3 \geq$ 3.5%
2016	66.3	$A_1 \geq 8.3$ %	8.3% > $A_2 \geq$ 4.0%	4.0% > $A_3 \geq$ 3.5%
2017	68.1	$A_1 \geq 8.5$ %	8.5% > $A_2 \geq$ 4.0%	4.0% > $A_3 \geq$ 3.5%
2018	70.4	$A_1 \geq 8.8$ %	8.8% > $A_2 \geq$ 4.2%	4.2% > $A_3 \geq$ 3.5%

Table 2. Findings illustrating quantitatively assessed operation riskiness of Ukrainian systemically important banks (within individual groups)

Integral operation riskiness indicators of *SIBs*	Years									
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
$IRSIB_1$	0.364	0.369	0.37	0.37	0.318	0.378	0.474	0.564	0.539	0.513
$IRSIB_2$	0.399	0.394	0.415	0.366	0.422	0.46	0.537	0.575	0.507	0.429
$IRSIB_3$	0.203	0.38	0.394	0.389	0.396	0.441	0.553	0.476	0.441	0.467

Ukrainian systemically important banks were divided into three groups according to the Table 1 criteria, and calculations aimed at an integrated assessment of their operation riskiness were made by the entropy method (formula (2)) taking into account the financial statements at the end of the year (Table 2).

The calculations given in Table 2 confirm the existing common tendencies in changing the quantitative operation riskiness levels for each of the three SIBs groups within the analyzed period. In particular in 2014–2016, when the maximum integral indicator values of the operation riskiness for systemically important banks (first-, second- and third-order) were determined and their significant growth was observed during this period. The maximum $IRSIB_1$ and $IRSIB_2$ values (0.564 and 0.575, respectively) were registered in 2016, and the maximum $IRSIB_3$ value (0.553) was observed in 2015.

Formula (1) shows that the integral operation riskiness indicators for SIBs with the considered weighting coefficients of the relevant parameters (Table 3) are synthesized for measuring the systemic risk in the banking system.

Justification of the weighting coefficients for the aggregated systemic risk indicator components confirmed the interconnectivity of the risks specific for systemically important banks, and, in accordance with the Chaddock's scale, there is a positive high and noticeable correlation between them. Just to name a few, the coefficient of pair correlation between $IRSIB_1$ and $IRSIB_2$ is equal to 0.777; between $IRSIB_1$ and $IRSIB_3$ – 0.571; between $IRSIB_2$ and $IRSIB_3$ – 0.655. Therefore, the pair correlation coefficients sums taken into account when ranking the *BSSRI* components by the level of interconnectivity between the systemically important bank groups are as follows: 1.348 for $IRSIB_1$, 1.432 for $IRSIB_2$, 1.227 for $IRSIB_3$.

The aggregated systemic risk indicator value in the Ukrainian banking system was calculated using the data from Tables 2-3. The practical value and informativity of the results obtained while measuring the systemic risk were confirmed through comparing the dynamics of change in the systemic risk level with the dynamics of change in the Bank assets to GDP (Figure 2). The use of the Bank assets to GDP (calculated using the reporting data provided by the State Statistics Service of Ukraine and the NBU) may be explained by the fact that it characterizes the banking system development level and its investment potential in terms of financial support for the real economy needs. Therefore, it may be considered as an information parameter

Table 3. Determination of weighting coefficients for the aggregated systemic risk indicator components in the banking system

BSSRI components, for which weighting coefficients are determined	Criteria for ranking the *BSSRI* components and justifying their weighting coefficients				Weighting coefficient averages for the *BSSRI* components in two rankings
	The systemic importance degree of bank groups		Interconnection between SIB groups		
	BSSRI component ranking	Weighting coefficients for the *BSSRI* components	*BSSRI* component ranking	Weighting coefficients for the *BSSRI* components	
$IRSIB_1$	1	0.5	2	0.3	0.4
$IRSIB_2$	2	0.3	1	0.5	0.4
$IRSIB_3$	3	0.2	3	0.2	0.2

http://dx.doi.org/10.21511/bbs.14(3).2019.04

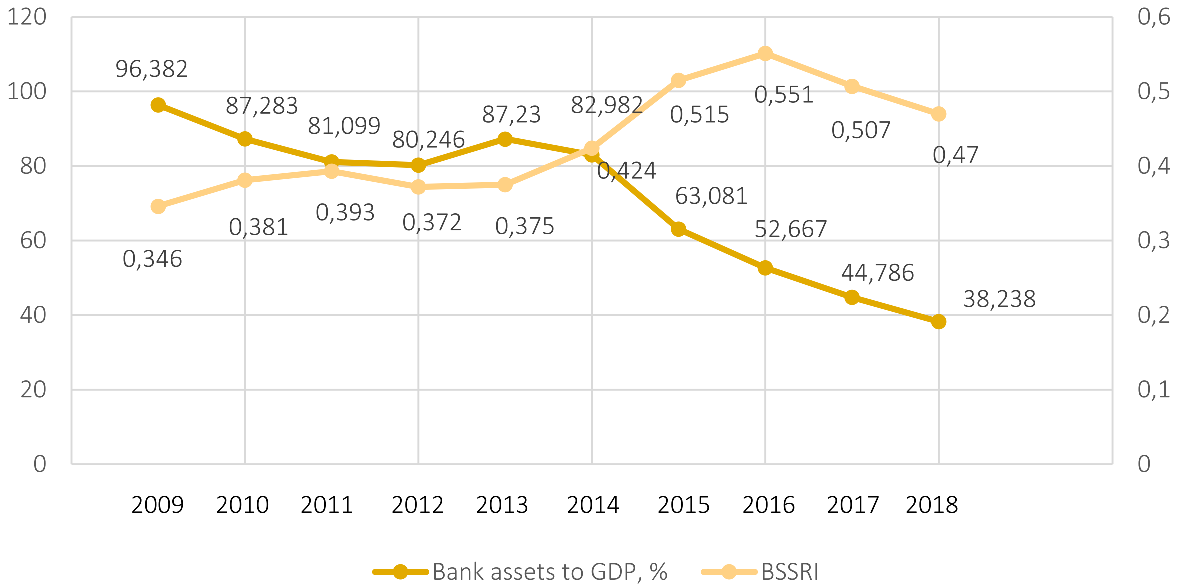

Figure 2. Dynamic changes in the aggregated systemic risk indicator in the Ukrainian banking system and the Bank assets to GDP

capable of reflecting the consequence scale associated with the implemented systemic risk, that is, its materialization.

As can be seen from Figure 2, the direction of the change in the *BSSRI* and the Bank assets to GDP for the different periods are opposite to a greater extent. This is evidenced by the correlation between these indicators, which amounts to 0.85. From this perspective, it can be confirmed that the increase in the systemic risk level in the banking system leads to a decrease in the Bank assets to GDP.

The first block of recommendations on interpreting the results of the quantitative systemic risk measurement represents a universal scale, which makes it possible to differentiate the levels of the aggregated systemic risk indicator in the banking system and integral operation riskiness indicators for SIBs. Since the data of the corresponding generalizing parameters were distributed with right-hand asymmetry (the asymmetry ratio was equal to 0.57), formula (5) was used when designing the interval scale, and three intervals were obtained for differentiating the quantitative values *BSSRI*, $IRSIB_1$, $IRSIB_2$ and $IRSIB_3$: [0; 0.417] – a low level, (0.417; 0.497] – a medium level, (0.497; 1] – a high level. Table 4 illustrates the interpreted systemic risk measurement results on the basis of the designed scale.

According to Table 4, the following changes in the qualitative *BSSRI* levels occurred during the ana-

Table 4. Findings illustrating qualitatively interpreted quantitative systemic risk assessment in the Ukrainian banking system

Years	$IRSIB_1$	$IRSIB_2$	$IRSIB_3$	BSSRI
2009	Low level	Low level	Low level	Low level
2010	Low level	Low level	Low level	Low level
2011	Low level	Low level	Low level	Low level
2012	Low level	Low level	Low level	Low level
2013	Low level	Medium level	Low level	Low level
2014	Low level	Medium level	Medium level	Medium level
2015	Medium level	High level	High level	High level
2016	High level	High level	Medium level	High level
2017	High level	High level	Medium level	High level
2018	High level	Medium level	Medium level	Medium level

SIB operation riskiness level	Degree of the SIB systemic importance		
	1st-order	**2nd-order**	**3rd-order**
High	**Quadrant 1** JSC CB PRIVATBANK, JSC Ukreximbank	**Quadrant 2**	**Quadrant 4**
Medium	**Quadrant 3** JSC OSCHADBANK	**Quadrant 5** JSB UKRGASBANK	**Quadrant 7** PJSC FUIB (PUMB), JSC UkrSibbank, JSC Alfa-Bank
Low	**Quadrant 6**	**Quadrant 8** JSC Raiffeisen Bank Aval	**Quadrant 9**

Figure 3. Positioning of the Ukrainian systemically important banks in the matrix "SIB operation riskiness level – Degree of the SIB systemic importance"

lyzed period: 2009–2013 – the systemic risk level in the Ukrainian banking system was low, in 2014 and 2018 it was medium, and in 2015–2017 – high. In this context, attention should be paid to the set forth below when comparing the results of quantitatively and qualitatively measured systemic risk in the banking system (Figure 2 and Table 4). A gradual increase in the *BSSRI* value was noted during 2012–2014, and, according to the calculations made, in 2014 the systemic risk level was interpreted as a medium one. Given this, one can conclude that the steady tendency toward approximating the quantitative value of the systemic risk indicator in the banking system to the lower limit of the third interval of the developed scale (which determines the high systemic risk level) indicates a high probability of its growth in the future and systemic crisis emergence. For example, this was shown by the *BSSRI* value in 2014 (it was equal to 0.424 and close to the threshold of 0.497, according to the scale interval (0.497; 1]) and confirmed through the aggravating situation in the banking system during 2015–2017.

The second block of recommendations on interpreting the results of the quantitative systemic risk measurement represents the distribution of banks (identified as systemically important in 2018) (see Figure 3).

According to the determined positions of the systemically important banks recorded in the quadrants of the shaped matrix, it is advisable to strengthen the supervision regime over the operation performed by JSC CB PRIVATBANK, JSC Ukreximbank and JSC OSCHADBANK (got into quadrants 1-3), that is, to plan and organize on-site inspections once a quarter. In turn, moderate and weakened supervision regimes should be applied to JSB UKRGASBANK (quadrant 5) and PJSC FUIB (PUMB), JSC UkrSibbank, JSC Alfa-Bank and JSC Raiffeisen Bank Aval (quadrants 7-8) with on-site inspections every six months and once a year, according to each type of regimes. At the same time, it is worth noting that the determined intensity of the SIBs inspections may be reviewed and/or adjusted (for example, due to unscheduled inspections) taking into account the results of both off-site supervision (takes place on a regular basis) and stress testing of banks. Generally speaking, inspections (both general and thematic) should result in the following: firstly, specified reasons that provoke a deteriorated financial situation in the systemically important banks, which may have a highly negative effect on the state of the entire banking system in the future. Secondly, specifying the deadlines for elimination of problems and recommendations on the financial rehabilitation for banks, in particular with regard to restructuring their assets and business processes.

http://dx.doi.org/10.21511/bbs.14(3).2019.04

CONCLUSION

It has been proposed to measure the systemic risk in the banking system with the formation of an aggregated indicator by convoluted integral operation riskiness indicators for systemically important banks, divided into groups depending on their systemic importance. Determining the weighting coefficients for the components of the aggregated systemic risk indicator in the banking system took into consideration the links between the financial risks specific for the systemically important banks and their degree of systemic importance. The following proposals were introduced with the aim to interpret the results of the quantitative systemic risk measurement: differentiation of the high, medium and low systemic risk levels; supervision over the SIBs operation.

The proposed approach is considered peculiar, since it can be used while developing macro-prudential policies and enables introducing practical recommendations for the systemic crisis prevention, monitoring the systemic risk level in the banking system and SIBs financial risks. For instance, first of all, its benefits include the available data to assess the systemic risk and simple implementation procedures as seen from the quantitative measurement position. Secondly, as for interpreting the assessment results for the presented approach, it is possible: to determine the threshold value of the aggregated systemic risk indicator (may serve as a marker for informing about the crisis phenomenon aggravation in the banking system in the future) according to the differentiated systemic risk levels; to determine the supervision regime types for systemically important banks that differ in the intensity of the on-site inspections by supervisory bodies with the help of the shaped matrix "SIB operation riskiness level – Degree of the SIB systemic importance". At the same time, the supervisory body, based on the results of determining the positions of systemically important banks in the designed matrix, has an option to review the inspection intensity, as well as apply additional and strengthened prudential requirements to banks (norms, capital buffers), which will contribute to ensuring their stability.

REFERENCES

1. Acharya, V. V., Pedersen, L. H., Philippon, T., & Richardson, M. P. (2010). *Measuring systemic risk* (AFA Denver Meetings Paper). http://dx.doi.org/10.2139/ssrn.1573171
2. Acharya, V., Pedersen, L., Philippon, T., & Richardson, M. (2009). Regulating systemic risk (pp. 283-304). In *Restoring financial stability: How to Repair a Failed System*. John Wiley & Sons, Inc. Retrieved from http://kad-amaee.ir/payesh/books-tank/24/Acharya%20&%20Richardson%20(Eds)%20-%20Restoring%20Financial%20Stability;%20How%20to%20Repair%20a%20Failed%20System%20(2009).pdf
3. Adrian, T., & Brunnermeier, M. K. (2011). *CoVaR* (FRB of New York Staff Report No. 348). http://dx.doi.org/10.2139/ssrn.1269446
4. Basel Committee on Banking Supervision. (2018). *Global systemically important banks: revised assessment methodology and the higher loss absorbency requirement.* Retrieved from https://www.bis.org/bcbs/publ/d445.pdf.
5. Bezrodna, O. S., & Lesik, V. O. (2017). Теоретико-методичні аспекти оцінювання фінансової стабільності банківської системи [Teoretyko-metodychni aspekty otsiniuvannia finansovoi stabilnosti bankivskoi systemy]. *Problemy Ekonomiky, 2,* 251-263.
6. Borri, N., Caccavaio, M., Giorgio, Di G., & Sorrentino, A. M. (2012). *Systemic risk in the European banking sector* (CASMEF Working Paper Series No. 11). http://dx.doi.org/10.2139/ssrn.2112919
7. Brownlees, C. T., & Engle, R. F. (2012). *Volatility, Correlation and Tails for Systemic Risk Measurement.* Retrieved from https://www.semanticscholar.org/paper/Volatility%2C-Correlation-and-Tails-for-Systemic-Risk-Brownlees-Engle/1a59f6c170253e5b17d842c707cce4e139ef4d59
8. Brownlees, C. T., & Engle, R. F. (2017). SRISK: a conditional capital shortfall measure of systemic risk. *The Review of Financial Studies, 30*(1), 48-79. https://doi.org/10.2139/ssrn.1611229
9. Capera, L., Gómez, E., Laverde, M., & Morales, M. Á. (2011). Measuring systemic risk in the Colombian financial system: a systemic contingent claims approach. *Temas de Estabilidad Financiera, 60*. Retrieved from http://www.banrep.org/docum/Lectura_finanzas/pdf/tref_sep_2011.pdf
10. Cerutti, E., Claessens, S., & McGuire, P. (2012). *Systemic risk in global banking: what*

can available data tell us and what more data are needed? (BIS Working Papers No. 376). Retrieved from https://www.bis.org/publ/work376.pdf

11. Cont, R., Moussa, A., & Santos, E. B. (2010). Network structure and systemic risk in banking systems. *SSRN Electronic Journal*. http://dx.doi.org/10.2139/ssrn.1733528.
12. De Bandt, O., & Hartmann, P. (2000). *Systemic risk a survey* (ECB Working Paper No. 35). Retrieved from https://www.researchgate.net/publication/4888720_Systemic_Risk_A_Survey
13. Di Cesare, A., & Picco, A. R. (2018). *A survey of systemic risk indicators* (Occasional Papers No. 458). Retrieved from https://www.bancaditalia.it/pubblicazioni/qef/2018-0458/QEF_458_18.pdf
14. Dumičić, M. (2016). Financial Stability Indicators – The Case of Croatia. *Journal of Central Banking Theory and Practice, 5*(1), 113-140. https://doi.org/10.1515/jcbtp-2016-0006
15. Dungey, M., Luciani, M., & Veredas, D. (2018). Systemic risk in the US: Interconnectedness as a circuit breaker. *Economic Modelling, 71*, 305-315. https://doi.org/10.1016/j.econmod.2017.10.004
16. Fan, H., Amalia, A. A. L. L. & Gao, Q. Q. (2018). The Assessment of Systemic Risk in the Kenyan Banking Sector. *Complexity*, *2018*, 1-15. https://doi.org/10.1155/2018/8767836
17. Fishburn, P. (1970). *Utility theory for decision making* (224 p.). New York: John Wiley & Sons, Inc.
18. Foggitt, G. M., Heymans, A., Vuuren, G. W., & Pretorius, A. (2017). Measuring the systemic risk in the South African banking sector. *(SAJEMS) South African Journal of Economic and Management Sciences*, *20*(1), 1-9. https://doi.org/10.4102/sajems.v20i1.1619
19. Gerlach, S. (2009). *Defining and measuring systemic risk*. Brussels: European Parliament's Committee on Economic and Monetary Affairs. Retrieved from http://www.europarl.europa.eu/document/activities/cont/200911/20091124ATT65154/20091124ATT65154EN.pdf
20. Gudelytė, L., & Navickienė, O. (2013). Modelling of systemic risk of banking sector. *Social Technologies, 3*(2), 359-371. https://doi.org/10.13165/ST-13-3-2-09
21. Hartmann, P., Straetmans, S., & de Vries, C (2005). *Banking system stability: A crossatlantic perspective* (NBER Working Paper No. 11698). https://doi.org/10.3386/w11698
22. Haubrich, J., & DeKoning, Ch. (2017). *Sizing up systemic risk*. Federal Reserve Bank of Cleveland. Economic Commentary. Retrieved from https://www.clevelandfed.org/newsroom-and-events/publications/economic-commentary/2017-economic-commentaries/ec-201713-sizing-up-systemic-risk.aspx
23. Hollo D., Kremer, M., & Duca, M. L. (2012). *A Composite Indicator of Systemic Stress in the Financial System* (ECB Working Paper Series No. 1426). Retrieved from http://www.ecb.europa.eu/pub/pdf/scpwps/ecbwp1426.pdf.
24. Hu, D., Zhao, J. L., Hua, Zh., & Wong, M. C. S. (2012). Network-based modeling and analysis of systemic risk in banking systems. *MIS Quarterly, 36*(4), 1269-1291. Retrieved from https://pdfs.semanticscholar.org/4f44/6a2995ed63e0f57bc515b702919b96296ea3.pdf
25. Huang, Q., de Haan, J., & Scholtens, B. (2015). *Analyzing systemic risk in the Chinese banking system* (CESifo Working Paper No. 5513). Retrieved from https://www.rug.nl/research/portal/files/24084967/cesifo1_wp5513.pdf.
26. Huang, X., Zhou, H., & Zhu, H. (2009). A framework for assessing the systemic risk of major financial institutions. *Journal of Banking & Finance, 33*(11), 2036-2049. https://doi.org/10.1016/j.jbankfin.2009.05.017
27. IMF. (2009). *Guidance to assess the systemic importance of financial institutions, markets and instruments: initial considerations* (Report to the G-20 Finance Ministers and Central Bank Governors). Retrieved from https://www.imf.org/external/np/g20/pdf/100109.pdf
28. Ivanets, O. (2017). Systemic Risk Index – Integrated Indicator of Financial Sustainability. *European Journal of Sustainable Development*, *6*(4), 502-510. https://doi.org/10.14207/ejsd.2017.v6n4p502
29. Karimalis, E. N., & Nomikos, N. K. (2014). Measuring systemic risk in the European banking sector: a copula CoVaR approach. *The European Journal of Finance, 24*(11), 944-975. https://doi.org/10.1080/1351847X.2017.1366350
30. Karkowska, R. (2015). What Kind Of Systemic Risks Do We Face In The European Banking Sector? The Approach of CoVaR Measure. *Folia Oeconomica Stetinensia, 14*(2), 114-124. https://doi.org/10.1515/foli-2015-0017
31. Kaufman, G. (1992). *Bank Contagion: Theory and Evidence* (Working Paper Series WP-92-13). Federal Reserve Bank of Chicago.
32. Kaufman, G. G., & Scott, K. E. (2003). What is systemic risk, and do bank regulators retard or contribute to it? *The Independent Review, 7*(3), 33-50. Retrieved from https://www.independent.org/publications/tir/article.asp?id=88
33. Kuznyetsova, A., & Pogorelenko, N. (2018). Assessment of the banking system financial stability based on the differential approach. *Banks and Bank Systems, 13*(3), 120-133. https://doi.org/10.21511/bbs.13(3).2018.12
34. Laeven, L., & Valencia, F. (2018). *Systemic banking crises revisited* (IMF Working Paper No. 18/206). Retrieved from https://www.imf.org/en/Publications/WP/Issues/2018/09/14/Systemic-Banking-Crises-Revisited-46232
35. Murphy, E. V. (2012). *What is systemic risk? Does it apply to recent JP Morgan losses?* (CRS Report for Congress). Congressional Research Service. Retrieved from https://fas.org/sgp/crs/misc/R42545.pdf
36. National Bank of Ukraine. (2009–2018). *Banking system indicators.*

http://dx.doi.org/10.21511/bbs.14(3).2019.04

Retrieved from https://bank.gov.ua/control/en/publish/article?art_id=34705283&cat_id=34798612.

37. National Bank of Ukraine. (n.d.a). *Macro-prudential policy strategy*. Retrieved from https://bank.gov.ua/doccatalog/document?id=85227142

38. National Bank of Ukraine. (n.d.b). *National Bank of Ukraine Strategy*. Retrieved from https://bank.gov.ua/doccatalog/document?id=64754196

39. Omelchenko, O., Dorokhov, O., Kolodiziev, O., & Dorokhova, L. (2018). Fuzzy Modeling of Creditworthiness Assessments of Bank's Potential Borrowers in Ukraine. *Economic Studies, 27*(4), 100-125. Retrieved from http://212.111.199.244/bitstream/123456789/20277/1/Omelchenko_Kolodiziev_Dorokhov.pdf

40. State Statistics Service of Ukraine. (n.d.). *Gross Domestic Product*. Retrieved from https://ukrstat.org/uk/operativ/operativ2003/vvp/vvp_kv/vvp_kv_u/arh_vvp_kv.html

41. Sum, K. (2015). Basic indicators of systemic risk in the EU banking sector. Implications for banking regulation. *International Journal of Management and Economic, 47*(1), 36-55. https://doi.org/10.1515/ijme-2015-0027

42. Teply, P., Kvapilikova, I. (2017). Measuring systemic risk of the US banking sector in time-frequency domain. *The North American Journal of Economics and Finance, 42*, 461-472. https://doi.org/10.1016/j.najef.2017.08.007

43. Van Oordt, M., & Zhou, Ch. (2015). *Systemic risk of European banks: Regulators and markets* (Working Paper No. 478). Retrieved from https://www.dnb.nl/binaries/WP478_tcm46-324614.pdf

44. Yun, J., & Moon, H. (2014). Measuring systemic risk in the Korean banking sector via dynamic conditional correlation models. *Pacific-Basin Finance Journal, 27*, 94-114. https://doi.org/10.1016/j.pacfin.2014.02.005

45. Zinchenko, N. (2007). Етапи визначення кредитно-рейтингової оцінки підприємств-емітентів [Etapy vyznachennia kredytno-reitynhovoi otsinky pidpryiemstv-emitentiv]. *Upravlinnia rozvytkom, 4*, 48-49.