FINANCIAL SUSTAINABILITY OF AGRICULTURAL ENTERPRISES: DEVELOPMENT AND APPROVAL OF THE INTEGRATED EVALUATION MODEL

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Abstract. The methodological and practical bases of integrated assessment of the financial condition of an agricultural enterprise are considered in the work. It is emphasized that the integrated method of assessment is the most objective for such an analysis, as it allows you to quantify and evaluate the relationship between the main factors and predict their level in the future. An expert method was used to determine the system of basic relative indicators for assessing the level of financial stability of the enterprise and their ratios. Verification of co-ordination of opinions of experts was conducted by the method of grade correlation with a calculation to the Kendall's coefficient of concordance and determination of statistical importance of opinions of experts on the Pearson criterion χ^2. The normative values of indicators were also adapted in accordance with the specifics of the industry and modern operating conditions. The values of the standards were determined on the basis of the results of financial and economic activities of the most efficient enterprises in the region, selected by the method of rating and scoring. Approbation of the developed model of financial condition assessment was carried out on the basis of financial reporting data of agricultural enterprises of Vinnytsia district for five years. The obtained results of calculations were used to check the presence of multicollinearity of factor features, which allowed to establish linearly dependent groups of relative indicators and to optimize the proposed model accordingly. A detailed econometric analysis of a number of dynamics of the integrated indicator of financial stability over ten years was conducted

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on the example of the most successful agricultural enterprise of Vinnytsia district. Theoretically and practically checked the presence of anomalous levels; the presence of a trend is determined; smoothing and alignment of a number of dynamics is carried out; the trend model is selected and its parameters are calculated; the trend model for adequacy, accuracy and presence of autocorrelation of residues is investigated; point and interval forecasting was carried out.

1. Introduction

System crisis phenomena in an economy of agrarian sector of Ukraine led to deterioration of its socio-economic development, slowing down the production of goods in agricultural enterprises and, as a result, worsening of their financial state. This situation does not contribute to an effective innovation policy, reduces the competitiveness of agricultural products, slows down Ukraine's integration processes into the European and world community. The urgency of improving the financial security of agricultural enterprises in such conditions becomes the most important task of both the state and the business. The search for opportunities to strengthen the financial situation should contribute to a systematic and objective analysis of agricultural enterprises, the results of which allow operatively to react on the change of external and internal environment of business, accept reasonable administrative decisions from the financial adjusting must assist. The criterion for the effectiveness of such decisions is the level of financial stability of economic entities, which assesses the adequacy of financial resources for balanced sustainable development of agricultural enterprises.

Assessment of the financial stability of an agricultural enterprise should be generalized, integrated, and give an unambiguous answer about the level of financial stability of the enterprise. It must accumulate all the main aspects of the operation of the enterprise, that is mean to take into account the importance of the most important indicators of financial and economic activities of economic entities.

In agriculture, unlike other industries, there is a complex system of relationships and dependencies, intertwining of various factors, including natural, related to the biological properties of objects and working conditions. To take into account all these parameters in a mathematical model – it is practically impossible. Therefore, it follows to take into account at development and use of such model, that not all phenomena and factors can be in number expressed, that complicates their plugging in a model.

Than deeper and more detailed analysis is conducted, than more difficult (branched) is the mathematical model, the more chances we have to get around the real reflection of reality of the investigated phenomena, and the higher the practical value of the model of analysis, and in our case – assessment and management of financial stability of agricultural enterprises.

Economic and mathematical modeling of the assessment of financial stability of the enterprise will quantify the relationship between the main factors that determine it and the magnitude of their impact.

The integrated method is objective because it includes any assumptions about the role of factors in the analysis. Unlike other methods of factor analysis, the integral method fulfills the condition of factor independence. Another important feature is that this method gives a general approach to solving problems of various kinds, regardless of the number of elements included in the model of the factor system, and the form of relationships between them.

Due to the numerous shortcomings of the existing methods of determining the level of financial stability of enterprises, the lack of real modern standards, adjusted to the characteristics of agricultural enterprises, the development of such methods is currently quite relevant.

The basis for an integrated assessment of financial stability is a group (or system of groups) of relative indicators that characterize the financial and economic activities of the enterprise. In the scientific literature, foreign and Ukrainian authors offer a significant number of such indicators and methods of their calculation. Therefore, the primary and most important stage of model development is the construction of such a base of indicators, in which the analysis will be reliable and multifaceted, and the number of selected factor characteristics will be optimal and linearly independent. Expert assessment method was used to select a system of basic indicators that meet the above requirements.

2. Expert assessment method

In cases when for some reasons it is impossible to obtain the necessary economic information (information array is limited or absent), it is appropriate to use the methods of expert assessments. They are used in the absence of sufficient and reliable information about the predicted phenomena (processes), as well as in conditions of significant uncertainty of the environment in which the object operates.

The use of expert methods is based on deep knowledge of specialists and the ability to summarize their own and world experience of research and development on a particular problem, the hypothesis of the expert's so-called "practical wisdom", foresight in a particular field of knowledge and practice, the ability to come in the process of certain activities, to assess fairly reliably the importance and significance of research areas, the timing of a particular event, the importance of a parameter, process (phenomenon), etc. [1].

All expert surveys, regardless of the chosen methods of conducting them, are based on the scoring of the objects of research on a given issue and determining their importance. Their main feature is the lack of mathematical confirmation of the optimal conclusions.

Methods based on the use of expert assessments are divided into two groups: individual and collective [1; 2].

Among the known methods of individual expert assessments should be noted the following: control issues; individual brainstorming; interview; script; Delphi method; questionnaire; paired comparisons.

Methods of collective expert evaluation: conference of ideas; brainstorming; "morphological box"; sevenfold search; associations and analogies; Delphi method; collective notebook; control questions; inversions; Pattern.

The division into methods of individual and collective expert assessments is made depending on whether the forecast is developed based on the conclusions of one expert or group of experts.

The main advantages of individual methods of expert assessment are the ability to use the abilities and knowledge of an individual expert, as well as the relative ease of conducting targeted analysis. Their main defect is limit nature of knowledge each of polled about the state and development of contiguous spheres of activity. The advantages of collective methods of expert questioning are: first, that experts agree on an open discussion that allows them to influence each other in such a way as to compensate for each other's mistakes; second, a group of specialists produces more "mental" energy than one specialist; and third, the group of experts is generally more willing to take responsibility for making important, risky decisions. However, these methods have a number of disadvantages:

– the part of the group may have some influence on other members of the group;

– there may be cases when the group thinks that a specialist, such as a great scientist, has a serious influence, and if he has a talent for persuasion, he will be able to decisively implement his ideas through persistent and constant argumentation;

– a thinking sluggishness, “honor of uniform”, convinces certain part of group to incline other members to the acceptance of certain decisions, especially if they were oriented to these decisions from the beginning;

– in groups, as a rule, there is an opinion that reaching an agreement is more important than developing the most reasonable and practically useful forecast [1].

All considered circumstances which are marked higher, as well as the sharp contrast of existing interpretations of the definition and components of financial stability, the only really possible method for research on this topic is the use of individual surveys. Significant shortcomings of collective expert research, as well as doubts about the ability to organize a quality group discussion of real experts in the field make these methods unsuitable for us.

At application of individual methods, from every expert get independent estimations for further them mathematical treatment and acceptance of corresponding decisions. Widespread among them are two methods: interviews and questionnaires. The disadvantage of the interview is that the expert does not have enough time to think about the answers. Therefore, a questionnaire of experts and the use of control questions were used to clarify some important points in the course of this study.

The experts were offered a questionnaire, which included 50 indicators that form the financial stability of the enterprise. The task of the experts was to assess the list of relative indicators proposed in the questionnaire, which characterize the financial stability of agricultural enterprises. The questionnaire provided that experts with a high level of professional knowledge were able to assess the impact of each indicator (factor) on the level of financial stability of economic entities on a ten-point scale.

45 people were involved as experts, including economists of Vinnytsia universities, managers, accountants, employees of analytical and financial departments of a number of agricultural enterprises in Vinnytsia district

and employees of the Main Department of Statistics and the Department of Agriculture in Vinnytsia region.

In the process of practical application of the method, independent estimates were obtained from each expert, which were processed using a mathematical apparatus.

In particular, the method of rank correlation was used to determine the consistency of experts' opinions and the Kendall concordance coefficient was determined [3], which in the absence of related ranks is calculated by the formula:

$$W = \frac{12 \cdot \sum d_i^2}{m^2 \left(n^3 - n\right)}, \tag{2.1}$$

Kendall concordance coefficient with associated ranks:

$$W = \frac{12 \cdot \sum d_i^2}{m^2 \left(n^3 - n\right) - m \cdot B}, \tag{2.2}$$

where, $d_i = \sum R_{ij} - \frac{\sum_j \sum_i R_{ij}}{n}$ (i = 1, 2, …, m) – the sum of ranks R_{ij}, provided by all experts i – element of the sample, minus the average value of these sums of ranks; m – the number of experts; n – the sample size (the number of factors or indicators), $B = \sum_k \left(B_k^3 - B_k\right)$, where B_k – the number of related (identical) ranks, r – the number of groups of related ranks.

The concordance coefficient can range from 0 to 1 and is an indicator of the tightness of the relationship in the case of multiple regression. The greater the value of the concordance coefficient, the higher the degree of agreement of experts. If, W = 1 that is, full agreement of experts' opinions, but when W = 0 – there is almost no agreement.

In our analyzed set of factors (indicators) that affect the financial stability of the enterprise concordance coefficient is W = 0,72 at a significance level of 0.05 (95%). This means that in the results of the expert assessment there is a non-random agreement of experts what gives us the opportunity among the many factors that may to some extent affect the formation of financial stability of agricultural enterprises to identify those that are most important.

The statistical significance of experts' opinions was tested by Pearson's criterion χ^2 [3]. The estimated value of this criterion is obtained by the formula:

$$\chi_r^2 = \frac{12 \cdot \sum d_i^2}{m \cdot n \cdot (n+1) - \frac{1}{n-1} \cdot B}. \quad (2.3)$$

The resulting value is compared with the tabular value χ_t^2 at (n – 1) degrees of freedom and confidence interval 0.95. Under condition $\chi_r^2 < \chi_t^2$ it is assumed that the concordance coefficient is significant, if $\chi_r^2 > \chi_t^2$ then there is a need to increase the number of experts.

In our case, the following values are obtained: $\chi_r^2 = 23{,}14 < \chi_t^2 = 28{,}87$.

This indicates that the concordance coefficient confirms a statistically significant assessment of expert opinions.

Thus, based on the above theoretical analysis of the experiment (questionnaire), taking into account the expert assessments of practitioners in the field of financial stability research, the main factors were identified, without which the assessment of financial stability of agricultural enterprises cannot be considered.

In particular, taking into account the opinions of experts, 19 indicators were selected, which best characterize the financial stability of enterprises in four different areas. That is, based on the results of the expert survey, four subsystems of relative indicators of financial stability were formed (Table 2.1). The table also shows the generally accepted normative values of indicators or the vector of their positive change.

Note that the introduction of methods of integrated assessment of the enterprise is considered in many works of Ukrainian authors [4–20]. At the same time, scientists introduce such concepts as “integrated indicator of the financial condition of the enterprise”, “integrated indicator of the financial potential of the enterprise”, “integrated indicator of anti-crisis potential of the enterprise”, “integrated indicator of enterprise efficiency” and others. A rather diverse set of basic indicators is proposed for their calculation, but arguments for their selection are usually not provided. In particular, evaluating the activity of the machine-building enterprise MOTOR SICH Joint Stock Company (Zaporizhzhia) [4], the author uses 22 financial relative indicators, which are classified into five different groups. However, the article does not provide arguments for the choice of these indicators to calculate the integrated indicator of financial and economic condition of the enterprise.

Table 2.1

Indicators of financial stability of the enterprise

Indicators	Generally accepted standards
I. Degree of financial independence	
1.1 Coefficient of autonomy	> 0,5
1.2 Ratio of own and borrowed funds	> 1
1.3 Rated capital structure ratio	Increasing
1.4 Equity maneuverability ratio	0,4–0,6
1.5 Coefficient of financial stability	> 0,6
II. Liquidity and solvency	
2.1 Coefficient of coverage	> 1
2.2 Current liquidity ratio	> 0,8
2.3 Absolute liquidity ratio (solvency)	0,2–0,35
2.4 The ratio of receivables and payables	> 2
III. Business activity	
3.1 Asset turnover ratio	Increasing
3.2 Mobile funds turnover ratio	Increasing
3.3 Coefficient of circulating of property asset	Increasing
3.4 Coefficient of capital investment	Increasing
3.5 Investment coefficient	0,5–0,7
3.6 Mobility coefficient	Increasing
IV. Profitability	
4.1. Return on assets ratio	Increasing
4.2. Coefficient of profitability of sales	Increasing
4.3. Coefficient of profitability of property asset	Increasing
4.4. Coefficient of profitability of productive capital	Increasing

Quite a thorough analysis of the activities of the industrial enterprise of the State Scientific Production Enterprise «Kommunar Corporation», which specializes in the production of control systems for media and space objects, was conducted in [5]. The overall integrated indicator of the operation of the enterprise was calculated on the basis of partial integrated indicators of the five groups, which included 34 relative indicators. At the same time, such a significant number of model parameters on the one hand significantly deepened the analysis, but on the other hand significantly complicated it. And the share of indicators used was interrelated and showed a sign of multicollinearity. The authors also did not substantiate the system of selected indicators.

In particular, an integrated assessment of the financial and economic condition of agricultural enterprises in the Kherson region for 2014–2018 was conducted in [6]. The authors assessed the performance of these enterprises on the general integrated indicator, based on the analysis of criteria: financial stability, business activity, profitability, liquidity and solvency, bankruptcy and business development. Unfortunately, the paper provides only a thorough analysis of the results of calculations of these indicators and does not provide the method used to calculate them. Such an integrated assessment of the economic security of machine-building enterprises is carried out in [7; 8].

Thus, the introduction of methods of integrated assessment of the enterprise is a very relevant scientific field, which includes a wide variety of approaches, is widely discussed in the modern scientific literature and has the potential for further research.

Note also that the method of calculating integrated indicators involves the use of a matrix of normative values of the system of selected components. Comparison of the actual values of relative indicators with their standards gives a general idea of the financial and economic condition of the enterprise and determines its level in comparison with the standard. The generally accepted values of standards, as a rule, may not always be sufficiently clear to the specifics of the industry, be only partially relevant to today's conditions, or even have no normative value, and determine only the direction (vector) of positive change. Therefore, the next section will focus on the development of an adapted system of normative values of financial stability indicators.

3. Justification of normative values indicators of financial stability

At the present stage of development of Ukraine's economy, in the agro-industrial sector in particular, there is a certain separation of theory from practice, so a very important and necessary step in creating a model of financial stability of the enterprise is a reasonable definition of normative (optimal) values of economic indicators. Such adaptation of standards, in accordance with current conditions, can be carried out on the basis of economic indicators of one or more of the most successful agricultural enterprises in the region. In this case, a necessary condition is to take into account the well-known standards that have long been formed and are in force today.

Agriculture, like no other industry, differs significantly in its specifics, and therefore needs exactly "their" standards. The normative limits of the indicators determined will be real and relevant, as they will be developed on the basis of the actual activity of agricultural enterprises in recent years. There is no doubt that the critical (optimal) limits of the main economic indicators must be constantly updated and adapted to the current dynamic environment.

A fairly simple and common method of ranking companies by level of financial stability is to determine their score rating "by the sum of places" [14]. Having the actual values of relative indicators and their standards (or the direction of optimization) (Table 2.1) it is necessary to determine the place of each enterprise on the relevant indicators (in points), and the maximum score is equal to the total number of analyzed enterprises. Summarizing the places obtained by each enterprise for the last four years, the general ranked rating of the level of financial stability of the researched enterprises of Vinnytsia district was determined.

The advantage of this technique is its ease of use, and the disadvantage is the inaccuracy of the results. However, the definition of such a rating is a necessary prerequisite for the development of relevant regulatory values of financial stability of the enterprise.

Thanks to this approach, the best companies and "outsiders" clearly stood out. A rather large gap in the score of the best and worst company confirmed the adequacy of the analysis.

Evaluating the results of the method of calculating the relative indicators of financial stability with the rating of enterprises, it should be noted that the score does not indicate the level of financial stability of the enterprise, but only allows to formally compare the results of economic entities. Also, this method does not take into account the level of importance of the components of financial stability.

Thus, to determine the standards, we chose the most successful profitable agricultural enterprise, which has long been operating in the agricultural market of Vinnytsia. The actual data of indicators of financial stability of this enterprise for the last five years were taken as a basis and

Table 3.1

Normative values of the system of indicators of financial stability, developed on the basis of test farms

Indicators	Generally accepted standards	Proposed standards
I. Degree of financial independence		
1.1 Coefficient of autonomy $K_1^{(I)}$	> 0,5	0,5–0,8
1.2 Ratio of own and borrowed funds $K_2^{(I)}$	> 1	0,1–0,5
1.3 Rated capital structure ratio $K_3^{(I)}$	Increasing	> 1
1.4 Equity maneuverability ratio $K_4^{(I)}$	0,4–0,6	0,1–0,6
1.5 Coefficient of financial stability $K_5^{(I)}$	> 0,6	> 0,6
II. Liquidity and solvency		
2.1 Coefficient of coverage $K_1^{(II)}$	> 1	> 1
2.2 Current liquidity ratio $K_2^{(II)}$	> 0,8	> 0,7
2.3 Absolute liquidity ratio (solvency) $K_3^{(II)}$	0,2–0,35	0,1–0,35
2.4 The ratio of receivables and payables $K_4^{(II)}$	> 2	1
III. Business activity		
3.1 Asset turnover ratio $K_1^{(III)}$	Increasing	> 0,8
3.2 Mobile funds turnover ratio $K_2^{(III)}$	Increasing	> 1,6
3.3 Coefficient of circulating of property asset $K_3^{(III)}$	Increasing	> 3
3.4 Coefficient of capital investment $K_4^{(III)}$	Increasing	> 3,6
3.5 Investment coefficient $K_5^{(III)}$	0,5–0,7	0,5–0,7
3.6 Mobility coefficient $K_6^{(III)}$	Increasing	> 1,7
IV. Profitability		
4.1. Return on assets ratio $K_1^{(IV)}$	Increasing	> 0,2
4.2. Coefficient of profitability of sales $K_2^{(IV)}$	Increasing	> 0,1
4.3. Coefficient of profitability of property asset $K_3^{(IV)}$	Increasing	> 0,1
4.4. Coefficient of profitability of productive capital $K_4^{(IV)}$	Increasing	> 0,15

their adjustment was carried out during the corresponding comparison with achievements of other enterprises of the district. Thus, the optimal (regulatory) limits of indicators were determined and based on the results of not only one enterprise but a group of the most successful agricultural enterprises in the region. This is the main value of the proposed method of setting standards. The results of the research are given in table 3.1.

4. Integrated indicator of financial stability

Also a necessary step in developing a mathematical model is to determine the level of importance of each group of indicators of financial stability in the formation of the overall result. The weights of each group, which differently characterize the level of financial stability of the enterprise, can also be determined only by expert assessments (due to the instability of economic processes in general and the environment in which enterprises operate, in particular). As a result of expert assessment with the help of questionnaires the following weights of individual groups were obtained: Group I (coefficients of financial independence) – 0.30; Group II (liquidity and solvency ratios) – 0.25; Group III (coefficients of business activity) – 0.24; Group IV (profitability ratios) – 0.21.

Thus, the model for calculating the integrated indicator involves taking into account the weights of the components of financial stability and adjusted critical (regulatory) values of each coefficient of the model. To determine the partial integrated indicators of individual subsystems of financial stability, each coefficient sets the degree of achievement of the regulatory level. To do this, calculate the ratio of the actual value to the normative (Table 3.1). Note also that the ratio of actual and normative values of the coefficients should not exceed one. In the case when such an excess is within the optimal limits (Table 3.1), the coefficient is taken equal to one.

That is:

$$K = \begin{cases} \dfrac{K_f}{K_n}, & if \quad K_f < K_n ; \\ 1, & if \quad K_f = K_n ; \\ \dfrac{K_n}{K_f}, & if \quad K_f > K_n . \end{cases} \qquad (4.1)$$

where K – relative indicator; K_f – the actual value of the relevant indicator; K_n – normative value of the relevant indicator.

The total integrated indicator $\Im$ is calculated by the formula:

$$\Im = \alpha_1 \sum K_i^{(I)} + \alpha_2 \sum K_i^{(II)} + \alpha_3 \sum K_i^{(III)} + \alpha_4 \sum K_i^{(IV)}, \quad (4.2)$$

where α_1, α_2, α_3, α_4 – weights of the first, second, third and fourth groups, respectively; $K_i^{(I)}, K_i^{(II)}, K_i^{(III)}, K_i^{(IV)}$ – relative indicators of the first, second, third and fourth groups, respectively.

It should also be noted that the relative indicators of groups I, III and IV may be negative. This will indicate certain crises in the company, the presence of large losses, a small share of equity, a large share of short-term liabilities, and so on.

The above method of calculating the integrated indicator of financial stability was tested on the basis of financial statements of agricultural enterprises of Vinnytsia region for five years.

Calculations have shown that most of the analyzed enterprises are in critical condition ($\Im < 0.5$), and almost half of them have a negative tendency to reduce the level of financial stability, and in some cases the decline is quite sharp. The main reasons for this negative trend in recent years are the loss of agricultural production (namely – livestock), lack of targeted funding, which leads to a decrease in equity and credit problems.

It should also be noted that only three enterprises in the study sample have a high level of financial stability and in recent years there have been no sharp fluctuations in the integrated indicator and positive dynamics.

The introduction of an integrated indicator according to formula (4.2) makes it possible to conduct a more in-depth economic and statistical analysis in two areas:

1) research on the presence of multicollinearity of relative indicators of the model. The audit is conducted in order to simplify the formula for calculating the integrated indicator of financial stability, due to the elimination of linear components. This analysis involves a significant amount of statistics and will therefore be based on the results of the calculation of relative indicators of financial stability of all surveyed enterprises, including taking into account the dynamics of their change over the past five years;

2) economic and statistical analysis of the time series of the integrated indicator of financial stability. This analysis is based on the actual results of one (test) company for the last 10-15 years and will include the following

stages: study of the presence of abnormal levels and the presence of a trend; leveling and smoothing of a number of dynamics; determination of the corresponding growth curve.

5. Study of the presence of multicollinearity indicators of financial stability

In many applied economic problems it is necessary to establish and evaluate the dependence of one random variable Y on another random variable X or several other random variables $X_1, X_2, \ldots, X_n$.

Two random variables *Y* and *X* can be related by functional dependence (when each value x of a random variable *X* corresponds to one and only one value of a random variable *Y*), statistical dependence (when each value x of a random variable *X* can correspond to several values $y_1, y_2, \ldots, y_k$ of a random variable *Y*) or be completely independent [21].

The functional relationship between economic indicators can be linear (straightforward) or close to linear, and curvilinear or close to a certain curvilinear relationship.

The most common among economic and mathematical models that express the relationship between economic indicators are linear functions, because even nonlinear relationships can be reduced to linear methods of introducing new variables. But a clear functional dependence (linear or curvilinear) is rarely realized, because both are variables X and Y can be influenced by different factors, and some of them can affect both X and Y at the same time. In this case, there is a statistical dependence.

Statistical is the dependence in which a change in one of the quantities causes a change in the distribution of the other. Set the statistical dependence using a correlation table or correlation field [21].

The statistical dependence is manifested in the fact that each value xi of a random variable X can correspond to several (rather than one) values $y_{i1}, y_{i2}, \ldots, y_{in}$ of a random variable *Y*. Then we can talk about the dependence of the average value

$$\overline{y}_{x_i} = \frac{y_{i1} + y_{i2} + \ldots + y_{in}}{n} \qquad (5.1)$$

from x_i, which is functional, given in a tabular way. Thus, $\overline{y}_x = f(x)$ a function that, again, can be linear or close to it or a certain curvilinear or close to it.

The dependence *Y* on *X*, the given equation, $\overline{y}_x = f(x)$ is called the correlation dependence, and the equation is called the regression *Y* on *X*. The line described by this equation is called the regression line *Y* on *X*.

It is known that the degree of correlation depending on two random variables *Y* and *X* is the correlation coefficient

$$\rho(X,Y) = \frac{M(XY) - M(X)\cdot M(Y)}{\sqrt{D(X)\cdot D(Y)}}, \tag{5.2}$$

where *M*(*X*) – mathematical expectation, *D*(*X*) – dispersion.

For arbitrary random variables *X*, *Y*:

$$-1 \le \rho(X,Y) \le 1 . \tag{5.3}$$

If $\rho(X,Y) = \pm 1$, then the values *X*, *Y* – are linearly dependent, if $\rho(X,Y) = 0$, then the values *X*, *Y* – uncorrelated to which belong and independent. If the number $|\rho(X,Y)|$ close to one, then points $(x_1; y_1),(x_2; y_2),...,(x_k; y_k)$ lie almost on a straight line [21].

In the case of studying the dependence of several random variables (compilation of multifactor mathematical models, which corresponds to our case), a matrix of paired correlation coefficients (correlation coefficients of pairs X_i X_j) is considered. It is called the correlation matrix. With the help of this matrix it is possible to estimate the presence of a linear relationship between individual random variables of the studied population. In this case, if the random variables X_1, X_2, …, X_n are explanatory (factor) variables of a certain resultant feature *Y*, and between some of them there is a linear relationship, it is said that in a multifactor model there is multicollinearity. Thus, multicollinearity is the existence of a close linear relationship, or strong correlation, between two or more explanatory variables [3].

The presence of multicollinearity in the evaluation of model parameters can lead to negative consequences that can significantly reduce the practical value of the obtained quantitative characteristics of the relationship or make them inconsistent with the main properties of these estimates and therefore cannot be used in practice. Therefore, the analysis to identify and eliminate multicollinearity is a mandatory step in the development and testing of any multifactor model.

In our case, the proposed integrated indicator of financial stability is a generalization of a set of relative indicators that are to some extent interrelated, and some of them, given the method of their calculation, may have a fairly close linear relationship. Therefore, the practical use of the proposed model involves checking the presence of multicollinearity among the indicators of the model and measures to eliminate it in case of detection. It should also be noted that in order to obtain reliable results, statistical analysis was conducted using financial statements for five years of all agricultural enterprises in Vinnytsia region. This allowed to significantly increase the size of the studied sample.

The study of multicollinearity was performed using a Microsoft Office Excel spreadsheet using the Farrar-Glauber algorithm [3]. To do this, in the first stage, all 19 indicators of the model were standardized according to the formula

$$x_{i_k}^{*} = \frac{x_{i_k} - \overline{x}_k}{\sigma_{x_k}}, \quad (5.4)$$

where m = 19 – number of explanatory variables, the indicators of the model $\left(k = \overline{1,m}\right)$; n – number of surveyed enterprises $\left(i = \overline{1,n}\right)$; $\overline{x}_k$ – arithmetic mean k- th indicator; $\sigma_{x_k}{}^{2}$ – dispersion k-th indicator.

To find the correlation matrix used the formula:

$$r_{xx} = \frac{1}{n}\left(X^{*}\right)^{T} \cdot X^{*}, \quad (5.5)$$

where X^* – matrix of normalized indicators; $(X^*)T$ – matrix transposed to the matrix X^*. Calculations have shown that there is a fairly close linear relationship between certain indicators (the closer the value of the partial correlation coefficients to ± 1, the closer the linear relationship, and vice versa).

But a more general test involves finding the value of the criterion χ^2 :

$$\chi^2 = -\left[h - 1 - \frac{1}{6}\left(2m + 5\right)\right] \cdot ln\left|r_{xx}\right|, \quad (5.6)$$

where $\left|r_{xx}\right|$ – determinant of the correlation matrix r_{xx}.

As calculations have shown the value of the determinant of the correlation matrix of the studied population $r_{xx} = -1.23 \cdot 10^{-17}$ and magnitude $\chi^2_{fact} = 304,95$ The value of this criterion is compared with the table when $\frac{1}{2}m\left(m-1\right)$ degrees of freedom and levels of significance α. If, $\chi^2_{fact} > \chi^2_{tabl}$ then there is multicollinearity in the array of explanatory variables. In our case, the tabular value for the number of degrees of freedom l = 171 and level of significance $\alpha = 0,05, \chi^2_{tabl} = 120.$ Therefore, it was concluded that there is multicollinearity in the proposed model.

After examining the closeness of the relationships between indicators, groups of indicators were identified, between which there is a significant linear relationship:

– 1 group of linear communication: the coefficient of autonomy, the ratio of borrowed and own funds, the coefficient of maneuverability of equity, the coefficient of financial stability;

– 2 group linear relationship: the ratio of receivables and payables and the ratio of investment;

– 3 group linear relationship: asset turnover ratio, equity turnover ratio, mobile assets turnover ratio, return on capital ratio and mobility ratio;

– 4 group linear relationship: return on assets, rate of return on equity, rate of return on production capital.

In order to eliminate multicollinearity, 10 indicators were removed from the proposed model for assessing the level of financial stability, which in turn greatly simplified its appearance and use. The selection of indicators that remained in the model was carried out on the principles of greater general economic significance (content) of coefficients and the maximum exemption from duplication of economic indicators of each other. As a result of selection 9 indicators of model are received (tab. 5.1).

When re-checking for multicollinearity, the calculated value $\chi^2_{fact} = 33,2$ turned out to be an order of magnitude less than the previously broken value. Comparing it with the tabular value of the distribution χ^2 $\left(\chi^2_{tabl} = 49,8\right)$ at the level of significance $\alpha = 0,05$ and the number of degrees of freedom $\frac{1}{2}m\left(m-1\right) = 36$, it was concluded that multicollinearity is not observed in the simplified model of integrated assessment of the level of financial stability.

Thus, after the elimination of multicollinearity, the integrated indicator of financial stability takes the following form:

$$\Im^* = \alpha'_1 \sum K_i^{(I)} + \alpha'_2 \sum K_i^{(II)} + \alpha'_3 \sum K_i^{(III)} + \alpha'_4 \sum K_i^{(IV)}, \qquad (5.7)$$

where $\alpha'_1, \alpha'_2, \alpha'_3, \alpha'_4$ – adjusted weighting factors of the first, second, third and fourth groups, respectively.

Table 5.1

System of indicators of simplified integrated assessment level of financial stability

Indicators	Generally accepted standards	Proposed standards
I. Degree of financial independence		
1.1 Coefficient of autonomy $K_1^{(I)}$	> 0,5	0,5–0,8
1.2 Rated capital structure ratio $K_3^{(I)}$	Increasing	> 1
1.3 Equity maneuverability ratio $K_4^{(I)}$	0,4–0,6	0,1–0,6
II. Liquidity and solvency		
2.1 Current liquidity ratio $K_2^{(II)}$	> 0,8	> 0,7
2.2 Absolute liquidity ratio (solvency) $K_3^{(II)}$	0,2–0,35	0,1–0,35
2.3 The ratio of receivables and payables $K_4^{(II)}$	> 2	1
III. Business activity		
3.1 Asset turnover ratio $K_1^{(III)}$	Increasing	> 0,8
IV. Profitability		
4.1. Return on assets ratio $K_1^{(IV)}$	Increasing	> 0,2
4.2. Coefficient of profitability of sales $K_2^{(IV)}$	Increasing	> 0,1

The recalculation of the level of financial stability of the surveyed enterprises showed that the discrepancy between the results obtained for the simplified and complete model is not significant, it means that the main positions of the ranked number of enterprises in terms of financial stability.

Thus, a simplified model can be used in the rapid analysis of the level of financial stability of enterprises. But for a more detailed and in-depth analysis to determine the main reasons for achieving a certain level of financial stability and for opportunities to develop financial recovery measures, it is necessary to use a complete model that is much more valuable for detailed internal analysis and forecasting factors that shape financial stability.

It should also be noted that considering and testing their own methods of calculating the integrated indicator, the authors of [4–20] did not test the presence of multicollinearity in the set of proposed models. However, as the above analysis shows, this stage should be a mandatory and integral part of the development of any integrated model. It is worth noting the scientific work [7], in which the authors mention the method of principal components, the task of which is to linearly transform the associated factor features into a new set of independent random variables. However, this method was implemented by scientists only to determine the weights of indicators that characterize the components of anti-crisis potential.

The computer implementation of the developed model for assessing the level of financial stability of an agricultural enterprise was carried out on the basis of the Microsoft Office Excel spreadsheet package. The following stages were performed:

1. Preparation of template tables for input and output data.
2. Construction of a mathematical model using the above algorithms for calculating indicators.
3. Input of initial data and output of the obtained results in tabular form.
4. Modification of template tables for in-depth analysis using a complete model of financial stability assessment.

Thus, the developed software template allows a comprehensive assessment of the financial stability of the enterprise; it provides for a sequential transition from one subsystem to another. Each subsystem characterizes a separate aspect of the financial stability of the enterprise. The advantages of using the proposed method of assessing financial stability using economic and mathematical modeling are:

1. Universal character, as it can be used both for external (surface) assessment of the level of financial stability, and for detailed internal analysis, so it is possible to use different users.
2. Flexibility, which means that in each case it can be supplemented by other indicators or, conversely, simplified, which will not change or distort the principles of analysis.
3. Complexity, because the model takes into account all the main components that comprehensively characterize the concept of financial stability of the enterprise. Therefore, it is possible to take into account all the main factors that affect (or may affect) the level of financial stability.

The application of the model of financial stability assessment will allow:

– quantitative and qualitative analysis of individual components of the financial stability of the agricultural enterprise and its overall level, determining the extent of the impact of individual factors on the overall level of financial stability;

– make a conclusion about the level of financial stability, analyzing the degree of remoteness of the overall integrated indicator from the unit (standard);

– visually assess the actual level of each coefficient included in the diagnostic model in relation to its optimal values;

– determining the limits of changes in satisfactory indicators of financial stability (margin of safety), the level of financial stability of the enterprise (because the concept of financial stability may be temporary);

– to compare the enterprises of one branch with each other, in order to determine their rating and expediency of reorganization.

6. Economic and statistical analysis of the time series integrated indicator of financial stability

As known, a number of dynamics is called the sequence of values of a socio-economic indicator for certain periods of time [3]. Statistical assessment of the levels of a number of dynamics allows us to assess the main trends in the indicator for the period under study and to make a forecast for the near future on the basis of growth curves. The necessary stages of the analysis are: checking for abnormal levels; determining the presence of a trend; smoothing and smoothing of a number of dynamics; selection of trend model and calculation of its parameters by the method of least squares; study of the trend model for the adequacy, accuracy and presence of autocorrelation of residues; point and interval forecasting.

A review of the literature showed that according to the stages described above, the statistical study of time series for the integrated indicators proposed by the authors was not conducted. Several scientific studies provided only a visual assessment and formal analysis of changes in the values of the indicator over 5-6 years. It is worth noting the works [8; 12; 19], in which the authors attempted to conduct a correlation-regression analysis of the introduced integrated indicator and the corresponding forecast calculation for next year. However, in [8; 12] the whole analysis and conclusions were based only on four [12] or five [8] values of the time series, which greatly calls into question their practical value and reliability of the forecast. A longer time interval (10 years) for the construction of trend models was used in [19]. The calculations were performed on the basis of the standard function “TREND” of the Microsoft Office Excel spreadsheet package. But no other econometric analysis of the studied time series was conducted by the authors.

In this regard, we consider it appropriate to acquaint the reader in detail with the basic methods and techniques of studying time series. Our further consideration will be focused mainly on the theoretical component of the econometric analysis of a number of dynamics. The result of the practical implementation of the above stages will be presented more concisely using the values of the integrated indicator of financial stability of the test enterprise for 10 years. Detailed data of practical calculations and their visualization can be found in [22]. In the future, the most successful agricultural enterprise of Vinnytsia district will be considered under the test enterprise.

1) Check for abnormal levels of a number of dynamics. It does not need to prove that the studied time series are not deterministic, but random. Therefore, abnormal values may appear among them. Such values may be due to technical errors or errors of the first kind. On the other hand, anomalous values may reflect real economic processes, such as rapid inflation, crises, changes in the vector of financial and economic activities of the enterprise and more; such anomalous values are errors of the second kind.

To detect anomalous levels of the time series $y_1, y_2, \ldots, y_n$ could be used the Irwin Test.

The calculation is carried out according to the formula

$$\lambda_i = \frac{y_i - y_{i-1}}{\sigma_y}, \ i = 1, 2, ..., n, \tag{6.1}$$

Note that in the case when the anomalous level of the time series is caused by an error of the technical order, it is replaced either by the corresponding value of the approximating curve, or the arithmetic mean of two adjacent levels of the series. Therefore, when abnormal levels are detected, the cause of their occurrence must also be determined. Checking for the presence of anomalous values of the above integrated indicator of financial stability of the test enterprise showed the presence of one anomalous level. A more detailed analysis of the work of this enterprise allowed to establish the cause of its occurrence. As it turned out, this year capital investments were made in the form of expanding the main herd of cattle, which is related to the main specialization of the enterprise (breeding cattle). In particular, the increase in the financial stability of the enterprise in the following years convincingly demonstrated the relevance of such a strategic management decision.

2) Methods of studying a number of dynamics for the presence of a trend. If a number of dynamics show a long-term trend of changing economic indicators, then in this case they say that there is a trend. Thus, the trend is understood as a change that determines the general direction of development or the main trend of the time series. That is, the trend is a systematic (not accidental) component of long-term action.

The presence of a trend in the time series is checked by special methods. One of them is the method of series of characters, which is implemented by the following algorithm:

1. For the studied time series determine the sequence of signs based on the conditions

$$\delta_i = \begin{cases} +, & when \quad y_{i+1} - y_i > 0, \\ -, & when \quad y_{i+1} - y_i < 0. \end{cases} \qquad (6.2)$$

in this case, if the adjacent values in the time series are the same, then take one of them.

2. Calculate the number of series $\upsilon(n)$. By series we mean a sequence of consecutive pros or cons, and one plus or one minus is considered a series.

3. Determine the length $l_{max}(n)$ of the longest series.

4. Find the number $l(n)$, that is determined by the following table.

Row length n	n < 26	26 < n < 153	153 < n < 170
Value $l(n)$	5	6	7

5. If at least one of the following two inequalities does not hold, then with a confidence level of 0.95 the hypothesis of no trend is rejected:

$$\begin{cases} \upsilon(n) > \left[\frac{1}{3} \cdot (2n-1) - 1{,}96 \cdot \sqrt{\frac{16n-29}{90}} \right]; \\ l_{max}(n) \le l(n). \end{cases} \qquad (6.3)$$

(Symbol $[a]$ means an integer part of a number a).

As calculations have shown, the first inequality was not fulfilled for the studied series of dynamics, therefore it was concluded that there is a trend of an integrated indicator of financial stability of the test enterprise.

Verification of the presence of a trend in the time series can be performed by other alternative methods, such as the method of checking the differences in the average levels or the Foster-Stewart method. It should be noted at once that the second method, the Foster-Stewart method, is more effective from the point of view of checking the presence of a trend, because it tests not only the mean value but also the variance. Here are the algorithms for implementing these methods.

The idea of the method of checking the differences of the middle levels is as follows:

1. Dynamic series $y_1, y_2, \ldots, y_n$ divide into two approximately equal parts in length n_1 and n_2 $(n_1 + n_2 = n)$;

2. For each of these parts, calculate the average values $\bar{y}_1, \bar{y}_2$ and unbiased variances σ_1^2 and σ_2^2 ;

3. Using Fisher's test F_α we check the homogeneity of the variances of both parts of the series, where

$$F_\alpha = \begin{cases} \dfrac{\sigma_1^2}{\sigma_2^2}, & when \quad \sigma_1^2 > \sigma_2^2; \\ \\ \dfrac{\sigma_2^2}{\sigma_1^2}, & when \quad \sigma_2^2 > \sigma_1^2. \end{cases} \tag{6.4}$$

The level of significance α is 0,1; 0,01 or 0,05. If the calculated value $F_\alpha^{(P)}$ is less than tabular $F_\alpha^{(T)}$, then the hypothesis of equality of variances is accepted and we proceed to check the presence or absence of a trend. If $F_\alpha^{(P)} \geq F_\alpha^{(T)}$, then the hypothesis of equality of variances is rejected and we conclude that this method does not answer the question of the presence or absence of a trend;

4. The hypothesis of no trend is tested using – Student's T Distribution Here

$$t_p = \frac{|\bar{y}_1 - \bar{y}_2|}{\sigma\sqrt{\dfrac{1}{n_1} + \dfrac{1}{n_2}}}, \tag{6.5}$$

where σ – standard deviation of the difference of the means:

$$\sigma = \sqrt{\frac{(n_1 - 1)\sigma_1^2 + (n_2 - 1)\sigma_2^2}{n_1 + n_2 - 2}}\ . \tag{6.6}$$

If at the level of significance *α*, $t_p \le t_\alpha$ (t_α – tabular value), then the hypothesis of no trend is accepted. If $t_p > t_\alpha$, then with probability (1 – *α*) we accept the hypothesis of the existence of a trend.

This method confirmed the previously concluded conclusions that the studied series has a tendency to develop.

Since two different methods of studying the trend of the integrated indicator of financial stability of the enterprise gave the same result, there is no need to use the Foster-Stewart method.

3) Mechanical smoothing of a number of dynamics. As a rule, forecasting of economic processes and phenomena on time series begins with construction of the schedule of a number of the chosen indicator. In order not to affect the forecast by random fluctuations of the series, smoothing and alignment of the series is carried out by various methods, which are divided into mechanical and analytical.

The simplest and most well-known methods of mechanical smoothing are the moving average method, the average growth rate method, the average growth method. These methods are more acceptable when the trend of the time series is close to linear.

Since the dynamics of a number of integrated indicators of financial stability of the test enterprise tends to increase first and then to saturation, it is advisable to use analytical curvilinear smoothing. For this purpose, the method of exponential smoothing was chosen, the essence of which is as follows.

If for a given dynamic series $y_1, y_2, \ldots, y_n$ the corresponding smoothed levels are denoted by S_i, $i = 1, 2, ..., n$, then at exponential smoothing their values are calculated by the formula:

$$S_i = \alpha\, y_i + (1 - \alpha)\, S_{i-1}, \tag{6.7}$$

where *α* – smoothing parameter, (1 – *α*) – discount rate. It is easy to show that

$$S_i = \alpha \sum (1-\alpha)^k\, y_{i-k} + (1-\alpha)^i\, S_0\,, \tag{6.8}$$

this means that S_i it is the weighted average of all previous levels.

It is recommended to choose when processing economic time series $\alpha \in [0{,}1; 0{,}3]$. In particular, the initial value S_0 accept or $S_0 = y_1$, or $S_0 = \frac{y_1 + y_2 + y_3}{3}$.

The advantage of this method in comparison with, for example, the moving average method is that during its use the first and last values of a series of dynamics are not lost. This is a very important argument in the study of small time series. Note also that the above technique was used in [22] for mechanical smoothing of the time series, which characterizes the integrated indicator of financial stability of the test enterprise, with the parameter.

4) Selection of the growth curve and calculation of its parameters. Growth curve models are typically used for economic forecasting. The set of analytical methods is to select a specific growth curve and determine its parameters. The growth curve is understood as a function that approximates this series of dynamics. The general stages of the forecast using growth curves are: the choice of the curve, the shape of which corresponds to the dynamics of the time series; finding the parameters of the selected curve; checking the curve for accuracy and adequacy of the studied process; calculation of point and interval forecasts.

Growth curves are usually selected from three classes of functions. The first class includes curves that are used to describe processes with monotonous development and no growth limits.

The second class includes curves that have a growth limit in the study period. Such curves are called saturation curves. If the saturation curves have an inflection point, they are referred to the third class. They are called S-shaped curves.

The integrated indicator of financial stability derived by us tends to saturate in its content. Therefore, the growth curve of this indicator can be taken as a curve of the type of Gompertz function, a logistic curve of the type of Pearl Reed function or a modified exponent.

Therefore, it is expedient to look for a model curve of growth of an indicator of financial stability of the test enterprise in the form:

$$\Im = \frac{1}{1 + a \cdot b^t}, \quad a > 0, \quad 0 < b < 1. \qquad (6.9)$$

Parameters a and b, of which were found by the method of least squares after the conversion of the above equation to a linear form [22]:

$$\tilde{\Im} = \frac{1}{1 + 1{,}143 \cdot (0{,}877)^t} .$$

5) Assessment of the trend model for adequacy. The next stage of the analysis is the assessment of the obtained trend model for adequacy. That is, it is necessary to find out how correctly it reflects the studied economic process. This requirement is equivalent to the fact that the sequence of residues must have random fluctuations with a normal distribution law, zero mathematical expectations and the independence of their levels.

To study the randomness of deviations between theoretical and empirical values, we use one of such methods as the series method. This method uses a concept such as the median of the sample and is reduced to the following stages.

First, a number of residues u_i are ranked in ascending or descending order and the median is found $u_{me} = u_{(n+1)/2}$, when n – odd or $u_{me} = \frac{u_{n/2} + u_{(n/2)+1}}{2}$, when n – even. Then compare the initial series of residues with the median u_{me}. If at the same time $u_i > u_{me}$, then we put a sign "+"; if $u_i < u_{me}$, then we put a sign "–"; if $u_i = u_{me}$, then the value u_i is not taken into account.

The sequence of plus and minus that go in a row is called a series. If V – total number of series, and $k_{\max}$ – the number of members of the longest series, then for the 5% level of significance we check the simultaneous implementation of the following two inequalities:

$$k_{\max} < \left[\ 3{,}3 \cdot \left(\lg n + 1\right)\ \right]; \qquad (6.10)$$

$$V > \left[\ \frac{1}{2} \cdot \left(n + 1 - 1{,}96 \cdot \sqrt{n-1}\right)\ \right], \qquad (6.11)$$

If at least one of the inequalities is not satisfied, then the hypothesis of randomness of the remnants of the time series is rejected and, therefore, the trend model is not adequate.

Calculations have shown that for the studied time series of the integrated indicator, both inequalities are satisfied, so it was concluded that the proposed trend model is adequate.

This result was also confirmed using the pivot point method. The idea of the method is as follows. A point u_i g is called turning point if, $u_{i-1} < u_i > u_{i+1}$ or $u_{i-1} > u_i < u_{i+1}$.

If Π – total number of turning points, $\overline{\Pi}$ – their mathematical expectation, σ_{Π}^{2} – their variance, where in case of random sampling of residues

$$\overline{\Pi} = \frac{2}{3}(n-2)\,; \tag{6.12}$$

$$\sigma_{\Pi}^{2} = \frac{(16n-29)}{90}\,, \tag{6.13}$$

then 5% of the significance of inequality

$$\Pi > \left[\overline{\Pi} - 1{,}96\sqrt{\sigma_{\Pi}^{2}}\,\right], \tag{6.14}$$

means that the trend model is adequate.

In practice, it is not always possible to immediately build a sufficiently high-quality forecasting model, so the stages of building trend models of economic dynamics can be performed repeatedly.

6) Check the presence of autocorrelation of residues. If the type of the trend function is chosen unsuccessfully, then the sequence of values of the residual series $u_1, u_2, ..., u_i$ may not have the property of independence. In this case, they say that there is an autocorrelation of errors.

The most common method of checking the presence of autocorrelation of residues is the Darbin-Watson test (DW):

$$d = DW = \frac{\sum_{i=2}^{n}(u_i - u_{i-1})^2}{\sum_{i=1}^{n} u_i^2}\,, \tag{6.15}$$

which can take values from the interval [0; 4]. (This criterion is sometimes called *d*-statistics).

If the residuals u_i are random variables normally distributed rather than auto correlated, then the DW values are near 2. With a positive autocorrelation of DW < 2, and with a negative DW > 2. For a given level of significance α, the number of observations n and the number of independent variables m in the table is the lower limit of DW_1 criterion and the upper limit of DW_2.

If $DW_{fact.} < DW_1$, the residues have a positive autocorrelation. When $DW_{fact.} > DW_2$, we accept the hypothesis of no autocorrelation.

When $DW_1 < DW > DW_2$, then specific conclusions cannot be made and further research is needed, increasing the set of observations. It is worth noting that the DW criterion is intended for small samples, which is important because the time series of the dynamics of economic phenomena are usually short.

You can also show the relationship between the autocorrelation coefficient ρ between adjacent residual members of the series and the DW criterion. Namely: if $\rho = 1$, then DW = 0; if $\rho = 0$, then DW = 2; if $\rho = -1$, then DW = 4. These ratios show that there are areas in which the Darbin-Watson test does not provide a specific answer about autocorrelation. The upper and lower limits of the DW criterion define the limits of this area for different sample sizes, a given level of significance, and a given number of explanatory variables.

Note that when $DW_{fact} > 2$, then we are talking about negative autocorrelation ($\rho < 0$). And since the critical values of the DW criterion are tabulated only for the case of positive autocorrelation, to draw a conclusion about the negative autocorrelation, it is necessary to compare with the critical value of the DW criterion is not calculated DW_{fact}, and number $4 - DW_{fact}$.

For the indicator of financial stability $DW \approx 1{,}98$ we are considering, therefore, it was concluded that there is no autocorrelation of balances.

The magnitude of the deviations of the values of the levels of the series on the growth curve from the actual level also characterizes the accuracy of the trend model. To do this, it is necessary to calculate such statistical indicators as the standard deviation, σ, the mean relative error of the approximation, δ, the coefficient of convergence φ^2, the coefficient of determination R^2. The method of their calculation and the obtained actual values for the studied integrated indicator of financial stability of the test enterprise are given in [22]. Note also that these indicators allow you to choose from several alternative trend models the most accurate. In particular, the logistics curve turned out to be the most accurate for the introduced integrated indicator.

7) Forecasting the level of financial stability. The study of trend models of the dynamics of economic processes, as a rule, is carried out in order to predict the studied phenomena. Forecasting the time series is based on the method of extrapolation, the transfer of trends in the past to the future.

The application of the extrapolation method, using growth curves, is based on the following two assumptions: the time series does have a trend; the trend identified in the past will not change significantly in the future.

The forecast according to the trend model has two components: point and interval [21].

Point forecast is a numerical characteristic of the predicted process, which is determined by one number. It is obtained when in the equation of the trend model instead of time t we substitute the period of bias (predicted period) $t = n + 1, n + 2, \ldots, n + \tau$. The length of the forecast period cannot be large and depends on the specifics of the forecast object, the time of its operation, the intensity of growth, the duration of the identified trends and patterns. In particular, the point forecast of the integrated indicator of financial condition, with a step of one year was carried out in [8; 12; 19]. Although, as noted above, the authors relied on a rather small time series (4-5 values) and did not conduct a general econometric analysis.

Interval forecast is a numerical characteristic, which is determined by two numbers – the ends of the interval, in which with a certain probability (confidence) should expect the appearance of the actual value of the projected economic and statistical indicator. From the economic point of view, the establishment of mathematically sound boundaries, gives an idea of the likely scenarios for the development of the phenomenon in the future, from the most possible pessimistic level to the most possible optimistic level. This approach is very important for the development of strategies for financial and economic activities of the enterprise. Unfortunately, a review of the literature has shown that the calculation of the interval forecast of the level of financial stability, the authors usually do not perform.

Finding the limits of confidence intervals in forecasting using growth curves is based on regression theory. These limits depend on the standard error of the forecast, the bias period, the number of time series levels and the significance level.

Here is an explanation of the use of general methods of interval forecasting in the time series $(y_1, y_2, \ldots, y_n)$.

At the beginning it is necessary to determine the standard error $S_{\tilde{y}}$ of estimation of the forecasted indicator (y) by the formula:

$$S_{\tilde{y}} = \sqrt{\frac{\sum_{i=1}^{n}\left(y_i - \tilde{y}_i\right)^2}{n-m}}\,. \qquad (6.16)$$

In the case of a straight-line trend, the confidence interval for y_p is:

$$y_p \in \left(\tilde{y}_{n+\tau} - S_{\tilde{y}} \cdot K \;;\; \tilde{y}_{n+\tau} - S_{\tilde{y}} \cdot K \right), \qquad (6.17)$$

where τ – period of prejudice; $\tilde{y}_{n+\tau}$ – point forecast according to the linear model on (n + τ)-period of time; $S_{\tilde{y}}$ – standard error in which m = 2;

$$K = t_{\alpha} \cdot \sqrt{1 + \frac{1}{n} + \frac{3 \cdot (n + 2\tau - 1)^2}{n(n^2 - 1)}};$$

t_{α} – tabular value of the Student's criterion at the level of significance α.

To calculate the confidence interval of the forecast in the case of a straight-line trend, you can use the following formula:

$$y_p = \tilde{y}_{n+\tau} \pm t_{\alpha} \cdot S_{\tilde{y}} \cdot \sqrt{1 + \frac{1}{n} + \frac{(t_{\tau} - \bar{t})^2}{\sum (t_{\tau} - \bar{t})^2}}, \quad (6.18)$$

where t – serial number of the row level $(t = 1, 2, ..., n)$; summation is conducted for all observations; t_{τ} corresponds to the (n + τ)-th period of time, for which we make a forecast; $\bar{t}$ – the time corresponding to the middle of the observation period for the original series.

If the beginning of the countdown is moved to the middle of the observation period,, $\bar{t} = 0$, then

$$y_{np} = \tilde{y}_{n+\tau} \pm t_{\alpha} \cdot S_{\tilde{y}} \cdot \sqrt{1 + \frac{1}{n} + \frac{t_{\tau}^2}{\sum t^2}}, \quad (6.19)$$

Similarly, confidence intervals can be found in the case of other growth curves that have a horizontal asymptote. In particular, for the logistics curve of the integrated indicator of financial stability introduced by us earlier

$$\Im = \frac{1}{1 + a \cdot b^t},$$

analysis involves reducing its appearance to linear $Y = B \cdot t + A$ by logarithm and further calculation of the confidence interval for the case of a linear trend in the new coordinates. The inverse transformation made it possible to determine the interval forecast of the integrated indicator of financial stability of the test economy with a confidence level of 0.95 [22]:

$$\tilde{\Im}_{np} = (0{,}663;\ 0{,}874).$$

Thus, the obtained interval value of the forecast level of financial stability indicates the existing potential in the test company to increase it (to 0.875), which is an optimistic scenario. However, there is also a pessimistic direction of a slight decrease in the value of the integrated