"Assessment and forecasting of Ukraine's financial security: Choice of alternatives"

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ASSESSMENT AND FORECASTING OF UKRAINE'S FINANCIAL SECURITY: CHOICE OF ALTERNATIVES

Abstract

Financial security of a country is an integral part of its economic security and the basis of national security. The paper aims to assess and forecast the level of Ukraine's financial security using two methodological approaches (the existing one and the authors' elaboration) to choose the best alternative. The first one is based on the Methodology of the Ministry of Economy of Ukraine. The alternative one has been developed as a multiplicative model of non-linear convolution of relevant direct and indirect impact indicators, considering the opportunity and risk, which is based on a combination of a power function and the Harrington method. A database of input indicators was formed with further differentiation according to their impact on Ukraine's financial security. The research results demonstrated that during 2013–2019 Ukraine's financial security integrated index was cyclical and constantly changing. A comparison of the existing methodology and the developed model demonstrated a certain discrepancy between the obtained results. It was substantiated that the proposed multiplicative non-linear convolution model for assessing and forecasting the state's financial security is more relevant, includes current indicators sorted by their direct and indirect impact, and adjusts them according to the risk of impact on overall security in the country.

Keywords	financial security, assessment, forecasting, diagnostics, indicators, multiplicative model, integrated index, methodology, Ukraine
JEL Classification	C51, C53, F65

INTRODUCTION

During the development of world globalization processes, ensuring economic security is a significant issue. One of the economic security segments is the financial component, which acts as a guarantor of country's effective and sustainable development since the formation of financial security is the main prerequisite for any economy. The financial security of each country, including emerging economies such as Ukraine, is characterized by certain indicators, including unemployment rate, financial independence, external and domestic debt, the nature of financial and credit policy, political climate, the level of resource provision of the healthcare system, culture, education, and science.

In this context, the role and importance of the financial system have changed dramatically in recent years. From being the usual mechanism for servicing economic processes, finance has become the basis of modern economic development and society, whose role in the growing globalization of the world economic relations is only increasing. The financial system must have a certain margin of safety in the event of unforeseen and extraordinary circumstances, in particular, to enable public authorities and other economic operators to respond in a timely manner to any threats and to prevent, neutralize, or at least

minimize potential socio-economic losses. Thus, one of the most important tasks of a country is to counter the threats to financial security and create an effective management system to ensure an adequate development level of economic and national security.

However, it is quite difficult to assess the level of protection against financial threats. This requires unique methods and models that can best describe the environment in which a business entity operates. To date, the criteria for assessing and predicting financial security characterize the economy in different ways, forming a single comprehensive assessment; however, a large number of indicators do not consider potential threats and do not include relevant external factors. Moreover, existing methods are mainly focused on quantifiable analysis and include a number of indicators, ignoring other equally important indicators and their impact on the level of security of individual components and financial security in general. Thus, the task of improving the mechanism for Ukraine's financial security assessment and forecasting is relevant, which can be implemented through the development of a supplementary system of financial indicators that would allow comprehensive management of the country's financial security.

1. LITERATURE REVIEW

In developed countries, financial security is ensured at a high level since competitive countries create an appropriate economic environment for business entities and the population. For example, Inglehart and Abramson (1994) took opinion polls on economic security and value change based on global surveys of country values. They found a relationship between post-materialist values and age. Opinion polls show that young and wealthy people in Western democratic states are becoming less and less concerned with matters of purely material income and more and more interested in civil liberties and security.

Global financial transformation affects the financial security (Bulatova et al., 2020). There is a certain correlation between global and regional financial trends that have shaped the financial security of Central and Eastern Europe (Bilozubenko et al., 2020).

The state of financial security, in which financial market participants can feel confident, is achieved if individuals and legal entities have sufficient financial resources to best meet their needs. The financial security of a state means the financial system's stability at the macroeconomic level (Allen & Wood, 2006). In addition, financial security is a set of socio-economic and legal relations that ensure such a financial situation in which there is resistance to external threats and risks, subject to the rational use of one's own financial resources (Mykolaichuk, 2012).

The financial security of a country is most effective under the state system of strategic economic management, which forms a set of forecasting, design, and planning (Tsapova, 2020; Kozmenko et al., 2014). It is necessary to take into account the threats and risks to a state's financial security in the process of diagnosing its level (Nakonechna, 2013).

The functional approach, which defines financial security as an integral part of a state's economic security, is expressed in a specific state of financial flows within the financial, monetary, currency, banking, budget, tax, settlement, investment, and stock systems of a country. They are characterized by balance, resistance to negative influences, the ability to prevent external financial expansion, ensure financial stability and efficient functioning of the state economic system and economic growth (Semenoh, 2018).

Zhuravka et al. (2021) assessed and projected Ukraine's debt security as a component of its financial security through time series analysis. They determined that in order to overcome the causes of crisis tendencies in a country, it is necessary to introduce practical tools for regulating the parameters of the banking system as a component of financial security (Kolodiziev et al., 2018; Bukhtiarova et al., 2020; Bondarenko et al., 2020).

Thus, financial security involves a system of measures to increase the level of its main elements (Ivashko, 2015).

Most modern scientific works deal with the issues of individual areas and components of financial security. At the same time, some of them deeply explore the methodological principles of managing the economic security of enterprises in a global environment (D'yakonova et al., 2018). State support for small businesses and their sustainable development affects financial security in a country (Grynko & Gviniashvili, 2015). The development of the financial environment is influenced by both economic factors and insufficient state financial and legal support. This, in turn, reduces a country's financial security (Frolov et al., 2017; Shkolnyk et al., 2019).

Another aspect of providing a high level of financial security is data protection technology. Pan et al. (2020) proposed a dynamic encryption algorithm to secure financial information and protect privacy based on special technology. However, the study focuses more on technical mechanisms and does not address qualitative aspects. The infrastructure of financial security is also essential, namely, accessibility and cybersecurity conditions in which the financial market is located (Goede, 2021).

Methods for determining the level of financial security of the state are mainly based on monitoring the main macroeconomic indicators of economic development. Quite a lot of scientific works define effective tools for assessing the level of state security. Ukrainian approaches are mainly based on integrated estimates and quantitative indicators. Expert methods, analysis methods, scenario processing, and optimization are also used (Blakyta et al., 2017). To monitor the financial security system and diagnose its level, it is advisable to use economic and mathematical modeling tools.

In practice, the complex nature of the assessment is used based on the calculation of integrated indices for each component of financial security, and directions for adjusting public policy to improve the current situation are proposed (Eitutis & Popova, 2018). In addition, when studying the problems of assessing financial security, an approach is used to identify the most critical economic determinants that prevent existing threats and predict a country's level of financial security (Haber et al., 2018).

The methodology for assessing the state security in Ukraine was proposed by the state regula-tor, the Ministry of Economy, and described in the Guidelines for Calculating the Level of Economic Security of Ukraine (Verkhovna Rada of Ukraine, 2013). The assessment of financial security is determined in the context of economic security. In addition, it is considered as a separate area and is based on calculating an integrated indicator. The methodology is based on a quantitative study of indicators that characterize a country's economic security and, accordingly, financial security as its priority component. The Financial Security Index consists of six weighted average sub-indices – security components represented by the relevant sectors of the financial market: the banking market, security of the non-banking financial sector (insurance and stock market), budget, debt, currency, and monetary security.

The stages of assessing the state of financial security according to this Methodology include:

- determining the characteristic (optimal, critical) values of indicators;

- rationing financial security indicators;

- determining weights for indicators of financial security;

- calculating sub-indices for individual areas and the overall integrated index of financial security.

However, despite many scientific papers studying the field of a state's financial security, the question of a qualitative and mathematically significant assessment and forecasting of its level remains open today.

Therefore, the study aims to assess and forecast Ukraine's financial security level using two methodological approaches (the existing one and the authors' elaboration) to choose the best practical alternative.

2. METHODOLOGY

The toolkit for assessing the state's financial security level is based on the method for constructing a non-linear convolution multiplicative model of

Stage 1: Selecting indicators and creating the information base of finacial security input indicators

Stage 2: Assessing the indicators in terms of the risk of their impact on the overall level of security using a fuzzy-logic approach

Stage 3: Prioritization of financial security indicators using the Fishburn formula in the context of direct impact indicators and the same priority of indirect impact predictors

Stage 4: Normalization of input indicators using the relative method of bringing data to a single dimension

Stage 5: Assessing the level of a state's financial and economic security by constructing a multiplicative model of a non-linear (combination of a power function and the Harrington method) convolution of direct and indirect impact indicators normalized by the relative method according to the degree of risk and opportunity

Figure 1. Stages of implementing the model to assess a country's financial security

relevant indicators of direct and indirect impact in terms of opportunities (for incentives) and risks (for disincentives). The developed model for calculating the integrated index of a state's financial security is based on a sequence of stages (Figure 1).

After selecting the most relevant indicators, the second stage is implemented – each of the selected indicators can have a different effect on the final indicator of the model, that is, on the level of financial security. Each of the indicators can act as a stimulator, when it increases, the overall level of security will increase, or as a de-stimulator, when the overall value of the level decreases with the growth of a specific indicator. It is also possible that up to a certain point, the indicator may be stimulating, and then at a certain interval, may change to a destimulating one. The value of the model's result largely depends on this. Therefore, it is important to perform these calculations as carefully as possible and avoid discrepancies in an inappropriate interval. First, the interval between the minimum possible and maximum possible values of each of the indicators of direct and indirect impact over the study period is divided into 11 intervals of varying confidence levels using the formulas given in Table A1 (Appendix A).

The value of k_{pdit} is the actual value of the indicator for a certain (t) year. Thus, to determine the opportunity and risk of each indicator, the minimum and maximum values in the corresponding analyzed period are determined, the intervals are divided into 11 levels (from 0 to 100%). Then, the procedure for matching the indicator for each year in the corresponding interval is carried out (if the value falls within the required interval, 1 is taken, and 0 if it does not fall). The values for the entire analyzed period are summed by intervals, and first the risk of the indicator is determined, and then its probability.

The third stage, which involves delimiting the priority of selected indicators, is carried out using the Fishburn formula (in terms of direct impact indicators) and the same priority of indirect impact indicators:

$$w_{pi} = \frac{2 \cdot (N - n_i + 1)}{N \cdot (N + 1)}, \tag{1}$$

where w_{pi} is the weighting coefficient of the i-th direct impact predictor; N is the total number of direct impact indicators; n_i is the rank of the considered i-th indicator.

At the fourth stage of modeling the assessment of the level of a country's financial security, the input indicators were normalized using the relative method in the context of time series with a non-negative value and an additional intermediate adjustment of negative values to the minimum possible level modulo, taking into account the standard deviation:

- normalization of direct impact indicators:

$$n_{pit} = \frac{k_{pit}}{\max_t k_{pit}}, \qquad (2)$$

where n_{pit} is the value of the i-th direct impact indicator for the t-th year normalized by the relative method;

- normalization of the indirect impact indicator:

$$n_{iit} = \frac{k_{iit} - \min_t k_{iit} + \sigma_{it}}{\max_t \left(k_{iit} - \min_t k_{iit} + \sigma_{iit} \right)}, \qquad (3)$$

where n_{oit} is the value of the i-th of indirect impact indicator normalized by the relative method for the t-th year; σ_{pt} is the standard deviation of the indirect impact indicator.

At the final stage, a generalized indicator of the level of financial security is calculated by constructing a multiplicative model of a non-linear (combination of a power function and the Harrington method) convolution of direct and indirect impact indicators, normalized by the relative method in terms of risk and opportunity:

$$FB_t = \left[\exp\left(-\exp\left(-\prod_i \left(n_{pit} \cdot \frac{r_{pi}}{100} \right)^{w_{pi}} \times \right.\right.\right.$$

$$\times \prod_i \left(n_{oit} \cdot \frac{r_{oi}}{100} \right)^{w_{oi}} \right) \times$$

$$\times \exp\left(-\exp\left(\prod_i \left(n_{pit} \cdot \frac{m_{pi}}{100} \right)^{w_{pi}} \times \right.\right.$$

$$\left.\left.\left. \times \prod_i \left(n_{oit} \cdot \frac{m_{oi}}{100} \right)^{w_{oi}} \right) \right) \right]^{\frac{1}{2}}, \qquad (4)$$

where FB_t is the level of a country's economic security; n_{pit} is the value of the i-th direct impact indicator for the t-th year, normalized by the relative method; r_{pi} is a fuzzy logic risk assessment of the i-th direct impact indicator; w_{pi} is the weighting coefficient of the i-th direct impact predictor; n_{oit} is the value of the i-th indirect impact indicator for the t-th year, normalized by the relative method; r_{oi} – a fuzzy-logic risk assessment of the i-th indirect impact indicator; w_{oi} is the weighting coefficient of the i-th indirect impact indicator; m_{pi} is a fuzzy-logic assessment of the possibility of the i-th direct impact indicator; m_{oi} is a fuzzy-logic assessment of the possibility of the i-th indirect impact indicator.

3. RESULTS

The results of assessing the general indicator of the level of Ukraine's financial security and its components according to the Methodology of the Ministry of Economy of Ukraine are shown in Table 1. To assess the overall level of the state's financial security, the security of its components, which include several indicators, is first calculated.

Characteristic values of indicators of state security components according to the Methodology of the Ministry of Economy of Ukraine are determined in the range of values measured from 0 to 1 (or from 0 to 100 percent) and divided into five intervals $[y_0, y_{crit}), [y_{crit}, y_{dang}), [y_{dang}, y_{unsat}), [y_{unsat}, y_{sat}), [y_{sat}, y_{opt}]$:

- y_0 is the indicator value, which is characterized as a minimum or absolutely dangerous level of economic security and at which the level of economic security is 0;

- y_{crit} – indicator value, which is characterized as a critical level of economic security and at which the level of economic security equals 0.2, or 20% of the optimal value;

- y_{dang} – indicator value, which is characterized as a dangerous level of economic security and at which the level of economic security is 0.4, or 40% of the optimal value;

- y_{unsat} – the value of the indicator, which is characterized as an unsatisfactory level of economic security and at which the level of eco-

Table 1. Integrated index of the general level of Ukraine's financial security and its components for 2013–2019

No.	Country security indicators	Year						
		2013	2014	2015	2016	2017	2018	2019
1	Banking security	0.581	0.506	0.497	0.725	0.429	0.487	0.349
2	Non-banking financial market security	0.458	0.375	0.422	0.258	0.225	0.266	0.286
3	Debt security	0.229	0.113	0.110	0.155	0.145	0.139	0.134
4	Budget security	0.594	0.578	0.677	0.619	0.635	0.654	0.381
5	Foreign exchange security	0.591	0.273	0.357	0.413	0.504	0.560	0.443
6	Monetary security	0.517	0.503	0.469	0.517	0.489	0.465	0.480
	Integrated index of financial security	0.499	0.398	0.429	0.465	0.422	0.445	0.350

nomic security equals 0.6, or 60% of the optimal value;

- y_{sat} – indicator value, which is characterized as a satisfactory level of economic security and at which the level of economic security is 0.8, or 80% of the optimal value;

- y_{opt} – indicator value, which is characterized as the optimal level of economic security and at which the level of economic security is 1, i.e. equals the optimal value.

The results show that the security of all components is below the average level of optimal value. Therefore, the level of overall financial security of Ukraine does not show high values.

The banking sector proved to be the most protected from financial threats, while debt security had the lowest performance of all sectors (Figure 2).

The obtained results show that the value of Ukraine's financial security assessment is below the average for the entire period. The highest level was recorded in 2013 (0.499). In subsequent periods, there is a decrease in the level, in the last analyzed year, the financial security of Ukraine has a level of 0.35.

The Ukrainian economy is not sufficiently resilient to financial shocks and imbalances. The biggest threats were identified in external debt, inefficient use of budget funds, high cost of bank loans, and a significant level of economic dollarization.

Source: Authors' elaboration.
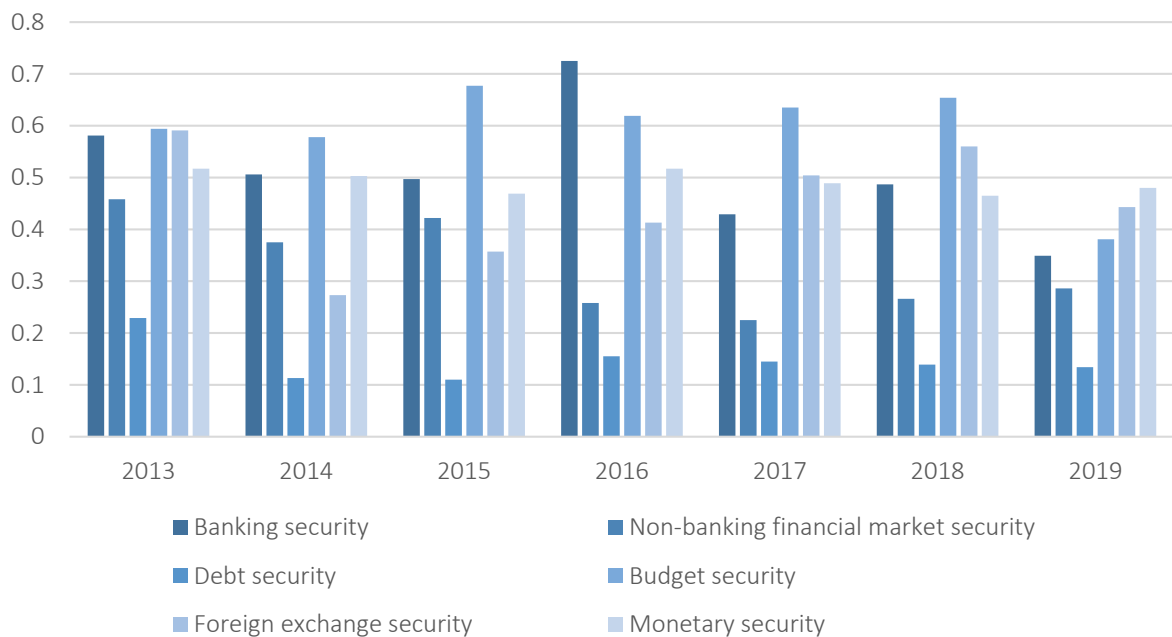
Figure 2. Dynamics of changes in the components of Ukraine's financial security for 2013–2019

Figure 3. Dynamics of changes in the integrated index of Ukraine's financial security for 2013–2019

However, having conducted a study using only this method, it cannot be argued that the result obtained is the final and true reflection of the real situation in the financial sector.

Analysis of the Methodology allows identifying a number of its characteristic shortcomings: the methodology is outdated (developed in 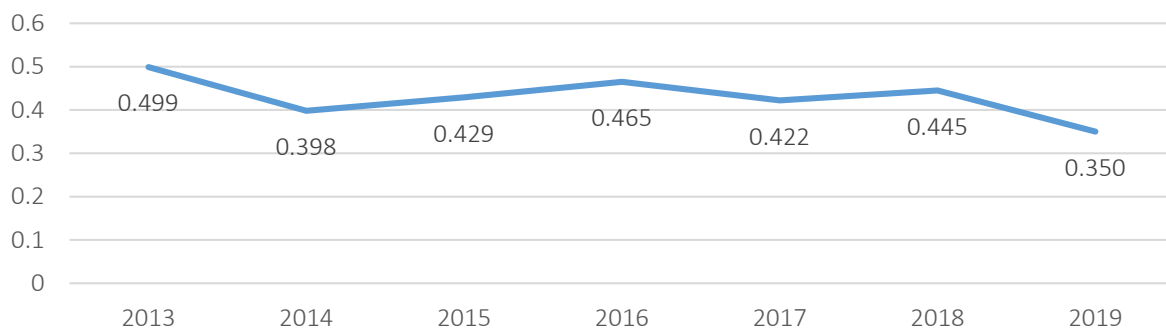2013), it is necessary to revise input indicators; as a rule, a feature of the methodology is its focus on a retrospective analysis, without a long-term financial forecast; the mechanism is aimed at analyzing quantitative indicators and does not consider non-financial, qualitative information and its impact on the level of security of individual components and financial security in general. The shortcomings of this mechanism lead to a decrease in the practical value of the results.

In Ukraine, this is the only methodology that allows one to determine a country's financial security; there are no analogs for verifying or analyzing financial security by other methods. Also,

given that statistical information for calculations according to this Methodology is collected from domestic reporting documents, we can talk about possible subjectivity and falsification.

The methodology for determining economic security and, within its framework, financial security of a country is not relevant today. Therefore, the need to develop alternative modeling tools that would assess the real level of security of Ukraine's financial and economic sector was identified.

To assess a country's financial security, it is proposed to build a structural-logical multiplicative model, the implementation of which includes a particular sequence of stages. At the initial stage, an information base of input predictors is created in dynamics and grouped according to different directions of influence (Table 2).

Input indicators were selected from the World Bank (n.d.a-n.d.d) international statistics data-

Table 2. Input indicators for the model for assessing Ukraine's financial security by influencing areas

Ukraine's financial security indicators	
Direct impact predictors	Indirect impact predictors
Total debt (% of GNI)	Consumer price index
Public and state-guaranteed debt (% of GNI)	Inflation rate (%)
Government final consumption expenditure (% of GDP)	Unemployment rate (%)
Current account balance (% of GDP)	Interest rate spread (%)
Subsidies and other transfers (% of costs)	S&P Global Capital Index (annual change)
Private sector lending (% of GDP)	Poverty rate by national poverty rates (% of population)
Tax income (% of GDP)	Business Disclosure Index (0 = less disclosure, 10 = more disclosure)
Total country reserves in months of imports	GINI index
Money supply dollarization level (%)	Statistical indicator of potential
Foreign direct investment, net inflow (% of GDP)	Official exchange rate (UAH per USD)
Foreign direct investment, net outflows (% of GDP)	Real interest rate (%)

base, namely, World Development, Poverty and Equity, Doing Business, World Bank Jobs, and Global Financial Development. This set of statistics can be considered unbiased and objective, reflecting the real situation in the country, since the World Bank's analysis is based on the actual performance of each country's economic sector.

The second stage of the model implementation involves determining the degree of character in terms of both opportunity and risk in the context of each input predictor, using a fuzzy-logic approach. This takes into account:

- the nature of the corresponding indicator within its stimulating or de-stimulating effect;

- splitting the interval between the minimum possible and maximum possible value for the studied period into 11 intervals of different confidence levels;

- carrying out the transition to binary values, based on the hit of each predictor for the corresponding year in a certain interval of the confidence level;

- generalization of the share of binary indicators within 11 levels of confidence as an assessment of opportunity and risk (for stimulants) and vice versa (for destimulators).

The basis is to carry out the transition to binary values based on the hit of each predictor for the corresponding year in a certain confidence level – a value of one if the considered actual value for a certain year belongs to the interval between the minimum and maximum values, and zero otherwise.

The final step of this stage is to summarize the share of binary indicators with a unit value within 11 confidence levels as an assessment of opportunity (summing the binary indicators selected in the previous step, followed by taking into account the number of periods) and the difference of the 100% risk assessment. Thus, a positive or negative value of each indicator is obtained, which is interpreted as stimulating or destimulating.

The rank of predictors is mainly determined based on expert methods (for example, a ques-

tionnaire used to interview experts in this field, which allows you to determine how in their opinion the indicators more or less affect a country's financial security). However, since this method cannot be implemented at this stage of the study, the econometric method of principal components was used as an alternative, which mechanically determined the ranks of direct impact indicators (Table 3).

Table 3. Determining the rank of direct impact indicators using the method of principal components

Source: Authors' elaboration in Statistica 13.

Variable	Variable number	Strength	Value
Indicator 6	6	0.944342	1
Indicator 7	7	0.934804	2
Indicator 10	10	0.925872	3
Indicator 1	1	0.925506	4
Indicator 3	3	0.919114	5
Indicator 2	2	0.898843	6
Indicator 5	5	0.896882	7
Indicator 9	9	0.875265	8
Indicator 4	4	0.843222	9
Indicator 8	8	0.842327	10
Indicator 11	11	0.659638	11

The significance is compared with the number of the variable; the 6th variable will have the highest priority, the 7th will be second, the 10th variable (indicator) will be third, and so on. The 11th variable will have the lowest priority for calculating the Fishburn value based on its direct impact weights. For indirect impact indicators, the rank is not determined, since the logic of the same impact on the final result works here; therefore, the values of the same priorities are taken, namely, one divided by the total number of indicators (1/11).

The hypothesis is accepted regarding the different degrees of influence of direct and indirect impact predictors on the generalized assessment of a country's financial security, namely 65% and 35%, respectively. Therefore, there is a need to adjust the calculated weights (columns 2 and 5 of Table 5) and obtain the final levels (columns 3 and 6 of Table 4, respectively).

Table 4. Priority of financial security assessment indicators

No.	Rank	Fishburne value	Weighting coefficients for direct impact indicators	Weight of direct impact indicators in total	The value of the weights of the same priority	Weighting coefficients of indirect impact indicators	Weight of indicators of indirect impact in general
1	4	0.12121	0.07879		0.09091	0.03182	
2	6	0.09091	0.05909		0.09091	0.03182	
3	5	0.10606	0.06894		0.09091	0.03182	
4	9	0.04545	0.02955		0.09091	0.03182	
5	7	0.07576	0.04924		0.09091	0.03182	
6	1	0.16667	0.10833	0.65	0.09091	0.03182	0.35
7	2	0.15152	0.09848		0.09091	0.03182	
8	10	0.03030	0.01970		0.09091	0.03182	
9	8	0.06061	0.03939		0.09091	0.03182	
10	3	0.13636	0.08864		0.09091	0.03182	
11	11	0.01515	0.00985		0.09091	0.03182	

Before proceeding with the basic calculations of the model, it is necessary to bring the value of financial indicators to a single comparable form because the indicators have different mathematical dimensions. Normalization is a process as a result of which all data are reduced to a single scale of measurement, which reduces the additional impact of the indicator on the result of the constructed model. There is a transition to such a scale of measurements when the best value of the indicator corresponds to the value 1, and the worst – the value 0. There are many approaches to data normalization. This study used the normalization of variables by the relative method with negative values adjusted for the minimum possible level in absolute value and standard deviation. The normalized values are systematized in Table 5 and Table 6.

Table 5. Normalized direct impact indicators in terms of assessing Ukraine's financial security

	Indicator	Year						
		2013	2014	2015	2016	2017	2018	2019
1	Total debt	0.64	0.48	1.00	0.40	0.36	0.33	0.27
2	Public and state-guaranteed debt	0.26	0.18	1.00	0.22	0.27	0.23	0.18
3	Government final consumption expenditure	0.89	0.89	0.90	0.89	0.99	0.99	0.90
4	Current account balance	0.85	0.32	0.52	0.19	0.29	0.46	0.25
5	Subsidies and other transfers	0.98	1.00	0.91	0.86	0.86	0.84	0.82
6	Private sector lending	0.81	0.83	0.62	0.52	0.42	0.38	0.33
7	Tax income	0.86	0.85	1.00	0.96	0.98	0.99	0.94
8	Total country reserves in months of imports	0.42	0.22	0.53	0.59	0.60	0.64	0.92
9	Money supply dollarization level	0.95	1.00	0.97	0.94	0.86	0.85	0.67
10	Foreign direct investment, net inflow	0.27	0.07	0.04	0.47	0.39	0.39	0.42
11	Foreign direct investment, net outflows	0.34	0.60	0.06	0.27	0.31	0.13	0.59

Table 6. Normalized indirect impact indicators in the context of assessing Ukraine's financial security

|	Indicator	Year						
		2013	2014	2015	2016	2017	2018	2019
1	Consumer price index	0.48	0.53	0.73	0.81	0.91	1.00	1.07
2	Inflation rate	0.19	0.39	1.00	0.42	0.43	0.37	0.32
3	Unemployment	0.34	0.64	0.62	0.66	0.68	0.58	0.49
4	Interest rate spread	0.23	0.22	0.33	0.30	0.28	0.28	0.27
5	S&P Global Capital Index	0.39	0.29	0.46	0.54	0.55	0.40	0.42
6	Poverty rate by national poverty rates	0.33	0.33	0.31	0.29	0.28	0.27	0.27
7	Business Disclosure Index	0.57	0.57	0.57	0.78	0.89	1.00	1.11
8	GINI index	0.24	0.20	0.28	0.26	0.31	0.31	0.34
9	Statistical indicator of potential	0.96	0.96	0.65	0.43	0.43	0.21	0.22
10	Official exchange rate	0.36	0.49	0.82	0.95	0.98	1.00	0.96
11	Real interest rate	0.79	0.55	0.22	0.56	0.40	0.59	0.77
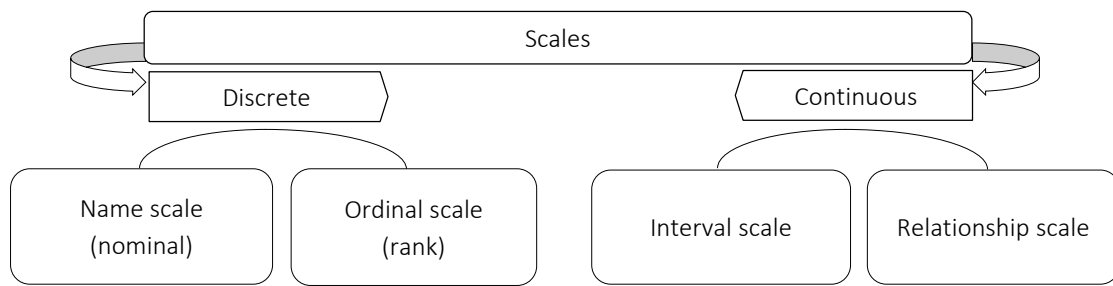
Figure 4. Scale types for qualitative measurement of results

The sequence of calculations for assessing the overall level of Ukraine's financial security is carried out in stages through a number of 8 intermediate steps.

The results are interpreted using the appropriate level gradation scale. Scaling is necessary to record the results of measuring the properties of an object by arranging them in a certain numerical system, in which the corresponding numbers depict the relationship between the individual results.

Certain types of scales can be used to explain the results and bring them to a qualitative form (Figure 4).

To interpret the results of assessing the state's financial security using a multiplicative model of non-linear convolution of direct and indirect impact indicators, a sequential (rank) scale was chosen that measures quantitative properties characterized by an equivalence ratio and order of increase or decrease in the quantitative manifesta-

tion of the property (Table 7). A special subtype of ordinal scales is used in this case – verbal-numerical scales. The main feature of verbal-numerical scales is that they allow one to measure the degree of intensity of any subjective property. In addition, the composition of the verbal-numerical scale includes semantic (verbal) description of the selected gradations and their corresponding numerical values.

Table 8 presents the results of the generalized assessment of a state's financial security, conducted based on a multiplicative model of non-linear convolution of direct and indirect impact indicators.

Modeling the assessment of the overall level of the state's financial and economic security shows that the integrated security indicator of Ukraine was cyclical and constantly changing during 2013–2019. The dynamics of the security level reflects the situation in the state's economy, which is explained by periods of financial and economic turmoil in Ukraine. A fairly significant decline in the

Table 7. Interpretation limits of the results of assessing a country's financial security using the multiplicative non-linear convolution model

Semantic description	Critical level	Low level	Sufficient level	Average level	High level
Numerical value	[0.000–0.120]	[0.121–0.137]	[0.138–0.164]	[0.165–0.180]	[0.181–0.200]

Table 8. Integral summary assessment of the level of financial security in Ukraine

Indicator	Year						
	2013	2014	2015	2016	2017	2018	2019
Risk of direct and indirect impact	1.151	0.974	1.118	1.102	1.090	0.995	0.947
Possibility of direct and indirect impact	1.341	1.161	1.231	1.360	1.328	1.279	1.231
Harrington's function in terms of risk	0.729	0.685	0.721	0.717	0.714	0.691	0.679
Harrington's function in terms of opportunity	0.022	0.041	0.033	0.020	0.023	0.028	0.033
The level of the state's financial security	0.126	0.168	0.153	0.121	0.128	0.138	0.149

Exp. smoothing: Additive season (3) S0 = .2057 T0 = −.004
Lin. trend, add. season; Alpha = 1.00 Delta = 1.00 Gamma = 0.00
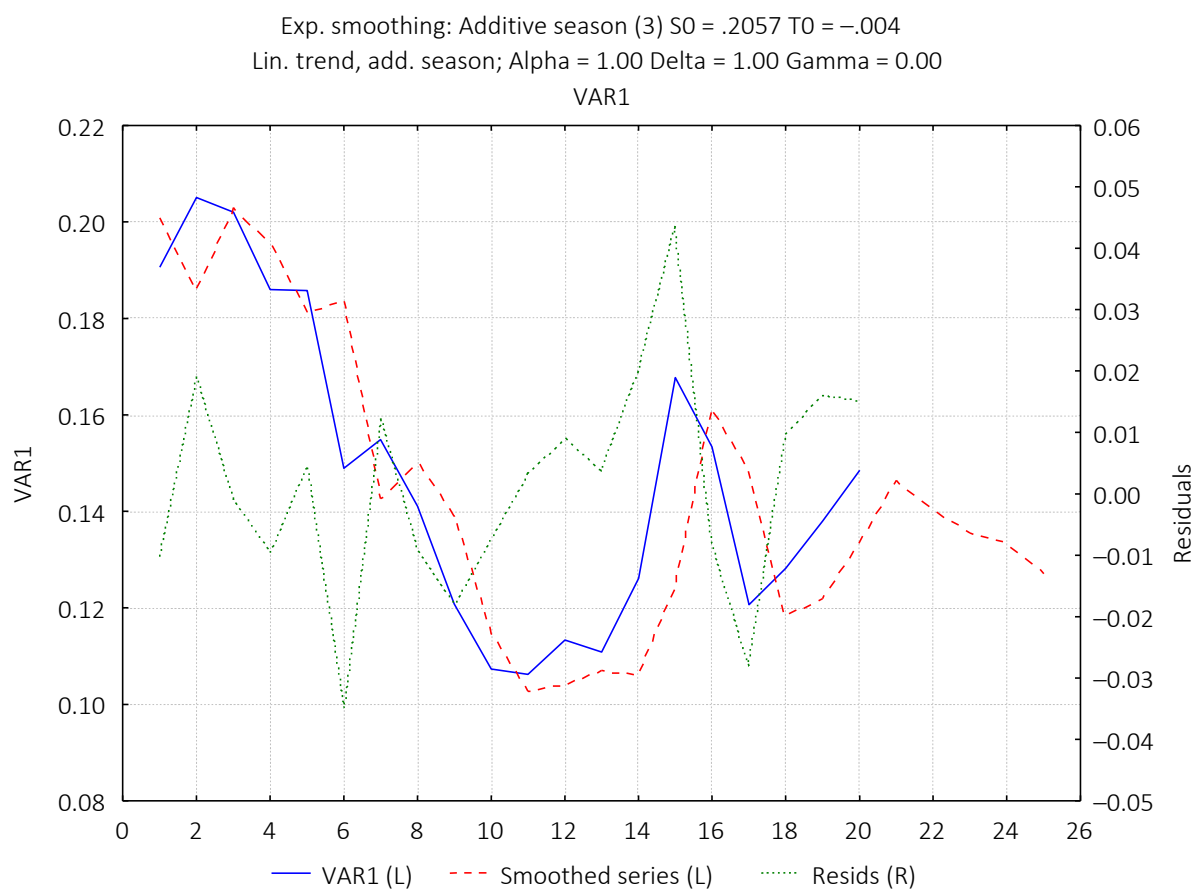
Figure 5. Exponential smoothing of the financial security forecast level

world's economies has been observed since the beginning of the global financial crisis that developed in the United States. However, it has spread to other countries as well as to emerging market economies and has become global (Lewkowicz, 2018). However, while the US financial system reacted strongly, some countries experienced a lagged effect. It was the banking crisis that characterized the rapid decline in the level of security of Ukraine's national economy to a critical level in 2013.

In 2014, a political crisis broke out that affected Ukraine's financial system and led to a further decline in overall financial security to 0.121 in 2016. Then the country begins to emerge from the crisis, and the level of security gradually increases. Economic conditions in the country provide a mainly low and medium level of security of the financial sector. The greatest threats are due to external debt, inefficient use of budget funds, high cost of bank loans, and significant economic dollarization. This indicates the lack of systematic

work of executive authorities to form a system to support the financial component of economic security, as well as monitoring the most influential destabilizing processes that affect its dynamics.

It is also advisable to assess the forecast values of the level of financial security for future periods; this allows one to predict a decrease or increase in the indicator and react accordingly. The forecast of the security level is performed using the exponential smoothing in the Statistica program (Figure 5, Table 9).

Model tools for assessing the overall level of financial security qualitatively reflect the situation in the country. According to the forecast level, the overall level of Ukraine's financial security shortly, although slightly, will decrease. Forecasts assume that financial sector security will have a declining impact going forward. However, the forecast is based on past periods and occurs in a stable environment, but does not consider the impact of
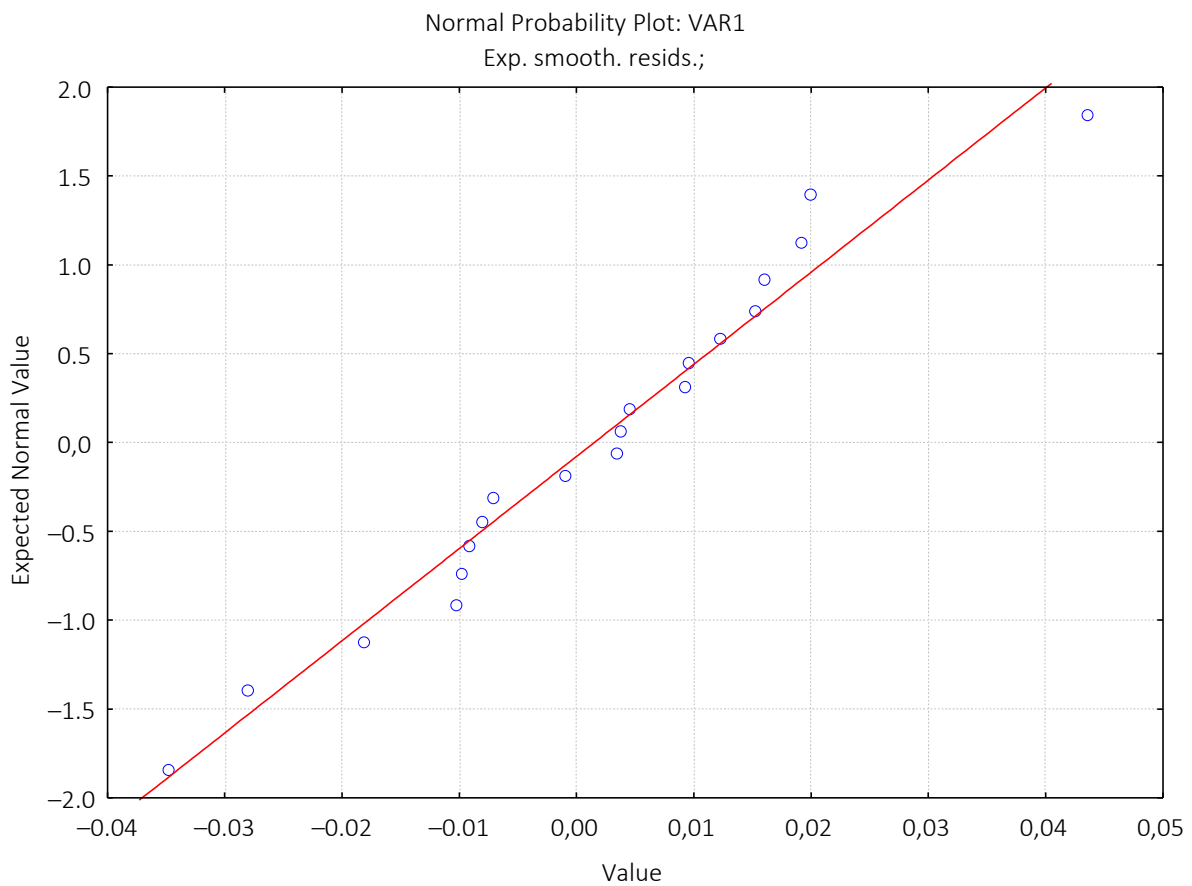
Figure 6. Normal probability plot

Table 9. Indicators of actual and forecast values of the level of Ukraine's financial security

Year	Calculated actual level of financial security	Smoothed series and forecast values
2013	0.12615	0.106187
2014	0.16769	0.124078
2015	0.15334	0.161373
2016	0.12066	0.148697
2017	0.12821	0.118585
2018	0.13798	0.121898
2019	0.14910	0.133345
2020	–	0.146447
2021	–	0.140131
2022	–	0.135492
2023	–	0.133420
2024	–	0.127104

unforeseen collapses, including a new global phenomenon such as COVID-19.

Assumptions about the consistency of observation errors with the normal law will be checked by constructing a normal probability plot of the residuals (Figure 6). If the observational errors agree satisfactorily with the normal law, the dependent variable can be predicted while assigning certain values to independent variables.

The normal probability plot confirms that the data are distributed normally, and the deviation of points from the general trend line is minimal,

confirming the adequacy of the constructed model and the veracity of the forecast. It should be noted that considering the first method, the results are interpreted according to a uniform gradation from 0 to 1 (or from 0% to 100%). In the second method, value fluctuation amplitude is smaller; therefore, a division into five intervals with different numerical segments is proposed, where 20 points are taken at the beginning and end, 17 points at the second and fourth intervals, and 26 numerical points in the middle.

4. DISCUSSION

A comparison of the existing methodology in Ukraine and a non-linear convolution model developed by the authors showed a discrepancy between the results obtained in some periods (Table 10).

Thus, in 2013, the level of financial security in Ukraine, according to the Methodology of the government, is characterized as unsatisfactory (3rd interval), according to the authors' model – low (2nd interval). In 2014, the first method obtained a dangerous level (2nd interval), instead, the second – the average (4th interval). In 2015 – it is unsatisfactory (3rd interval) and sufficient (3rd interval). In 2016 and 2017 – it is unsatisfactory (3rd interval) and low level (2nd interval), respectively; in 2018 – unsatisfactory (3rd interval) and sufficient (3rd interval); in 2019 – dangerous (2nd interval) and sufficient (3rd interval).

Thus, the study showed that the proposed model describes the results better. When analyzing the level of financial security in Ukraine according to the Methodology of the Ministry of Economy, one can see that the country has dangerous and unsatisfactory financial environment. In contrast, according to the multiplicative non-linear convolution model, the level of financial security in Ukraine shows different values following the changes taking place in the country. At the beginning of the analyzed period, the country did not have the best conditions not only for economic activity, but also for all spheres of life and security of the entire population. Political collapses, the Revolution of Dignity (Euromaidan), and the outbreak of war in eastern Ukraine – all this played a role in the overall level of financial security.

In 2014, the reform processes of the banking system significantly affected financial security. First, the National Bank of Ukraine raised the norm of the minimum authorized capital of banks to UAH 500 million. The economy was cleansed of "vacuum cleaner banks" that could not withstand the new requirements. As a result, many insolvent banks left the market, security in the banking market increased, the overall level of financial security in the country increased; therefore, according to the second method, a high level of security was shown this year. Then a gradual adaptation to the new operating conditions begins. However, the country still has risks associated with a number of economic, political, and social problems, so the level of financial security in subsequent periods is characterized as low and medium.

The main drawback of the Methodology from the Ministry of Economy of Ukraine is an outdated list of input indicators. The revision of indicators has not been carried out for eight years, so the results do not reflect the real situation and do not show the necessary change in the processes taking place in the country. What happened at the beginning of the decade cannot be considered relevant today. One of the advantages of using the proposed structural and logical model is that it is

Table 10. Comparison of the results of assessing Ukraine's financial security using two methodologies

Year	The level of Ukraine's financial security, according to the Ministry of Economy's Methodology			The level of Ukraine's financial security according to the multiplicative non-linear convolution model		
2013	[0.0 − 0.2) critical; [0.2 − 0.4) dangerous; [0.4 − 0.6) unsatisfactory; [0.6 − 0.8) satisfactory; [0.8 − 1.0] optimal	0.499	Unsatisfactory	[0.000 − 0.120] critical; (0.120 − 0.137] low; (0.137 − 0.164] sufficient; (0.164 − 0.180] average; (0.180 − 0.200] high	0.126	Low
2014		0.398	Dangerous		0.168	Average
2015		0.429	Unsatisfactory		0.153	Sufficient
2016		0.465	Unsatisfactory		0.121	Low
2017		0.422	Unsatisfactory		0.128	Low
2018		0.445	Unsatisfactory		0.138	Sufficient
2019		0.350	Dangerous		0.149	Sufficient

unique in determining the most suitable predictors (a variation of both their additions and replacements is possible) from the World Bank database, which is recognized as a globally objective think tank. Input indicators can be considered unbiased and reliable. In contrast, according to the state methodology, input indicators are selected from Ukrainian sources (although the Ministry of Economy provides links to official reports, the calculations revealed difficulties in finding data on certain indicators).

The proposed multiplicative non-linear convolution model for assessing a state's financial security is more relevant, includes current indicators sorted by direct and indirect impact, and adjusts them according to the risk of impact on overall security in a country.

CONCLUSION AND STUDY IMPLICATIONS

The paper aims to assess and forecast the level of Ukraine's financial security using two methodological approaches (the existing one and the authors') in order to choose the best practical alternative.

Since it has been proved that there are no alternative approaches to determining the level of financial security in Ukraine, and the current Methodology is a bit outdated, the authors' methodological approach for assessing and predicting the country's financial security was proposed. The developed technique calculates the integrated indicator, which is based on constructing a multiplicative non-linear convolution model of relevant direct and indirect effect indicators. In addition to the quantitative and qualitative distribution of indicators, the evaluation mechanism involves considering their priority and adjusting according to the ratio of opportunity and risk.

Determining the overall level of financial security in Ukraine using the two methodologies allowed one to compare the results. The tested new model better describes the level of financial security and reflects the real situation in a country.

The proposed model can be used to determine not only the level of financial security, but also other security areas of a state, in particular to assess the overall economic security and its individual components: production, energy, demographic, social, foreign economic, etc. This will help solve the problem of an objective assessment, minimize risks, eliminate subjectivity, increase the efficiency, quality, and accuracy of assessing Ukraine's national security.

AUTHOR CONTRIBUTIONS

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APPENDIX A

Table A1. Formulas of a fuzzy-logic approach to assessing indicators in terms of the risk of their impact on the overall level of financial security

Corresponding level interval	Formula
Interval 1: 0% risk and 100% opportunity	$$\min_t k_{pdit}$$
Interval 2: 10% risk and 90% opportunity	$$\left(\min_t k_{pdit}; \min_t k_{pdit} + \frac{\max_t k_{pdit} - \min_t k_{pdit}}{9}\right] = \left(\min_t k_{pdit}; \frac{\max_t k_{pdit} + 8 \cdot \min_t k_{pdit}}{9}\right]$$
Interval 3: 20% risk and 80% opportunity	$$\left(\frac{\max_t k_{pdit} + 8 \cdot \min_t k_{pdit}}{9}; \min_t k_{pdit} + 2 \cdot \frac{\max_t k_{pdit} - \min_t k_{pdit}}{9}\right] =$$ $$\left(\frac{\max_t k_{pdit} + 8 \cdot \min_t k_{pdit}}{9}; \frac{2 \cdot \max_t k_{pdit} + 7 \cdot \min_t k_{pdit}}{9}\right]$$
Interval 4: 30% risk and 70% opportunity	$$\left(\frac{2 \cdot \max_t k_{pdit} + 7 \cdot \min_t k_{pdit}}{9}; \min_t k_{pdit} + 3 \cdot \frac{\max_t k_{pdit} - \min_t k_{pdit}}{9}\right] =$$ $$\left(\frac{2 \cdot \max_t k_{pdit} + 7 \cdot \min_t k_{pdit}}{9}; \frac{3 \cdot \max_t k_{pdit} + 6 \cdot \min_t k_{pdit}}{9}\right]$$
Interval 5: 40% risk and 60% opportunity	$$\left(\frac{3 \cdot \max_t k_{pdit} + 6 \cdot \min_t k_{pdit}}{9}; \min_t k_{pdit} + 4 \cdot \frac{\max_t k_{pdit} - \min_t k_{pdit}}{9}\right] =$$ $$\left(\frac{3 \cdot \max_t k_{pdit} + 6 \cdot \min_t k_{pdit}}{9}; \frac{4 \cdot \max_t k_{pdit} + 5 \cdot \min_t k_{pdit}}{9}\right]$$
Interval 6: 50% risk and 50% opportunity	$$\left(\frac{4 \cdot \max_t k_{pdit} + 5 \cdot \min_t k_{pdit}}{9}; \min_t k_{pdit} + 5 \cdot \frac{\max_t k_{pdit} - \min_t k_{pdit}}{9}\right] =$$ $$\left(\frac{4 \cdot \max_t k_{pdit} + 5 \cdot \min_t k_{pdit}}{9}; \frac{5 \cdot \max_t k_{pdit} + 4 \cdot \min_t k_{pdit}}{9}\right]$$
Interval 7: 60% risk and 40% opportunity	$$\left(\frac{5 \cdot \max_t k_{pdit} + 4 \cdot \min_t k_{pdit}}{9}; \min_t k_{pdit} + 6 \cdot \frac{\max_t k_{pdit} - \min_t k_{pdit}}{9}\right] =$$ $$\left(\frac{5 \cdot \max_t k_{pdit} + 4 \cdot \min_t k_{pdit}}{9}; \frac{6 \cdot \max_t k_{pdit} + 3 \cdot \min_t k_{pdit}}{9}\right]$$
Interval 8: 70% risk and 30% opportunity	$$\left(\frac{6 \cdot \max_t k_{pdit} + 3 \cdot \min_t k_{pdit}}{9}; \min_t k_{pdit} + 7 \cdot \frac{\max_t k_{pdit} - \min_t k_{pdit}}{9}\right] =$$ $$\left(\frac{6 \cdot \max_t k_{pdit} + 3 \cdot \min_t k_{pdit}}{9}; \frac{7 \cdot \max_t k_{pdit} + 2 \cdot \min_t k_{pdit}}{9}\right]$$
Interval 9: 80% risk and 20% opportunity	$$\left(\frac{7 \cdot \max_t k_{pdit} + 2 \cdot \min_t k_{pdit}}{9}; \min_t k_{pdit} + 8 \cdot \frac{\max_t k_{pdit} - \min_t k_{pdit}}{9}\right] =$$ $$\left(\frac{7 \cdot \max_t k_{pdit} + 2 \cdot \min_t k_{pdit}}{9}; \frac{8 \cdot \max_t k_{pdit} + \min_t k_{pdit}}{9}\right]$$

Table A1 (cont.). Formulas of a fuzzy-logic approach to assessing indicators in terms of the risk of their impact on the overall level of financial security

Corresponding level interval	Formula
Interval 10: 90% risk and 10% opportunity	$$\left(\frac{8 \cdot \max\limits_{t} k_{pdit} + \min\limits_{t} k_{pdit}}{9}; \min\limits_{t} k_{pdit} + 9 \cdot \frac{\max\limits_{t} k_{pdit} - \min\limits_{t} k_{pdit}}{9} \right] =$$ $$\left(\frac{8 \cdot \max\limits_{t} k_{pdit} + \min\limits_{t} k_{pdit}}{9}; \max\limits_{t} k_{pdit} \right)$$
Interval 11: 100% risk and 0% opportunity	$$\max\limits_{t} k_{pdit}$$