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SIMULATION MODELING OF THE FINANCIAL RISK OF BANKRUPTCY OF AGRICULTURAL ENTERPRISES IN THE CONTEXT OF COVID-19

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Abstract

Severe restrictions on the operation of logistics chains for the supply of raw materials, equipment needed for the smooth and efficient operation of agricultural enterprises and difficulties in the sale of agricultural products caused by the COVID-19 pandemic threaten the economic stability of these entities and could lead to their bankruptcy. In this regard, it is important to systematically monitor the actual financial and economic results of agricultural enterprises, their forecasting, and taking into account the negative impact of environmental factors and the adaptation of production processes to new realities. At the same time, in the context of the frequent absence of the full amount of information necessary for making managerial decisions, this forecast should compensate for its insufficiency by imitating vectors of possible options for the functioning of agricultural enterprises. Given the above, the purpose of the study is to develop a simulation economic and mathematical model for assessing the financial risk of bankruptcy of agricultural enterprises.

In the course of the study, simulation modeling was used - to develop a model for assessing the financial risk of bankruptcy of agricultural enterprises and predicting the financial condition of business entities, taking into account the action of external environmental factors; abstract-logical method - for the implementation of theoretical generalizations to determine the algorithm for constructing a simulation economic and mathematical matrix for assessing the financial risk of bankruptcy of agricultural enterprises; and graphic method - for a visual representation of the architectonics of the process of economic and mathematical modeling of the probability of bankruptcy of agricultural enterprises.

In the article, an algorithm for calculating a simulation model adapted to the rapidly changing conditions of the environment of agricultural enterprises is developed. The proposed simulation model helps to obtain realistic results of assessing the financial risk of bankruptcy of agricultural enterprises due to its adaptive properties, which take into account the dynamics of future changes in financial performance of economic entities. In addition, the repeated implementation of simulation replications fully compensates for the lack of full information needed to make management decisions. In this regard, the study substantiates the advantages of using simulation as one of the most promising and accurate tools for constructing an average vector for forecasting the development of agricultural enterprises, which, in turn, will objectively assess the likelihood of their bankruptcy in the future.

The practical significance of this model is to enable managers to prevent in advance the onset of crises in

agricultural enterprises in future periods of time and to quickly develop appropriate measures to respond to the projected results of this modeling.

Key words: *Bankruptcy, Risk, Financial stability, Imitation replications, Model.*

1. Introduction

The COVID-19 pandemic has made significant adjustments to the functioning of enterprises in almost all sectors of the economy, including the agricultural sector. Thus, significant restrictions on internal and cross-border movements entailed a disruption in the supply chains of raw materials, materials, equipment necessary for the smooth and efficient operation of agricultural enterprises, and also led to the loss of a significant number of markets for agricultural products. It is worth noting that the inability to supply the markets and sell their goods in full by agricultural enterprises for a long time threatens not only the economic stability of these enterprises, but also the food security of many countries of the world as a whole. This situation requires on the part of public authorities to take prompt action to ensure the smooth functioning of supply chains of agricultural products to consumers. At the same time, on the part of company managers, systematic monitoring of the actual financial and economic results of the activities of agricultural enterprises, their forecasting taking into account the negative impact of environmental factors and the adaptation of production processes to the new realities caused by the COVID-19 pandemic is necessary.

The deterioration of the conditions for the functioning of agricultural enterprises leads to an inevitable decrease in the planned volumes of income, the level of liquidity of assets and, as a result, threatens with bankruptcy and termination of the activities of these economic entities. In this regard, an urgent task for managers is to assess the likelihood of bankruptcy of agricultural entities in the near future to develop appropriate measures to respond quickly and stabilize the situation of agricultural enterprises. At the same time, in the frequent absence of the full amount of information needed to make management decisions, this assessment should compensate for its inadequacy by simulating vectors of potential options for the functioning of agricultural enterprises, which, in turn, can be provided by using simulation economic and mathematical modeling.

The scientific works of many scientists are devoted to the study of methods for assessing the risk of bankruptcy at enterprises of various sectors of the economy. Thus, Kang *et al*., [1], considered the bankruptcy of enterprises as an effective mechanism for restructuring existing assets and debt and forecasting the moment of promotion of "strategic bankruptcy" of the entity's exit from the state of real bankruptcy and continued operation as an independent organization. Davalos *et al*., [2], and Almaskati *et al*., [3], analyzed the most common mathematical models for predicting the bankruptcy of enterprises and concluded that increasing their efficiency in the case of non-parametric valuation methods. In this case, the addition to the model of a variable that reflects the level of corporate management in the studied entity will contribute to a high level of accuracy in the calculations. Le *et al.,* [4], developed a model of machine learning for early diagnosis of bankruptcy in agro-industrial enterprises. Blaszczyk and Blaszczyk, [5], proposed to use the method of least squares to assess the risk of bankruptcy of agricultural enterprises in Poland. In articles by Asadi and Shahrabi, [6], and Uthayakumar *et al*., [7], it is proposed an optimization model of qualitative and quantitative analysis of corporate bankruptcy risks based on the use of Ant Colony Optimization. Dhawan *et al.,* [8], and Ricca *et al.,* [9], investigated the nature of the relationship between corporate tax evasion and the level of bankruptcy risk for them and based on mathematical modeling determined a directly proportional relationship between these characteristics. Muhammad, [10], identified the advantages and disadvantages of using Altman's Z-score model in the process of forecasting the financial risk of bankruptcy of agro-industrial enterprises. The articles by Jardin, [11, 12], considered the methods of intellectual analysis of financial data used to filter the necessary information for bankruptcy prediction. Park and Hancer, [13], identified the advantages of using neural networks compared to the logit model to determine the risks of bankruptcy in the hotel business. Martin *et al.,* [14], classified existing quantitative methods of bankruptcy prediction, which use non-financial parameters. Iturriaga and Sanz*,* [15], developed a model of neural networks to reflect the possibility of bankruptcy 3 years before the financial crisis in the studied bank. Tsai and Cheng, [16], carried out a comparative analysis of the most common methods of bankruptcy prediction (neural networks, decision trees, logistic regression, auxiliary vector machines) and identified the benefits of their use depending on the specifics of a particular enterprise. The research of Boratyńska and Grzegorzewska, [17], is devoted to the formulation of the approach of asymmetric and critical thinking to the assessment of the probability of financial crisis in the enterprise with subsequent bankruptcy.

In the articles of Armeanu and Cioaca, [18], and Armeanu *et al*., [19], using cluster analysis, Altman's model, analysis of the main economic indicators of the functioning of business entities, enterprises listed on the Bucharest Stock Exchange are grouped into 3 groups according to the level of financial risk of bankruptcy; and based on the data obtained, a forecast of their further economic development are developed. In the scientific work of Agustia *et al.*, [20], based on financial statements of 1,068 enterprises listed on the Indonesian Stock Exchange, the impact of income management and business strategies on the level of financial risk of their bankruptcy was analyzed and it was found that the effectiveness of income management did not affect the possibility of bankruptcy while the effectiveness of business strategy had a direct impact. However, at the same time, income management is one of the key parameters for external investors and lenders to assess the possibility of financing the studied enterprises. Erol *et al.*, [21], and Laperche *et al.*, [22], considered theoretical approaches to taking certain financial measures and developing innovative strategies aimed at avoiding bankruptcy of enterprises in various sectors of the economy in the global economic crisis, and conducted a survey among managers of research enterprises on the effectiveness of these measures. Mai *et al.*, [23], tested the use of US mathematical model of deep learning with the disclosure of textual information to predict the bankruptcy of industrial enterprises. Darrat *et al.*, [24], investigated the nature of the relationship between the effectiveness of corporate governance and the financial risk of bankruptcy of enterprises depending on the specifics of their internal structure and external operating conditions. In the work of Martins, [25], the approach to optimization of mathematical modeling of an estimation of probability of bankruptcy of the enterprises in the course of financial planning of activity of the company in the conditions of realization of measures of anti-crisis management is offered. Achim *et al.*, [26], developed a statistical model for diagnosing bankruptcy, adapted to the conditions of operation of enterprises of various sectors of the economy in Romania in the global economic crisis, tested it during 2000 - 2011 and formulated recommendations for its effective use. In the scientific works of [27 - 43] methods and tools for mathematical modeling of various phenomena or trends are used, which should be adapted within the framework of our study to model the financial risk of bankruptcy of agricultural enterprises in the context of COVID-19.

Paying tribute to the above scientific work, it should be noted the need for further research aimed at optimizing the process of determining the probability of bankruptcy of economic entities, taking into account the limitations of operation due to the pandemic COVID-19. In this regard, the purpose of the article is to develop a simulation model for assessing the financial risk of bankruptcy of agricultural enterprises.

2. Materials and Methods

The dynamic functioning of national economic systems and the presence of a set of exogenous and endogenous factors, characterized by a lack of static strength and nature of their impact on agricultural development, necessitate the development of flexible simulation economic and mathematical models to assess the probability of their bankruptcy in the future. In this case, these models must have a universal structure and quickly adapt to rapidly changing environmental conditions. Since the difficulty of forecasting the future financial condition of the surveyed agricultural enterprises is determined by the lack of information on the nature of qualitative and quantitative changes that will occur in the next period, it is possible to ensure realistic results of financial risk assessment only by developing models with adaptive properties. These simulation models in the process of assessing the financial performance of agricultural enterprises are able to take into account the dynamics of their future changes. In this case, the repeated implementation of simulation replications can fully replace the lack of full information needed to make management decisions. We believe that simulation is one of the most promising and accurate tools to build an average vector for forecasting the further development of agricultural enterprises, which will assess the likelihood of bankruptcy in the future.

3. Results and Discussion

Given the severe constraints on the logistics chains of agricultural enterprises caused by the COVID-19 pandemic, the success of these businesses is directly dependent on the level of their financial stability not only at a particular time, but also in future periods. In this case, determining the level of financial risk of possible bankruptcy of agricultural enterprises should be done by building a simulation economic and mathematical model, which should objectively reflect possible future changes in the strength and nature of the impact on the performance of environmental factors. In addition, simulation will predict the behavior of the studied agricultural enterprises depending on these changes. That is, the essence of the proposed model is to form a realistic scenario of a possible vector for the development of the modeled process.

Let us consider in detail the algorithm of calculations in the simulation economic and mathematical model for assessing the financial risk of bankruptcy of agricultural enterprises. Thus, the definition of the level of bankruptcy risk is reflected in the formula (1):

$$R^b_{t_{i+1}}(C_x) = \frac{\sum_{n=1}^{Q} I^n_{t_{i+1}}(c_x(t_{i+1}))}{Q}, x = 1,2,3,4;\ i = 1,2,3,\dots k;\ n = 1,2,3\dots Q. \quad (1)$$

Where: $R^b_{t_{i+1}}$ is a projected financial risk of bankruptcy in the time period t_{i+1}, calculated on the basis of the results of a certain set of simulation replications (Q) of one of the ratios for determining the solvency (c_x) of the studied agricultural enterprise, and $I^n_{t_{i+1}}$ is an indicator variable.

$I^n_{t_{i+1}}$ is an indicator variable, which reflects the probability of deviation of the indicators of the *x*-th coefficient of solvency (c_x) from the established limit restrictions (C^{st}_x) as a result of the n-th order of simulation replication in the time period t_{i+1} (2):

$$I^n_{t_{i+1}}(C_x(t_{i+1})) = \begin{cases} 0, if\ c_x(t_{i+1}) > c^{st}_x(t_i) \\ 1, if\ c_x(t_{i+1}) \leq c^{st}_x(t_i) \end{cases} \quad (2)$$

In a simplified form, the simulation of the solvency ratios (C_x) is reflected in the formula (3):

$$c_x\ (t_{i+1}) = E_{t_i} * \ v_{t_i}$$
$$E_{t_i} = f\ (E_{t_{i+1}};\ v_{t_i};\ c_x(t_i);\ \delta\ ) \quad (3)$$

Where: E_{t_i} is an indicator of estimation of weight indices of the model in the current period of time (t_i); $E_{t_{i+1}}$ is a projected indicator of estimation of weight indices of the model in the future period of time (t_{i+1}); $c_x(t_i)$ is the value of the *x*-th solvency ratio explores my agricultural enterprise in the current period of time (t_i); v_{t_i} is a vector of a set of independent variables in the current period of time (t_i); and δ is a certain external factor influencing the financial stability of the agricultural enterprise in the future (t_{i+1}).

It should be noted that c_x is one of the four ratios for determining the solvency of the studied agricultural enterprise, which have a mutual influence on the results of each other's calculations, namely (4 - 7):

$$c_1 = A_c * D_s^{-1} \Rightarrow A_c = c_1 * \ D_s, \quad (4)$$

Where: c_1 is a current liquidity ratio; A_c is current assets of the studied agricultural enterprise; and D_s is a short-term debt of the investigated agricultural enterprise.

$$c_2 = A_c^{-1} * (C_{ow} - A_{nc}) = (c_1 * \ D_s)^{-1} * \ (C_{ow} - A_{nc}), \quad (5)$$

Where: c_2 is the ratio of the provision of an agricultural enterprise with its own current assets; C_{ow} is the equity of the agricultural enterprise; and A_{nc} is non-current assets of the investigated agricultural enterprise.

$$c_3 = 0{,}5 * (c_1^s + 0{,}5\ (c_1^e - c_1^s)), \quad (6)$$

Where: c_3 is the recovery (loss) ratio of solvency by an agricultural enterprise; c_1^s is the initial value of the current liquidity ratio; and c_1^e is the final value of the current liquidity ratio.

$$c_4 = C_{ow} * B_t^{-1} = (A_{nc} + A_c * c_1 * D_s\ ) * B_t^{-1} \quad (7)$$

Where: c_4 is the agricultural enterprise autonomy ratio; and B_t is the balance sheet total.

According to formulas 4 - 7, changes in the indicators of the current liquidity ratio (c_1) will cause changes in the indicators c_2, c_3, c_4. Therefore, it is advisable to form the following system of equations, the solution of which is the main task of simulation economic and mathematical modeling of the financial risk of bankruptcy of the studied agricultural enterprise (8):

$$\begin{aligned} c_1(t_{i+1}) &= z^0_{c_i} + z^1_{c_i} * c_1(t_i) \\ c_2(t_i) &= z^0_{c_2} + z^1_{c_2} * c_2(t_{i+1}) + z^2_{c_2} * c_1(t_{i+1}) \\ c_3(t_i) &= z^0_{c_3} + z^1_{c_3} * c_3(t_{i+1}) + z^2_{c_3} * c_1(t_{i+1}) \\ c_4(t_i) &= z^0_{c_4} + z^1_{c_4} * c_4(t_{i+1}) + z^2_{c_4} * c_1(t_{i+1}) \end{aligned} \quad (8)$$

Given the above, it should be noted that in order to increase the level of compliance of simulation replications to the actual economic processes in the agricultural enterprise, it is necessary to use two random variables in the algorithm for calculating the simulation model, which will reflect forecast errors (m_p) and approximation errors (m_{ap}). In addition, to bring the set of simulation replications to a form suitable for modeling the probability of financial risk of bankruptcy, it is necessary to average the numerical values of the simulation experiments. Since, unlike the results of individual imitation replications, the averaged result of the entire set of experiments is one of the most probable options, it realistically reflects the predicted trajectory of changes in the financial performance of the tested enterprise in the future period of time.

Thus, taking into account formulas (1 - 8), the algorithm for calculating the simulation economic and mathematical model for assessing the financial risk of bankruptcy of agricultural enterprises can be schematically shown as follows in Figure 1.

It should be noted that as the initial data required for calculations in accordance with the above simulation algorithm, the indicators reflected in the financial statements of the studied agricultural enterprise are used. In turn, to determine the numerical indicators of the distribution of random variables (m_p) and (m_{ap}) it is advisable to use time series that most fully reflect the dynamics of the studied solvency ratios and changes in the strength and nature of environmental factors of the agricultural enterprise.

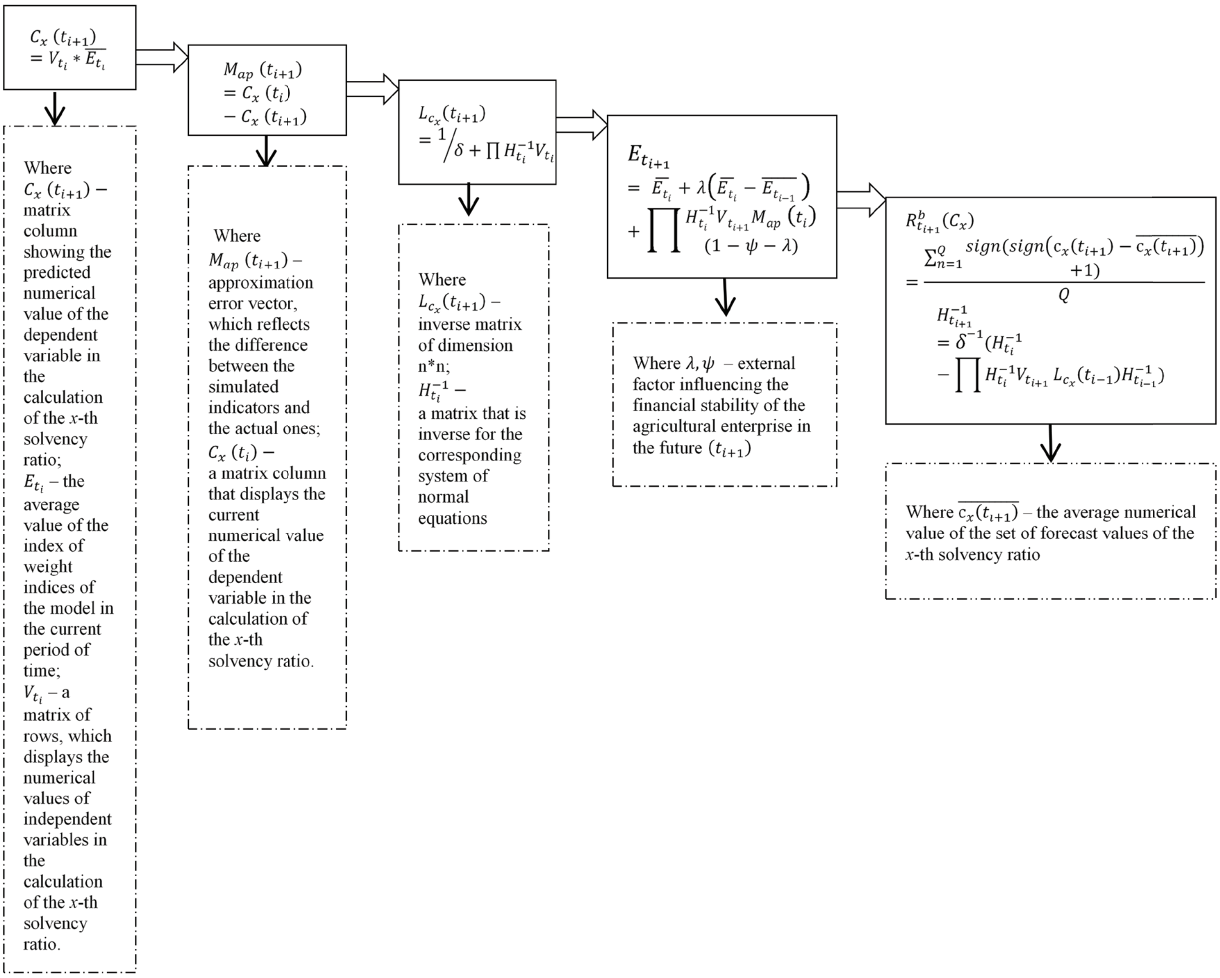

Figure 1. Algorithm for constructing a simulation economic and mathematical matrix for assessing the financial risk of bankruptcy of agricultural enterprises

4. Conclusions

- As a result of the study, it was found that the existing approaches and methods for assessing the actual solvency of agricultural enterprises based on the available statistical information are ineffective for predicting their financial condition and the size of the financial risk of bankruptcy in the coming period of time. With their ease of application, the existing valuation methods lead to a complex further analysis of a large set of interpretations, comparisons, comparisons and, as a consequence, to obtain superficial conclusions that do not reflect the real situation of agricultural enterprises in the relevant economic system, which is characterized by significant restrictions on entrepreneurship due to the COVID-19 pandemic.

- At the same time, in the practical activity of agricultural enterprises there is an urgent need to identify trends in the dynamics of financial condition over several periods, as well as in the long-term analysis of their development. In this regard, a simulation economic and mathematical model for assessing the financial risk of bankruptcy is proposed, which has a universal structure and can quickly adapt to rapidly changing environmental conditions. The use of this model will allow managers to prevent the onset of crises in the agricultural enterprise in future periods of time and promptly develop appropriate measures to respond to the projected results of this assessment.

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