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FORMATION OF LOGIT-MODEL FOR PREDICTING THE PROBABILITY OF BANKRUPTCY OF UKRAINIAN ENTERPRISES

Introduction. *Uncertainty and instability in the modern economy have put a large number of businesses of various forms of ownership on the verge of bankruptcy. Given the above, the development of a new methodological approach to predicting (or prognosticating) the probability of bankruptcy becomes particularly relevant.*

Problem Statement. *In modern economic science, there have been many studies in the field of analysis and assessment of the probability of bankruptcy, but most of them have been outdated and not adapted to the Ukrainian economy, which makes it necessary to build and implement at enterprises such a model for prognosticating the probability of bankruptcy, which would be able to detect negative trends that can lead to bankruptcy in the present-day Ukrainian conditions.*

Purpose. *The purpose of this research is to study the evolution of the methodological approaches to predicting the probability of bankruptcy and building a logit model based on the data of Ukrainian enterprises in recent years.*

Material and Methods. *Empirical, experimental, and theoretical methods of research, methods of correlation and regression analysis have been used in this research. Microsoft Excel and IBM SPSS Statistics application packages have been employed to process the selected statistical data of Ukrainian enterprises.*

Results. *The evolution of views and methodological approaches to predicting the probability of bankruptcy of enterprises has been studied. The main advantages and disadvantages of methods and models currently used in prognosticating the probability of bankruptcy have been determined. A sample of Ukrainian enterprises has been formed, indicators affecting bankruptcy have been determined, and as a result, a logit model for prognosticating the probability of bankruptcy has been developed. It is easy to use and has a high predictive quality.*

Conclusions. *The developed logit-model has been proposed for the analysis of enterprise's financial position in terms of prognosticating crises, insolvency, and bankruptcy.*

Keywords: enterprise, bankruptcy, prognosticating/predicting, methodical approaches, logit-model, and financial position.

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The negative consequences of the pandemic have led to uncertainty and instability in the modern economy. Because of the pandemic, among the bankrupt enterprises, there have been such world-famous companies as *Debenhams*, *JC Penney*, *Flybe*, *Virgin Australia*, *Ernest Airlines*, *J. Crew*, *Cirque du Soleil*, and many others. However, if we take a closer look at these companies, some of them have been in debt and incurring losses for many straight years, with the new economic crisis being just a catalyst for their bankruptcy. This has been confirmed by world practice, which shows that, on average, the threat of enterprise's financial instability is caused for 25—30% by external factors and for 70—75% by internal factors [1]. Effective management plays an important role in ensuring the enterprise economic stability, in particular in the early detection and prevention of bankruptcy as the highest stage of the crisis.

Many researchers have paid attention to the analysis and diagnostics of the probability of bankruptcy. Among the foreign scholars who have dealt with this problem there are E. Altman, U. Beaver, G. Springate, R. Lees, R. Taffler, G. Tishaw, J. Argenti, J. Olson, O. Belikov, O. Kolyshkin, R. Saifullin, G. Kadykov, G. Savytska, G. Haidarshina, and many others. Their Ukrainian colleagues, including O. Tereshchenko, A. Matviichuk, V. Martynenko, A. Cherep, O. Komisarenko, V. Parena, I. Dolgalov, A. Shtangret, and others have also contributed to the study of the probability of bankruptcy of Ukrainian enterprises. They have studied the adaptability foreign models for assessing the probability of bankruptcy of Ukrainian enterprises and, as a result, have presented their own models capable of prognosticating bankruptcy. However, despite this, at the current stage, there has been no single approach to diagnosing the probability of bankruptcy of Ukrainian enterprises. In addition, many existing methods and models have been outdated, and therefore there is an urgent need to create new ones.

Bankruptcy of enterprises in a market economy is a fairly common phenomenon. As *Eastern Air Lines* CEO Frank Borman once said, "capitalism without bankruptcy is like Christianity without hell" (*Eastern Air Lines* filed for bankruptcy in 1989). While the institution of bankruptcy had been working successfully in advanced economies for a long time, in Ukraine, this issue became relevant as late as at the beginning of the 1990s, with the transition to a market economy. In the economic sense, bankruptcy is interpreted as the inability of an enterprise to satisfy claims of creditors and to make mandatory payments to budget and off-budget funds. From a legal point of view, the Code of Ukraine on the Bankruptcy Procedures dated October 18, 2018, states that "bankruptcy is the inability of a debtor, which has been recognized by commercial court, to restore its solvency through the rehabilitation and restructuring procedure and to pay creditors' claims otherwise than through the application of the liquidation procedure" [2]. Based on this, we may note that the enterprise's financial loss and inability to satisfy creditors' claims are not bankruptcy until the fact of bankruptcy has been recognized by the commercial court. However, in this research, bankruptcy should be interpreted from an economic point of view, with both operating and non-operating enterprises at any stage of legal procedure for bankruptcy should be recognized as bankrupt.

Of course, bankruptcy has an effect on the country's economy. Its negative consequences are a decline in GDP, a decrease in tax revenues to the budgets of all levels, a reduction in the number of jobs, an increase in unemployment and in social tension. However, bankruptcy, like the crisis, has a positive effect in market economy. As an economic phenomenon, bankruptcy reveals financially weak, inefficient, and uncompetitive businesses. That is, thanks to this institution, the economy gets rid of inefficient enterprises that are forced either to restructure and improve their activities, or to free up the market. Liquidated business entities, in turn, are replaced by newly created ones, which does not stop the flow of capital in market economy.

Today, many Ukrainian enterprises have been experiencing losses. In 2020, 28.6% of Ukrainian

enterprises suffered a loss, which was by 2.6% more than in the previous year [3]. Such a critically large percentage of unprofitable enterprises in the economy of Ukraine has indicated the presence of crisis processes at enterprises that may become bankrupt. Many scholars believe that bankruptcy may be prognosticated and prevented. Below, we consider the evolution of views and methodical approaches to prognosticating the bankruptcy of enterprises.

The very first steps to identify bankruptcy were made back in the 19thcentury. Creditworthiness was the first indicator used for this purpose. For those times, merchants were most interested in determining the potential solvency of their customers. In 1821, even the first digest of companies that failed to pay their obligations was created (Stubbs Gazette). However, as late as in the 20th century, financial and economic indicators started being actively used to prognosticate financial failure. The results were highlighted in works of J. Ramser and L. Foster (1931) [4], P.J. Fitzpatrick (1932) [5], C. Merwin (1942) [6] and W. Chudson (1945) [7]. The researchers compared and methodically justified the use of certain coefficients. In particular, P.-J. Fitzpatrick came to the conclusion that the best indicators of bankruptcy were the profit to working capital ratio and the working capital to debt ratio (their decrease indicates approaching insolvency). Later, C. Merwin, based on the data of 939 enterprises, came to the conclusion that the first step to bankruptcy is negative dynamics of the interest payment coverage ratio, the financial autonomy ratio, and the working capital to debt ratio. Thus, at the early stage of bankruptcy prognosis, only certain financial and economic coefficients were used, while the first complex indicators (models) started to be employed in the second half of the 20th century [8, 9].

After the Second World War, because of increasing number of bankruptcies, the problem of prognosticating the insolvency of enterprises became more relevant. The first work in this area was the article by the American economist W.H. Beaver (1966) [10], where the author analyzed the financial statements of 158 American enterprises and singled out only 5 of the 30 financial indicators, which were the most important and significant. W. Beaver, in his approach, unlike other authors in previous studies, verified the predictive abilities of the chosen indicators. However, this approach was not yet a statistical prognosis of bankruptcy, as the researcher could not offer a single integral indicator for estimating its probability. For example, the main disadvantage of this approach was that one indicator could be a sign of the financial stability of the enterprise, while other one could indicate bankruptcy.

The first and most successful attempt to solve this problem was a complex integrated model based on multiple discriminant analysis (MDA) of another American economist E. Altman, in 1968 [11]. The author proposed a linear equation of the Z-score, which allowed dividing enterprises into the two groups: with a high probability of bankruptcy and with a low one. The source of the study was data on the financial status of 66 enterprises, half of which went bankrupt, while the other half continued to operate successfully. Out of 22 coefficients, E. Altman chose 5 ones from each block of financial status indicators (liquidity, financial stability, profitability, turnover and business activity). This approach allowed Altman to reduce several financial indicators to a single one (Z-score), which made it possible to give an unambiguous assessment of the financial status of the enterprise, unlike in the previous studies.

Altman's research gave impetus to the creation of new discriminative models for prognosticating the probability of bankruptcy. Some researchers adapted Altman's model using the financial statements of companies in their countries, while others created new models with their own indicators. Among the authors of the most famous models of that time, there are Lees (Great Britain, 1972), Taffler and Tisshaw (Great Britain, 1977), Springate (Canada, 1978), Conan and Holder (France, 1979), and Fulmer (USA, 1984).

The next stage in the development of methods for creating bankruptcy prognosticating models

was the application of logistic regression (logit model). One of the first to propose the logistic regression method for assessing the financial status of an enterprise was J. Ohlson (the author of the well-known EBO business value assessment model), in 1980 [12]. This method has certain statistical advantages as compared with the MDA models. So, the discriminant models describe linear dependencies, whereas the logit models allow describing nonlinear dependencies between variables in the model. Also, as a result of logistic regression, there are no "gray zones" that give uncertainty in the MDA models. J. Ohlsonwas the founder of the approach to modeling with the use of logistic regression and initiated the use of this method by other researchers. Other well-known and widely used logit models for prognosticating bankruptcy include models by Begley, Ming and Watts (USA, 1996), Joo-Ha and Taehong (South Korea, 2000), Lyn and Pyess (Great Britain, 2004), Altman and Sabato (USA, 2007).

It should be noted that all the mentioned models are the balance sheet-based models, that is, the explanatory variables in the equation are the financial indicators (calculated based on the company's balance sheet data) and some non-financial ones (for example, the age of the company or the market share). However, in addition to the balance sheet-based models, there are other models with an alternative approach to prognosticating, such as market models. The first such market model was R. Merton's model (1974) for estimating company's structural credit risk by modeling its equity as a real option for purchase of its own assets. The peculiarity of such models is that the calculations are based on the market value of company's shares, which, under the conditions of efficient markets, allows taking into account information that is not contained in the balance sheet data. The market models have been actively used by banks and financial institutions.

Sometimes it impossible to assess the financial condition through the use of quantitative methods because of the lack of information about the company's financial indicators, and therefore researchers have also proposed qualitative (expert) bankruptcy prognosticating models. The first and the most famous model was the one by J. Argenti (A-model) (1976) [13]. The author found that most bankrupt firms had went through the three distinct stages: defects, errors, and symptoms. Thus, each factor at each stage is given a certain score, and an aggregate indicator — A-score — is calculated. Among the qualitative models, it is worth to mention the model by T. Scown and the of *Ernst&Young* (formerly *Ernst&Whinney*) assessment test. The peculiarity of the qualitative models is that in these models the potential for bankruptcy is estimated given the influence of both external and internal factors. They make it possible to evaluate not only the financial indicators, but also company's management, accounting, and other factors that cannot be quantified.

In the 1990s, methods based on the use of artificial neural networks (ANN) started to be used in bankruptcy prognosticating, which allowed establishing the nonlinear nature of relationship between financial ratios. The first study in the field of bankruptcy prognosticating with the use of neural networks was research by M. Odom and R. Sharda (1990) [14]. Today, neural networks have become one of the modern bankruptcy prognosticating tools. The recent studies in the field of artificial neural networks has shown that they are a powerful tool in pattern recognition and classification due to their nonlinear non-parametric properties of adaptive learning [15]. The models based on the application of fuzzy logic have been popular today, as well. Such models are presented in natural language expressions, have a high accuracy of reproduction of the original statistics and may work even without adjustment to real data, only based on the sets of logical rules embedded in them and the set parameters of the membership functions [16]. Moreover, today, there has been used the neuro-fuzzy models that combine the advantages of neural networks and fuzzy logic. Many researchers who deal with the problem of bankruptcy prognosticating have stated that the methods with the use of neural networks

and fuzzy logic provide significantly higher accuracy of prognosis as compared with the classical statistical approaches. However, the methods based on the use of artificial intelligence have their disadvantages. In particular, the neural network models do not make it possible to unambiguously determine the contribution of each indicator to the worsening of company's financial status and depend on the representativeness of the training sample, which depends on the quality of the designed neural network. In the fuzzy models, there is the subjectivity of experts [17]. It is also worth mentioning the development of such prognosticating methods as: SVM, precedent-based considerations, rough sets, decision tree, and genetic algorithm. All methods based on artificial intelligence have shown a sufficiently high accuracy of bankruptcy prognosis, but their disadvantages are the complexity of design and implementation; in addition, they do not allow deriving a classical equation with coefficients for variables, which complicates the interpretation of the obtained results.

While the institution of bankruptcy and its prognosticating have been successfully working abroad for a long time, in former Soviet countries this problem became relevant as late as in the early 1990s. It was believed that the system that existed in the USSR did not allow for crises or bankruptcies, so there was nothing to prognosticate. One of the first proposed models was the MDA model proposed by Belikov and Davydova (Irkutska) of Russia [18] and presented in Belikov's dissertation in 1998. Some coefficients were taken from the Altman model while others are borrowed from the Taffler model. The model was built on a sample of trading enterprises that went bankrupt and remained financially stable, which questioned its applicability to enterprises from other industries. Since the early 2000s, there appeared many Russian and Belarusian bankruptcy prognosticating models, including those by Savitskaya, Kolyshkin, Saifulin-Kadykov, Zaitseva, Liugovskaya, and Haydarshina. Most of the models are specific to certain industries and we should keep in mind this fact when using them.

In Ukraine, the enterprise bankruptcy prognosis started developing in the early 2000s. The Ukrainian researcher O. Tereshchenko has made a significant contribution to the study of the probability of bankruptcy of domestic enterprises, in 2003 [19]. The author has developed the universal MDA model that includes 6 indicators and is based on financial reports of 850 companies from various industries. In addition, he has proposed a model consisting of 10 indicators, which takes into account the differentiation of enterprises by industry. The indisputable advantage of his models is that they are built on statistical data of domestic enterprises, that means they take into account the specifics of the Ukrainian economy. However, they have disadvantages, in particular, research [20] contains a deviant distribution line between the groups of financially stable and bankrupt enterprises, a significant error in the identification of potential bankrupt enterprises as financially stable, and a wide uncertainty interval. A. Matviichuk [20], O. Cherniak [21], V. Martynenko [22], A. Cherep and O. Komisarenko [23], V. Parena and I. Dolgaliov [24], A. Stangret [25] and other authors have contributed into prognosticating of bankruptcy of Ukrainian enterprises, as well. The authors have proposed their own models based on different methods, for different sectors of the economy.

To summarize, it should be noted that the evolution of approaches to bankruptcy prognosis has come a long way: from the first financial indicators to the models based on artificial intelligence. However, in Ukraine, this field of knowledge started to develop as late as after gaining independence. According to the authors of this research, the world-known models of bankruptcy prognosis are completely unsuitable for Ukrainian enterprises and are not recommended for use. Among the main reasons are the fact that these models are based on the financial statements of other countries, use out-of-date and different limit values of the indicators, have incorrect interpretation and translation of financial indicators. Ukrainian, Russian, and Belarus researchers have tried to

solve these problems, but their models also have disadvantages.

Thus, although many attempts have been made to prognosticate the bankruptcy of domestic enterprises, in Ukraine there has been still an urgent need for an effective economic mathematical model for bankruptcy prognosis, which would be capable of ensuring high accuracy, given the specifics of the Ukrainian economy. According to the authors, one of these methods is logistic regression.

The logistic regression or logit model is a statistical model used to prognosticate the probability of a certain event with the use of logistic function. As mentioned above, unlike the MDA models that describe linear dependencies, the logit models allow describing nonlinear dependencies between variables in the model, which is extremely important in conditions of instability of the national economy. In addition, the discriminant models determine whether the enterprise belongs to the group of bankrupts, while in the logit models there are no problems with the unambiguous interpretation of the resulting indicator, because its value ranges between 0 to 1 and immediately determines the nominal value of the probability of the enterprise bankruptcy. The effectiveness of logistic regression has been confirmed by J. Lennox [26], where the author has determined that the logistic model has more accurate results of assessing the risk of bankruptcy than the MDA models.

To predict the probability of some event, there are introduced the so-called dependent variable Y that takes only one of two values, as a rule, 0 (if the event did not occur) and 1 (the event occurred) and many independent variables (signs, predictors or regressors) x_1, x_2, ..., x_n, based on which the probability of taking a particular value of the dependent variable is determined. The probability of an event, in our case bankruptcy, is calculated with the use of the general formula of the logistic function that has the form:

$$P = \frac{1}{1 + e^{-Y}}, \qquad (1)$$

where P is the probability of bankruptcy, that ranges from 0 to 1; e is the natural exponent (equal to 2.71828); Y is the integral indicator that is calculated depending on the model.

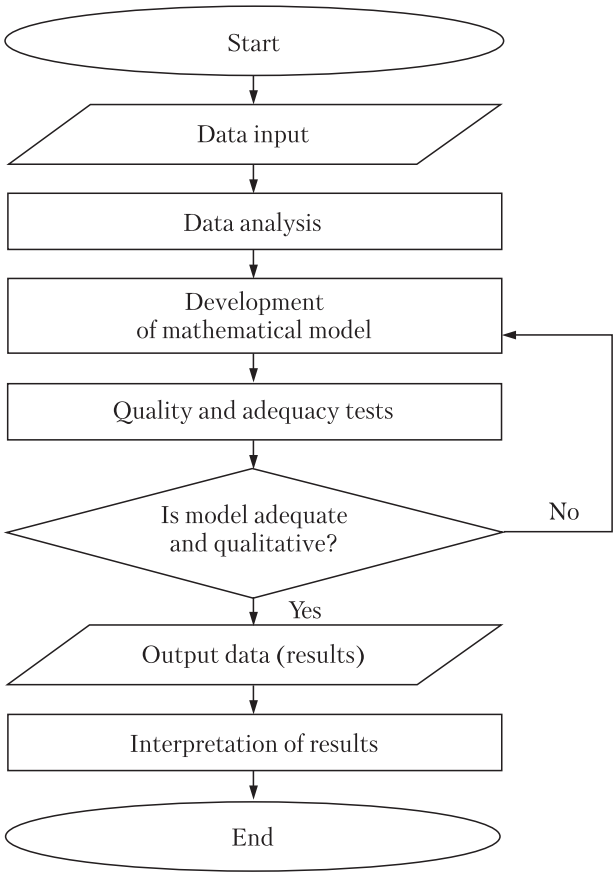

Fig. 1. *Logit-model development algorithm*

The integral indicator is calculated as follows:

$$Y = b_1 \cdot x_1 + b_2 \cdot x_2 + ... + b_n \cdot x_n + a, \qquad (2)$$

where b_n is the regression coefficient; x_n is an independent variable; a is the free term of the regression equation (constant).

The logit model is developed according to the algorithm shown in Fig. 1.

The logit model for prognosticating the probability of bankruptcy consists of the following stages:

- the formation of a representative sample of bankrupt and non-bankrupt enterprises;
- the formation of a system of financial indicators of bankruptcy and their calculation for each enterprise;

- the creation of a logit model for assessing the risk of bankruptcy of enterprises;
- the determination of the range of probability of enterprise's bankruptcy.

THE FORMATION OF A REPRESENTATIVE SAMPLE OF BANKRUPT AND NON-BANKRUPT ENTERPRISES

The informational and empirical basis for the creation of the logit model is the financial reporting data of Ukrainian enterprises for 2013—2020. According to the authors, this period, unlike the first decade of the 2000s, is characterized by significant changes in the economy, in particular because of the crises, war, reforms, etc. Undoubtedly, this turbulence and economic instability also have affected the activities of enterprises, mainly adversely, which has led to worsening financial indicators and losses. That is, the financial indicators and results of enterprises of the first decade have been significantly outdated, because the economy functioned in completely different conditions. Due to this, the norms of financial indicators, the threshold of existence or other factors of the operation of enterprises could change. Thus, it is very important that the models are based on the actual data of the enterprises. The Ukrainian models developed after the third decade in the future will certainly differ from those of the first and second decades.

The enterprises are sampled given following criteria:

- the size of the business entity: large (mostly) and medium;
- the type of ownership: PrJSC, PJSC, and LLC;
- the industry: all industries, except the financial one;
- the period of existence: more than 7 years.

Some researchers have stated [27] that for a qualitative bankruptcy assessment model, it is necessary to use weighted data, that is, an equal number of bankrupt and non-bankrupt enterprises. With this in mind, 31 bankrupt and 31 non-bankrupt enterprises have been included in the analysis. As mentioned above, enterprises are considered bankrupt if they are at any legal stage of bankruptcy. That is, the sample of bankrupts includes both active enterprises that are going through the bankruptcy procedure and inactive enterprises that have been liquidated or are in the process of liquidation. The non-bankrupt enterprises include only operating enterprises.

The following resources have been used as the financial reporting database: smida.gov.ua, zvitnist.com, stockworld.com.ua and official websites of selected enterprises. For the purpose of this study, the Balance Sheet (Form No. 1) and the Profit-and-Loss Statement (Form #2) are considered sufficient. In the case of bankrupt enterprises, the model is based on the reporting for 1 year before the start of bankruptcy.

THE FORMATION OF A SYSTEM OF FINANCIAL INDICATORS OF BANKRUPTCY AND THEIR CALCULATION FOR EACH ENTERPRISE

Both financial and non-financial indicators can be used to prognosticate and assess the probability of bankruptcy of an enterprise. When building the model, we have used only financial indicators, since the first sign of bankruptcy is the enterprise's unsatisfactory financial status. The indicators of an unsatisfactory financial status and bankruptcy can be selected by the two methods: the expert or the statistical one. For better quality of the model, it is advisable to combine them.

It should be noted that there is no universal set of indicators of bankruptcy. Each researcher tries to select such financial ratios that, in his/her opinion, best describe the financial status of enterprise. Thus, the authors first have overviewed the existing bankruptcy prognosticating models to identify the indicators that are most often used by other researchers. More than 35 models for estimating the probability of bankruptcy, both classical (Beaver [10], Altman [11], Ohlson [12]) and modern (Tereshchenko [19], Zhdanova [28], Mat-

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viychuk [20]) authors have been considered. The results are systematized in the Table 1.

Table 1 shows the indicators used in the analyzed models more than 6 times. We can see that the most popular are asset turnover ratio, current liquidity ratio, assets profitability, and the working capital to total assets ratio. Most researchers have tended to believe that these indicators are able to prognosticate bankruptcy.

Having analyzed the studies of domestic and foreign researchers on bankruptcy risk assessment and financial analysis, 42 indicators from the five groups that characterize the financial status of enterprise: liquidity, solvency, business activity, profitability and wealth status have been selected for the total set of indicators. The next step is to calculate the financial indicators of the selected sample of enterprises and to test them for multicollinearity. The correlation analysis reveals pairs of mutually correlated financial ratios and allows excluding one of two statistically interdependent indicators. This makes it possible to reduce the number of studied indicators without losing the informativeness of the studied set of data. In the process of correlation analysis, strong relationships between many indicators, for example, multicollinear pairs such as the return on assets and the working capital to total assets ratio (correlation is equal to 0.91), the return on assets and the financial autonomy ratio (0.92), the financial leverage and the maneuverability of equity (–0.81), and so on have been found. High statistical correlation between them indicates the impossibility of their simultaneous application in the model. Thus, out of the indicators that are not multicollinear, those that, in the opinion of the

Table 1. **The Indicators Most Widely Used in the Bankruptcy Prognosis Models**

Indicator	Formula	Models in which the indicator is used
Asset turnover ratio (transformation ratio)	Revenue / Assets	The five-factor model by Altman, the seven-factor models by Altman, Fulmer, Springate, Taffler and Tishaw, Belikov-Davydova, Saifulin-Kadykov, Savitskaya, Tereshchenko, Parena-Dolgaliov, Dontsova-Nikiforova, Zhdanov, Mashyzhko-Zavadskyi, and Shtangret
Current liquidity ratio (coverage ratio)	Working assets / Short-term liabilities	The two-factor model by Altman, the seven-factor models by Altman, Kolyshkin, Saifulin-Kadykov, Fedotova, Liugovskaya, Martynenko, Sheremet-Saifulin, Kovaliov-Volkova, Kopchak, Parena-Dolgaliov, Zhdanov, Beaver, and Shtagret
ROA	Net profit (loss) / Assets	The seven-factor model by Altman, Kolyshkin, Savitskaya, Liugovskaya, Tereshchenko, Kovaliov-Volkova, Yashchuk, Dontsova-Nikiforova, Ohlson, Beaver, Laitynen-Suvas (European corporate failure risk model).
Working Capital / Total Assets	(Working assets-Short-term liabilities) / Assets	The five-factor models by Altman, Springate, Lees, Kolyshkin, Belikov-Davydova, Parena-Dolgaliov, Dontsova-Nikiforova, Ohlson, Laitinen-Suvas (European corporate failure risk model).
ROE	Net profit (loss) / Equity	The models by Belikov-Davydova, Kolyshkin, Saifulin-Kadykov, Martynenko, Zaitseva, Sheremet-Saifulin, Savitskaya, and Shtangret
Share of borrowed capital in assets	Borrowed capital / Assets or Short-term (long-term) liabilities / assets	The two-factor models by Altman, Fulmer, Fedotova, Taffler and Tisshaw, Matviichuk, Ohlson, Chesser, and Beaver.
ROS	Net profit (loss) / Sales	The models by Kolyshkin, Saifulin-Kadykov, Tereshchenko, Zaitseva, Kurchenko, Sheremet-Saifulin, andKopchak.
Financial autonomy ratio	Equity / Assets	The seven-factor models by Altman, Savitskaya, Martynenko, Yashchuk, Dontsova-Nikiforova, and Laitinen-Suvas (European corporate failure risk model).

authors, are the most suitable for assessing the risk of bankruptcy, given their economic content and statistical significance, have been chosen. It has been proposed to introduce the following 5 indicators into the model (the matrix of paired correlation coefficients is given in Table 2):

- the asset turnover ratio: allows assessing the efficiency of the use of all company's assets. The financial status of the enterprise, its solvency and liquidity depend on the rate of turnover of invested funds. In addition, this indicator shows how the company's products are perceived by the market.
- the working capital to total assets ratio is a widely used indicator of liquidity and solvency. An increase in working capital indicates that even if all creditors demand repayment of current debt, the enterprise is able to continue its normal operation without the threat of bankruptcy. Its ratio to total assets determines the company's short-term solvency.
- the profitability is a coefficient used to assess the operational efficiency of the enterprise. Profit is an indicator for investors and creditors, because if there are problems in the company's operation, profit often goes downward long before the revenue and net profit. The indicator informs about the profitability of manufacture of goods, provision of services, potential dividends, capacity for reinvestment and the company's ability to repay debts.
- the borrowed capital structure is an indicator that reflects the financial stability of the enterprise and characterizes the share of long-term liabilities in the structure of borrowed capital.
- the binary predictor that is equal to 1, if the net profit is negative in the last two periods, otherwise it is equal to 0. It is first used in Ohlson's model [12] and characterizes the dynamics of the net profit/loss. Given the fact that stable unprofitability is the first step to the insolvency, this indicator is important for assessing the risk of bankruptcy.

According to the correlation matrix (Table 2), it has been found that there is an insignificant correlation between the working capital to total assets ratio and the profitability, as well as between the asset turnover ratio and the binary predictor. However, this does not prevent their application in the model, since only strong correlations (>0.9) can affect the results.

THE CREATION OF A LOGIT MODEL FOR PROGNOSTICATING THE RISK OF BANKRUPTCY

The logit model of bankruptcy risk has been developed with the help of *IBM SPSS Statistics* 23.0 program. Using the method of binary logistic regression, the following mathematical model has been obtained for bankruptcy prognosis:

$$Y = -1{,}105 - 3{,}271x_1 - 2{,}927x_2 - \\ - 0{,}361x_3 + 2{,}366x_4 + 2{,}694x_5, \qquad (3)$$

where x_1 is the asset turnover ratio (sales revenue to assets ratio); x_2 is the working capital to assets ratio; x_3 is the profitability of operation (profit (loss) to sales revenues ratio); x_4 is the borrowed capital structure (the ratio of long-term liabilities to the total borrowed capital); x_5 is the binary

Table 2. **Matrix of Paired Correlation Coefficients of the Selected Indicators**

Indicator	X1	X2	X3	X4	X5
Asset turnover ratio (X1)	1	0.095406	0.232668	–0.03286	–0.41589
Working capital to total assets (X2)	0.095406	1	0.435098	0.279568	–0.04526
Profitability (X3)	0.232668	0.435098	1	0.115514	–0.2107
Borrowed capital structure (X4)	–0.03286	0.279568	0.115514	1	–0.01025
Binary predictor (X5)	–0.41589	–0.04526	–0.2107	–0.01025	1

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Table 3. **The Binary Logistic Regression Model Coefficients**

Indicator	Regression coefficient (*b*)	Root mean square error	Wald test	Exp (B)
Asset turnover ratio (X1)	–3.271	1.355	5.827	0.038
Working capital to total assets (X2)	–2.927	1.453	4.057	0.054
Profitability (X3)	–0.361	0.348	1.074	0.697
Borrowed capital structure (X4)	2.366	2.021	1.370	10.658
Binary predictor (X5)	2.694	1.030	6.834	14.784
Constant	–1.105	1.251	0.780	0.331

predictor that is equal to 1, if the enterprise has shown a net loss for the last two periods, otherwise it is equal to 0.

The statistical significance criterion (χ^2) of the cumulative effect of all independent variables in the model on the dependent variable is 55.913, $p < 0.001$. Thus, the model is statistically significant. The results of the logit model for bankruptcy risk prognosis are shown in Table 3.

The model consistency with the original data has been assessed with use of the Hosmer-Leme show goodness of fit test. The value of the criterion should be, at least, 0.5—0.6. The criterion value in the author's model is equal to 0.726, which indicates a high quality of the model.

Nigelkirk's indicator (R^2) shows how strongly the change in the dependent variable is explained by the change in the set of independent variables. It varies from 0 to 1, and the closer to unity, the better. In our case, Nigelkirk's indicator R^2 is equal to 79.2%. It means that the share of the variance explained by the resulting logistic function is 79.2%, so the model is high-quality.

The next parameter that characterizes the obtained model is the prognosis quality indicator that determines the probability of a correct prognosis. Thus, the percentage of correct prognosis of non-bankrupt enterprises is 90.3%, and that of bankrupt enterprises is also 90.3%, which gives an average prognosis accuracy of 90.3%. That is, the model determines with a high accuracy the probability of bankruptcy of the studied statistical population, which also testifies to a high quality of the model.

THE DETERMINATION OF THE BANKRUPTCY PROBABILITY RANGE

It is recommended to interpret the obtained results according to the following scale proposed by the authors (Table 4).

Bankruptcy of enterprises in the economy is primarily a negative phenomenon that harms not only entrepreneurship, but also the economy as a whole. For more than a century, researchers have been proving that bankruptcy can be prognosticated before it starts. This problem has evolved from the first creditworthiness indicators to the models based on artificial intelligence. At first, researchers paid little attention towards the probability of bankruptcy, while with the development of science and technology, as well as the development of crisis phenomena in economy, the

Table 4. **Linguistic Description of Bankruptcy Probability Ranges**

Bankruptcy probability (*P*)	Comment
$P < 0.01$	Minimum risk of bankruptcy
$0{,}01 \le P < 0.1$	Low risk of bankruptcy
$0{,}1 \le P < 0.3$	Moderate risk of bankruptcy
$0{,}3 \le P < 0.5$	Significant risk of bankruptcy
$0{,}5 \le P < 0.8$	High risk of bankruptcy
$0{,}8 \le P < 0.9$	Very high risk of bankruptcy
$P \ge 0.9$	The enterprise is likely in default

Source: Developed by the authors based on [28—30].

number of studies in this field has been showing a significant increase. Today, there have been numerous both foreign and domestic models for assessing the probability of bankruptcy. However, all of them have disadvantages when applied to Ukrainian enterprises, which in some cases leads to false results. The main shortcoming of the foreign methods is the unsuitability of data for the Ukrainian economy, while for the domestic methods the main problem is the time aspect, because Ukraine's economy is instable and the coefficients and the models themselves need to be revised and updated.

Based on the results of this research, the authors have proposed their own logit model for prognosticating the probability of bankruptcy. The model has a high predictive quality, easy-to- calculate, with its variables fully describing the financial status of the enterprise. The peculiarity of the model is that it is based on the financial statements of large and medium-sized enterprises for the period 2013—2020 (a period of instability and crisis shocks in Ukraine's economy), which testifies to its relevance and adaptability to modern realities. The application of this model to Ukrainian enterprises will help to prognosticate crisis phenomena to enable the quick reaction on them and the prevention of bankruptcy.

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ФОРМУВАННЯ *LOGIT*-МОДЕЛІ ПРОГНОЗУВАННЯ ЙМОВІРНОСТІ БАНКРУТСТВА УКРАЇНСЬКИХ ПІДПРИЄМСТВ

Вступ. Невизначеність та нестабільність сучасної економіки призвели до того, що значна кількість суб'єктів господарювання різних форм власності опинилися на межі банкрутства. Зважаючи на зазначене, розробка нового методичного підходу до прогнозування ймовірності банкрутства набуває особливої актуальності.

Проблематика. У сучасній економічній науці існує чимало розробок у сфері аналізу та оцінки ймовірності банкрутства, проте більшість з них є застарілими та не адаптованими до української економіки, що спричиняє необхід-

ність створення та впровадження на підприємствах такої моделі прогнозування ймовірності банкрутства, яка здатна своєчасно виявити негативні тенденції, що можуть призвести до банкрутства у сучасних українських умовах.

Мета. Дослідження еволюції розвитку методичних підходів до прогнозування ймовірності банкрутства та побудова *logit*-моделі, за показниками українських підприємств за останні роки.

Матеріали і методи. У роботі використано емпіричні та експериментально-теоретичні методи дослідження із застосуванням методів кореляційного та регресійного аналізу. Для обробки вибраних статистичних даних українських підприємств застосовано пакети прикладних програм *Microsoft Excel* та *IBM SPSS Statistics*.

Результати. Досліджено еволюцію поглядів та методичних підходів до прогнозування ймовірності банкрутства підприємств. Визначено основні переваги та недоліки методів і моделей, що на сьогодні використовуються при прогнозуванні ймовірності банкрутства. Сформовано вибірку українських підприємств, визначено показники, що впливають на банкрутство, та розроблено *logit*-модель прогнозування ймовірності банкрутства, яка є простою у розрахунку та має високу прогнозну якість.

Висновки. Розроблену *logit*-модель запропоновано для використання в аналізі фінансового стану підприємства щодо прогнозування настання криз, неплатоспроможності та банкрутства.

Ключові слова: підприємство, банкрутство, прогнозування, методичні підходи, *logit*-модель, фінансовий стан.