Model for Assessment of the Financial Security Level of the Enterprise Based on the Desirability Scale

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Abstract. Modern economic realities of Ukraine in the conditions of growing destabilizing influences of external and internal environment convincingly prove that each year the influence of various threats on the level of financial security of economic entities increases. This necessitates constant monitoring of the financial security level in order to timely detect and neutralize possible crisis phenomena as a result of its decrease. The study aims to assess the financial security level of enterprises based on the theory of comprehensive assessment. The scientific and methodical approach to design a composite index of financial security and the identifying its level based on the double use of Harrington's desirability scale is proposed. The resulting model was tested on the particular enterprise data. The proposed approach may be used for another set of partial indicators, as well as in assessing the level of financial security at the national level. The results of the study may serve as the basis for making managerial decisions on raising the business entities financial security level and public administration.

Keywords: financial security, comprehensive assessment, composite index, financial security level, enterprise, desirability scale

1 Introduction

Security is an integral characteristic of the economic system functioning, which ensures its viability, stable development and confrontation with external disturbance. Business activity at macro-, meso-level micro-levels is always subject to various risks and threats, which in a certain way affect the financial and economic results.

The global financial and economic crisis of 2008-2009 had a significant destabilizing effect on the financial and economic system of most world countries. This led to the fall of the stock market, caused the problem of decreasing liquidity and deregulation of financial institutions, reducing business, rising unemployment. For countries with a weak economy, such as Ukraine, this has led to an increase in dependence on the international monetary fund. According to assessments given in [1], as of 2018 85% of countries affected by the crisis still have production below the level that would have been achieved according to forecasted estimates taking into account pre-crisis trends.

Therefore, issues related to the assessment of financial security level of business entities in order to timely identify and neutralize the negative consequences of its reduction are relevant. The solution of this problem is possible through the use of modern cognitive tools, an important element of which is modeling. One of the most common approaches is to assess the level of financial security based on the analysis of a large number of financial and economic indicators by aggregating them into a single comprehensive index. This minimizes the loss of information, allows to get the result in the foreseeable form which convenient for further analysis, use and interpretation. Among the problems that may be solved with its serve, we can identify such as the comparison of objects studied between themselves, the identification of the objects structure, the objects classification under the level of the investigated quality, the identification of the overall quality level, the classification of new objects into a certain structure, determination of the correspondence degree of objects under study to some imaginary "ideal" and identifying the directions of situation improvement.

2   Literature Review

Issues of financial security in context of its study of both an important component of economic security, and an independent attribute of the economic mechanism of business entities, relevant for a long period of time.

Certain aspects of financial security modeling related, in particular, to the assessment of its factors, identification of threats and assessment of risks, diagnostics of the level and identification of the appropriate security class, forecasting of the financial and economic state of business entities, despite a significant number of publications and results, remain in the focus of many researchers. This is due to the complexity and multiple features of the financial security category, the dependence of its state and level on a large number of various indicators, and the high dynamism of the external environment, which is a source of new perturbations and challenges. Paper [2] presents an analysis of approaches to determine the content of the financial security category of business entities, their advantages and disadvantages.

In particular, it is focuses on the fact that key issues in ensuring financial security are the ability to protect own priority financial interests from potential and real threats of internal and external environment, realized through the achievement and maintenance of an appropriate level of financial stability, solvency and liquidity, and ensuring enterprises' financial independence.

Among the problems whose study is most often met, the problem of identifying the level of financial security, assessing and forecasting its state are taken as a special place. Side by side with this there is a task of forming a system of indicators that determine its level and state. The most common approach to solve these problems, which is presented in the scholars' papers, is based on the formation of a comprehensive indicator of financial security.

Investigation of modern issues related to the assessment of financial security on the state level is shown, in particular, in the papers [3, 5-8]. Paper [3] contains calculation of assessment of financial security level of Ukraine according to the Ukrainian

methodology for assessing the economic security [4]. The Ukraine's rating was identified by value of this estimation. Authors also used regression analysis to assess the influence of different factors on the country's financial security level. Based on the calculations, the authors made proposals to improve the methodology for assessing the financial security level aimed at reducing the subjectivity of the evaluation and improving the final result quality. The article [5] also uses the mentioned above methodology for analyzing the dynamics of comprehensive indicators that are components of Ukraine's financial security. The authors identify some of the methodology drawbacks, and propose a set of measures to increase the financial security level of Ukrainian enterprises.

Paper [6] proposed to use Corruption Perceptions Index for assessing financial security level. Paper [7] authors designed a set of models to analyze dynamics of the financial security indicators base on the multidimensional analysis statistical analysis, vector autoregression technologies, error correction models. Calculation and comparison of financial security indexes for Ukraine and some EU countries were made. Financial security subsystems which are most sensitive to the external threats are highlighted. The influence of internationalization and globalization to the financial security assurance on the national level has been studied in the paper [8].

An especially important problem for the development of the country's economy is to assess the financial security level of individual enterprises. In [9], the scoring model for financial security assessment of an enterprise is proposed based on five groups of initial indicators that reflect profitability, solvency, business activity, market stability and investment attractiveness of the business entity. Components of resulting index are calculated by the dynamic rating assessment method. The disadvantage of this approach is that it allows you to determine the financial security level in relation to the importance of this characteristic in the industry average. However, the actual level of financial security is not determined here, which complicates the results interpretation.

Another approach to use rating assessment is presented in [10]. Financial security level is assessed on three classes by the calculation of the weighted scoring estimation using the ratings of initial indicators. In our view, disadvantages this method are certain "artificiality" in the transition from quantitative values of initial indicators to the corresponding ratings, the lack of justification of the value's boundaries for determining the financial security level. This significantly limits the application of this method.

An approach to calculate comprehensive index based on the use of a linear additive convolution of partial composite indices, is become quite widespread [11-14]. In most cases, such indicators reflect certain components of the financial condition of the enterprise. Initial data for the designing partial composite indexes for each group are calculated by matching the corresponding values of the financial conditions' coefficients to their normative values. This approach also provides for definition of the minimum of financial security level of enterprises. Among the disadvantages it should be noted that the composite index goes beyond 0 to 1, which complicates the results interpretation. In addition, the authors determine the financial security level by grading the values of the corresponding composite index, but the boundaries of these levels don't have sufficient justification. Another disadvantage is that the compensation effect influences the definition of the minimal value of financial security level in general,

when the high value of the partial composite index of financial security for one group of initial indicators can overlap the low values for other groups.

Regression models for assessing the of enterprises financial security level are proposed in [15, 16]. They allow to identify the influence of the most significant factors on the final result, which helps to determine the direction of making managerial decisions to increase security. In addition, such models can be used to assess the value of a financial security index in subsequent periods. In our view, such models have a limited application because number of predictors including to the model is limited by the volume of initial data. Furthermore, they don't allow to assess the financial security level.

The results of this review make it advisable to develop an own approach to assessing the enterprises financial security level. It aimed to eliminate the disadvantage inherent in the methods described above, in particular, to reduce the compensation effect from overrun normative values by indicators, as well as to identify and justify the financial security levels.

3   Problem Description and Methodology

To assess the financial security level, we propose an approach also based on the calculation of the composite index. Let's consider the essence and peculiarities of each stage of the proposed approach.

The first stage of its design is the formation of a set of initial characteristics of financial security, $X = \{X_1, X_2, ..., X_m\}$, m – the number of characteristics, each of which in this case is an indicator measured on a metric scale. The number of such indicators, the feasibility of their distribution into groups is determined by the specific objectives of the study. A large number of indicators reduces the impact of each component on the variability of the final result. In addition, the weight coefficients values for the components of the composite index may be statistically insignificant. Instead, too few of them can take into account not all the features of components of financial security.

In the case of a large number of initial indicators, it is expedient to use a sequential convolution procedure in which they are initially grouped according to certain characteristics. At the same time, following conditions are provided for each group:

1. The indicators of each group should reflect one characteristic of the investigated phenomenon.
2. There must be high correlation between the indicators within the group.
3. The correlations between the indicators of different groups must be insignificant.

So, in this case, the correlation matrix of the initial indicators serves to group the initial data.

Another way to group indicators is to combine them using meaningful analysis. Partial composite index is calculated for each group. The final composite index is formed from these partial indexes. This approach is predominantly used in the reviewed above papers [9-14]. It should be noted that second and third requirements described above may not be met.

The formation of a synthetic generalized index for each group can also be done using multidimensional analysis like factor analysis or principal component analysis. These methods are particularly effective when there are high correlations between indicators within the group. Also, their advantage is that they allow to determine the importance (or weight) of each component of group composite index.

Ones more way for processing group of initial indicators is to select from each group the most "informative" indicator using heuristic methods of diminishing the dimension. However, the part of the information is necessarily lost in the final result in this case. In addition, these methods have a high level of subjectivity in determining the appropriate indicators.

Next stage is to shape vector of indicators $\mathbf{q}=\{q_1, q_2, ..., q_n\}$, that are functions from set of initial indicators and aimed on the assessment of separate components of financial security. The vector $\mathbf{q}$ is characterized by the fact that the influence of the measurement units of the initial indicators is removed from it, and it has a direction of positive change its values in accordance with increase of values of it components. A typical situation is when each indicator of the set X somehow transforms to the component of the vector $\mathbf{q}$: $q_i = f(X_i)$, $i=1, 2, …, n$, $m=n$.

Additionally, the components of this vector should meet the normalization condition, that is, its value must be on the interval [0; 1]. It simplifies further analysis of the comprehensive assessment results of financial security.

The choice of the form of a synthesizing function $Q=F(w_1, w_2, ..., w_n, q_1, q_2, ..., q_n)$ is further make. This procedure puts into compliance the vector $\mathbf{q}$ to the corresponding value of composite index Q, which reflects the latent characteristic of the investigated phenomenon, in this case – an assessment of the level of financial security. Aggregation of the vector $\mathbf{q}$ into the composite index is carried out taking into account the vector of some positive parameters $\mathbf{w}=\{w_1, w_2, ..., w_n\}$, which represent the significance of the individual components of the vector $\mathbf{q}$. Usually a standard condition $w_1+w_2+...+w_n=1$ imposed additionally on its components which gives grounds to conclude about the relative importance of each component of the composite index.

In the case of grouping initial indicators, for each group we can use different aggregation procedure depending on the type of initial indicators and the way of their transformation into a $\mathbf{q}$ vector. The most common method is the convolution (additive or multiplicative) and the distance method. There is no reason to argue that using one type of convolution can produce better results than using another one. Usually, the choice of a concrete convolution type is determined by the problems solved, and the values that initial (normalized) data can take. In our study, we propose to use multiplicative convolution. The justification for this choice will be given below.

Last stage is meaningful interpretation of results. It involves establishing a match between the estimated values of the composite index and the financial security level. The identifying the number of levels, their correspondence to certain ranges of the composite index values and the justification of ranges boundaries form a separate non-trivial issue. In our view, the solution of this problem should be based on certain tools, in particular, use of cluster analysis, iterative procedures for calculating index ranges' boundaries, scale of desirability, etc. Last approach is used in our studies.

4 Findings

In the framework of the considered approach to design financial security composite index, according to the analysis of previous studies results [9-15], to form the information base of the study, we propose to select as initial indicators ones that characterize the enterprise financial conditions. In so doing we include to the initial set only those indicators which have known normative values. The basis for further calculations is the assumption that the equality of all indicators to their normative values corresponds to high (proper) level of financial security.

To obtain a vector $\mathbf{q}$, which will serve as the basis for designing an composite index, we use a five-step procedure based on the use of E. Harrington's function $H(Z_i)=\exp(-\exp(-Z_i))$ and its appropriate desirability scale [17], where Z_i is the value of the initial indicator on the scale of partial indices Z. The value of the function $d=H(Z)$ form a desirability scale.

In the first step, it is necessary to establish a correspondence between the values of the scale Z of the E. Harrington's function and the values of the initial index X_i, $i=1, 2, \ldots, n$. Based on the graph of the function $H(Z)$ (Fig. 1), we can conclude that $H(-2)\approx0$, $H(5)\approx1$. Therefore, the effective values range of partial indicators scale is the range $[-2; 5]$.

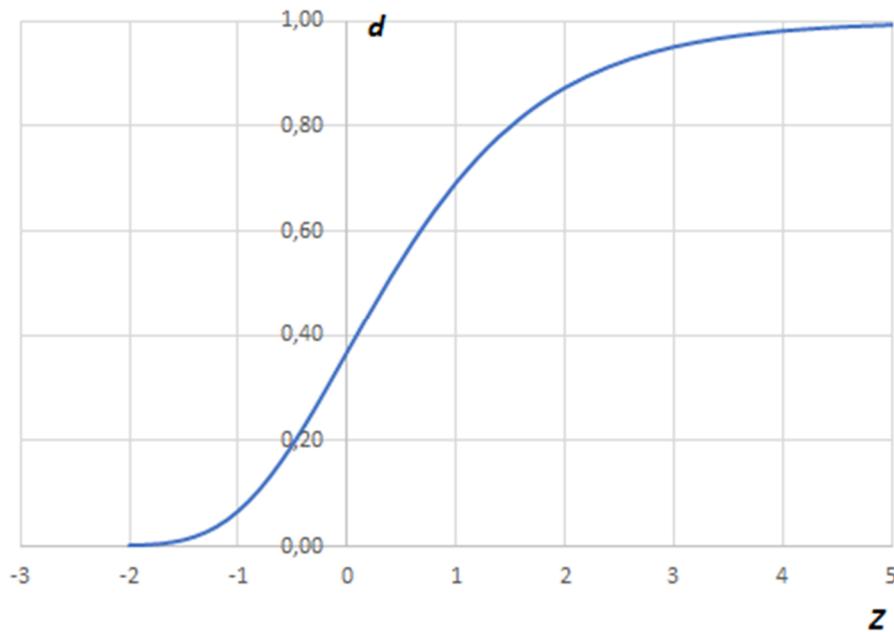
Fig. 1. Harrington function graph.

Let's use this fact, putting the value $Z = Z^* = 5$ in line with the normative value X_i^* of each initial indicator, $i=1, 2, \ldots, n$. This means that at the normative value of the X_i, the

highest value on the desirable scale d is reached. The value X_{i*} of the initial indicator, for which the critical level of desirability $d=0$ is reached, corresponds to the value $Z = Z_* = -2$. Usually $X_{i*} = 0$. So, the coefficient k_i, $i=1, 2, \ldots, n$, for transformation of the values of the indicator X_i to the values of the scale of partial indices Z_i is calculated by the formula:

$$k_i=(Z^*-Z_*)/X_i^*. \tag{1}$$

In the second step, we calculate the value of Z_i, $i=1, 2, \ldots, n$, by the formula:

$$Z_i=k_iX_i+X_{i*} \tag{2}$$

In the third step, we find image d_i of indicator X_i on the desirability scale using corresponding value of the scale of partial indicators Z_i, $i=1, 2, \ldots, n$:

$$d_i=H(Z_i). \tag{3}$$

In the fourth step, we identify the "level" of the indicator X_i, $i=1, 2, \ldots, n$, on the desirability scale in accordance with Table 1 [17].

Table 1. The connection between the quantitative values of the desirability scale and its qualitative levels.

Qualitative expression of desirability	The range of quantitative values on the scale of desirability
Very good	0.80..1.00
Good	0.63..0.80
Satisfactorily	0.37..0.63
Badly	0.20..0.37
Very badly	0.00..0.20

In the fifth step, we calculate the value of indicator q_i as middle of an interval that corresponds to the level of desirability of the indicator X_i:

$$q_i=(d_{2i}+d_{1i})/2 \tag{4}$$

where d_{2i}, d_{1i} are right and left boundaries of desirability scale range, which contains calculates value d_i.

To design composite index Q of the financial security, we propose to use weighted multiplicative convolution:

$$Q = \prod_{i=1}^{n} q_i^{w_i} \tag{5}$$

Such a choice is justified by the fact that it is consistent with the rule of constructing a comprehensive index proposed by E. Harrington [17]. Also, it should be noted that among the values of qi there are no zero ones, which makes it impossible to obtain the zero value of the resulting function Q. Otherwise, the zero values would completely reduce the influence of other indicators on the result.

To identify the financial security level, we again use desirability scale by the determining the range on the scale d which contains value of index Q. In this case, we establish an interpretation of financial security levels in accordance with Table 2.

Table 2. The relationship between the quantitative values of composite index Q and financial security levels.

Qualitative expression of financial security level	The range of quantitative values of the composite index Q
High	0.80..1.00
Normal	0.63..0.80
Satisfactory	0.37..0.63
Critical	0.20..0.37
Crisis	0.00..0.20

In our opinion, presented approach has such advantages.

1. Results don't depend from the simple which is used to assess the financial security level. Transformation of initial indicator values is determined in relation to its normative value, and not in relation to the maximal or the minimal sample values.
2. Calculating the values of the composite index by the proposed algorithm reduces compensation effect, when exceeding the normative value of one indicator will affect deviations from the normative value of another indicator.
3. It allows to establish a reasonable financial security level.

Among the disadvantages it should be noted that not all indicators that characterize the financial condition, have justified normative values. Some indicators have positive features as the characteristics of their dynamic, that usually increase their values during the time.

Let we test the proposed approach under the data of the private joint-stock company "Derazhnia dairy Plant". Initial data for the calculation was provided by annual financial reports for 2016 and 2017 [18].

We selected follow financial indicators for calculations, which presented in the Table 3.

Table 3. The list of initial financial indicators and their normative values.

	Financial indicators	Normative value
X_1	Absolute liquidity ratio	0.2
X_2	Quick liquidity ratio	0.6
X_3	Current liquidity ratio	1.0
X_4	Total solvency ratio	2.0
X_5	The ratio of short-term receivables and payables	1.0
X_6	Autonomy ratio	0.5
X_7	The financial stability ratio	1.0
X_8	The maneuverability of equity ratio	0.7
X_9	The ratio of coverage of inventories and costs	0.8
X_{10}	The financial stability ratio	0.8

Values of indicators calculated using the financial reports are shown in the Table 4.

Table 4. The values of initial data.

Indicator	Indicator's value	
	2016	2017
X_1	0.01	0.01
X_2	0.41	0.27
X_3	1.03	0.93
X_4	1.75	1.58
X_5	0.20	0.14
X_6	0.43	0.37
X_7	0.75	0.58
X_8	-0.16	-0.20
X_9	-0.22	-0.18
X_{10}	0.51	0.40

We use the formulas (1) and (2) to calculate the values of the indices on the Z-scale. Results are shown in Table 5.

Table 5. The values of indicators on Z-scale and d-scales.

Indicator	Indicator's value		Appropriate value on the scale d	
	2016	2017	2016	2017
Z_1	-1.71	-1.75	0.00	0.00
Z_2	2.84	1.13	0.94	0.72
Z_3	5.18	4.51	0.99	0.99
Z_4	4.14	3.52	0.98	0.97
Z_5	-0.61	-1.01	0.16	0.06
Z_6	4.02	3.13	0.98	0.96
Z_7	3.28	2.04	0.96	0.88
Z_8	-3.55	-4.01	0.00	0.00
Z_9	-3.95	-3.62	0.00	0.00
Z_{10}	2.46	1.48	0.92	0.80

In the next step, we find by the formula (3) the values of the indicators on the desirability scale d. The results are also shown in Table 5.

Then we use formula (4) to identify components of the vector **q**. Results are presented in the Table 6.

Considering the initial indicators weights are the same (w_i=0.1, i=1, 2, …, 10), we calculate the value of the composite index Q. As a result, we obtain: Q_{2016}=0.36, Q_{2017}=0.36. According to Table 2, the financial security level of the studied enterprises during the investigated period is identified as critical but close to satisfactory.

We made calculations to assess the financial security level for the same data in accordance with the method presented in [11]. According to it, a quantitative

assessment of this level may be calculated according to the set of indicators identified in this study. As a result, we obtained such estimations of the financial security level: $R_{FS\ 2016} = 0.459$, $R_{FS\ 2017} = 0.363$. At the same time, the minimum required level of financial security, as determined by the paper's author, in this case is 10 (according to the number of initial indicators for which the calculation was made).

Table 6. The values of components of the vector **q**.

Indicator	Indicator's value	
	2016	2017
q_1	0.10	0.10
q_2	0.90	0.72
q_3	0.90	0.90
q_4	0.90	0.90
q_5	0.10	0.10
q_6	0.90	0.90
q_7	0.90	0.90
q_8	0.10	0.10
q_9	0.10	0.10
q_{10}	0.90	0.72

Consequently, we can state that the financial security level assessed significantly deviates from the minimum required level established by this method and can be classified as critical. This result is consistent with what was obtained in our study.

5   Conclusions

Assessing the financial security level is an urgent problem both at the state level and for individual business entities. The conducted studies showed the widespread use of the comprehensive assessment methodology to solve this problem. The article considers an approach to assessing the financial security level of an enterprise by designing a composite index. Its calculation contains four stages. The first stage involves identifying the set of initial indicators that characterize financial security. In the second stage, selected indicators are reduced to a single form by removing the measurement units and transformation into indicators-stimulants. These calculations use the normative values of the selected indicators, the E. Harrington's function and desirability scale. In the third stage, the convolution of obtained new indicators is carried out. Taking into account the procedure of transformation of indicators in the second stage, we proposed and justified the use of convolution in the multiplicative form. The fourth stage is devoted to the interpretation of the result, that is, to identify the financial security level. To do this, we used the desirability scale again. The proposed four-stage procedure, qualitative expression of financial security levels and their appropriate ranges of quantitative values of the composite index Q are the subject of scientific novelty of this study.

Practical testing of the presented approach was carried out according to the data of the private enterprise "Derazhnia dairy Plant" and was compared with the results obtained by another approach. The final conclusions were similar.

The proposed approach doesn't depend on the number of initial indicators and the direction of their positive change. In the case that their number is too large to evaluate the impact of an individual component, the article proposes ways to solve this problem.

The results of the study may serve as the basis for making managerial decisions on raising the business entities financial security level and public administration.

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