EVALUATING THE EFFECTIVENESS OF THE MODELS FOR ASSESSING THE INITIATION OF BANKRUPTCY PROCEEDINGS

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ABSTRACT

Using predictive models for assessing the initiation of bankruptcy proceedings constitutes a proactive strategy aimed at preserving financial stability and promoting the long-term viability of businesses. This study focuses on companies in the agricultural and food production sectors within the Republic of Serbia, specifically examining those for which bankruptcy proceedings were initiated in 2022, based on their operational activities in 2021. The primary objective of this research is to evaluate the efficiency of the predictive models in forecasting the likelihood of bankruptcy proceedings one year before their initiation. The requisite data for applying these models were obtained from the financial statements of the analyzed companies. The findings indicate that the Vlaović Begović (VB) model demonstrated the highest efficacy in predicting the onset of bankruptcy proceedings within the agricultural sector. Conversely, the Altman Z' score proved to be the most appropriate model for assessing bankruptcy within the food sector.

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Introduction

In the modern environment, where companies are facing consequences of the COVID 19 pandemic, an unstable political and economic situation as well as the global economic crisis, the issue of firm failure and insolvency proceedings is again a topic of interest among practitioners and researchers (Pervan et al., 2023). The opening of bankruptcy proceedings marks the terminal phase of a company's business activities with significant consequences for creditors, debtors and the economy in general. According to Jocić et al. (2024), evaluating the potential for bankruptcy within market-driven economies is crucial for sustainable financial management practices. The concept of financial sustainability refers to liquidity, long-term returns, growth potential, and the ability to withstand financial distress. Ignoring the signs of financial distress can lead to a situation in which bankruptcy is the only option (Srebro et al., 2021). A variety of predictive models have been developed to anticipate bankruptcy events, employing diverse methodologies ranging from statistical analyses to machine learning techniques. Zenzerović and Peruško (2006) point out that the models of the following authors are the most cited and/or most used in practice: William H. Beawer, Edward I. Altman, Edward B. Deakin, James A. Ohlson, Robert O. Edmister, Christina V. Zavgren and Peter Kralicek. The risk of bankruptcy cannot be eliminated but it can be identified before it occurs (Voda et al., 2021). Traditional models, such as Altman's Z-score and Ohlson's O-score, have established a foundation for bankruptcy prediction, utilizing financial indicators and historical data to evaluate a company's financial integrity. In corporate failure prediction models, financial variables are still primarily used, while other variables are used complementary (Veganzones and Severin, 2021). However, as the economy evolves, so must the models used to evaluate the risk of bankruptcy. Since 2021, the 45 countries that collectively represent nearly 90% of global GDP have experienced an average annual increase of 12% in corporate bankruptcy filings. By 2023, the number of corporate insolvencies had reached its highest level in over a decade (Dun and Bradstreet, 2024). This research will evaluate the performance of prediction models in agricultural and food companies. The assessment of the adequacy of various models for predicting the initiation of bankruptcy proceedings has been the focus of extensive research by numerous scholars. In the research conducted by Muminović et al. (2011), which focused on companies whose shares were traded on the Belgrade Stock Exchange, it was determined that the original Z-score, Z'-score, and Z''-Score models are not reliable for prediction of bankruptcy in the Republic of Serbia. Pavlović et al. (2011) also analyzed companies listed on the Belgrade Stock Exchange. The authors performed an analysis of the adequacy of Taffler's model in assessing the possibility of bankruptcy in a sample of 62 companies. Their findings indicated that the model is inadequate in the specific economic context of Serbia. Further assessment of predictive accuracy was undertaken by Pavlović et al. (2012), who assessed the Zmijevski model's effectiveness in forecasting bankruptcy. Despite the notable economic disparities between the Republic of Serbia and the United States during the period when this model was developed, the authors found that the Zmijevski

model exhibited a surprisingly high level of accuracy in predicting bankruptcy among Serbian companies. In their research, Stanišić et al. (2013) developed three predictive models utilizing both standard and specific financial indicators to forecast the initiation of bankruptcy proceedings in developing markets. The authors constructed these models based on an initial sample of 130 companies, employing logistic regression, decision trees, and artificial neural networks. Their findings revealed that, in an independent evaluation involving a sample of 102 companies, only the artificial neural network model demonstrated superior performance compared to the Altman models. Mizdraković and Bokić (2016) examined the adequacy of Altman's Z' and Z'' models, along with a specially created M score, within the context of the Serbian economy. This analysis was conducted on a sample of 70 medium and large companies. The results indicated that, on average, the M model accurately assessed 74.3% of the companies, though this accuracy represented a decline from the 80% observed during the model's original development period. Additionally, the research highlighted the inadequacy of using Altman's Z' and Z'' scores within the Serbian economic context, as these models successfully evaluated the financial performance of the analyzed companies in only 48.2% to 74.7% of cases. Stojanović and Drinić (2017) also tested the adequacy of the use of Altman's models (Z, Z' and Z''), but on a sample of 270 agricultural companies operating in Bosnia and Herzegovina from 2010 to 2015. The authors concluded that these models were unable to reliably predict the occurrence of bankruptcy 2 to 3 years in advance. Furthermore, the accuracy assessment of Altman's Z'' score and the Zmijewski model was conducted by Begović et al. (2020) on a sample of 159 companies, of which 53 had initiated bankruptcy proceedings, within the Republic of Serbia during the period from 2012 to 2013. The authors noted a slight advantage of the Zmijewski model; however, both models demonstrated satisfactory average accuracy in predicting the initiation of bankruptcy proceedings. Koziol and Pitera (2020) examined the suitability of ten bankruptcy prediction models in assessing the financial viability of food companies operating in Poland between 2005 and 2016. The study analyzed the performance of 50 companies, half of which had declared bankruptcy, while the remaining half were financially stable. Models developed by M. Hamrol, T. Korol, J. Gajdka and D. Stos, as well as D. Appenzeller and K. Szarzec, demonstrated an average accuracy of 68% in correctly identifying companies that initiated bankruptcy proceedings. Valaskova et al. (2020) also conducted a comparative analysis of models for evaluating the bankruptcy risk but on a sample of agricultural enterprises. The authors concluded that models specifically developed for a particular economy (Slovak) and tailored to a specific sector yield significantly better results than generalized models such as Altman's. Following the aforementioned context, this research focuses on companies engaged in agricultural production and food processing in the Republic of Serbia during the year 2021. The primary objective of the study is to evaluate the effectiveness of the models employed to predict the initiation of bankruptcy proceedings for the analyzed companies.

Materials and methods

The adequacy of using specific models for predicting bankruptcy among agricultural and food companies in the Republic of Serbia was assessed based on financial data. The study analyzed data from nine agricultural and twelve food companies that initiated bankruptcy proceedings in 2022. Additionally, an equal number of stable companies from both sectors were selected using a random sampling method, ensuring that they were comparable in terms of size and location. The analysis was based on financial statements for the 2021 fiscal year, obtained from the final accounts available on the official website of the Serbian Business Registers Agency. Information regarding ongoing bankruptcy proceedings was obtained from the Bankruptcy Supervision Agency. It is important to note that, under the current legal framework in the Republic of Serbia, the term bankruptcy includes both liquidation and reorganization procedures as alternative approaches to addressing corporate insolvency. In accordance with the scope and purpose of the research, the following hypothesis has been articulated:

H_0: The applied models successfully forecasted bankruptcy within the analyzed agricultural and food processing companies.

The models evaluated in this research include those developed by the following authors:

Edward I. Altman was the pioneer in applying discriminant analysis within a bankruptcy assessment models. In 1968, he developed a model based on the performance of 66 manufacturing companies, half of which had declared bankruptcy while the other half exhibited no solvency issues. This model was specifically designed to evaluate the bankruptcy risk of publicly traded firms (Altman, 1968). However, the initial model was not applicable to companies whose capital is not listed on the stock exchange. To address this limitation, Altman subsequently refined the formula in 1983 (Altman, 1983):

$$Z' = 0.717X_1 + 0.847X_2 + 3.107X_3 + 0.420X_4 + 0.998X_5$$

The indicators constituting the discrimination function were determined according to:

X_1 = (current assets-current liabilities) / total assets;

X_2 = retained earnings / total assets;

X_3 = earnings before interest and taxes / total assets;

X_4 = book value equity / total liabilities and

X_5 = sales / total assets.

The obtained results facilitate the classification of companies into three zones: safe ($Z' > 2.9$), gray (denoting potential bankruptcy risk; $1.23 < Z' < 2.9$), and distressed ($Z' < 1.23$).

James Ohlson is regarded as a foundational contributor of applying logit analysis to models for estimating bankruptcy. In 1980, he developed a model based on a sample of 2,163 manufacturing companies that filed and initiated bankruptcy between 1970 and 1976. This model achieved an impressive average accuracy rate of 96.12% in predicting bankruptcy one year in advance (Ohlson, 1980):

$$O = -1.32 - 0.407X_1 + 6.03X_2 - 1.43X_3 + 0.0757X_4 - 2.37X_5 - 1.83X_6 + 0.285X_7 - 1.72X_8 - 0.521X_9$$

The indicators utilized in this model were computed in accordance with:

X_1 = log (total assets / gross national product index), the index year is as of the year before the year of the balance sheet date;

X_2 = total liabilities / total assets;

X_3 = working capital / total assets;

X_4 = current liabilities / current assets;

X_5 = relation between total liabilities and total assets, if total liabilities exceed total assets this indicator takes the value of one, zero otherwise;

X_6 = net result / total assets;

X_7 = funds provided by operations / total liabilities;

X_8 = an indicator of net income change, one if net income was negative for the last two years, zero otherwise and

X_9 = (net income in the current year – net income in the previous year) / (|net income in the current year|+|net income in the previous year|).

Sanja Vlaović Begović developed a logit model for predicting bankruptcy one year before its occurrence, utilizing a sample of 120 companies from the processing sector. The companies included in this research operated in the Republic of Serbia from 2011 to 2017. The model demonstrated an overall prediction accuracy of 91.67% (Vlaović Begović, 2020):

$$VB = 0.934 - 4.053X_1 - 7.630X_2 + 2.253X_3 + 1.730X_4 + 4.205X_5 - 0.406X_6$$

The indicators incorporated in this model were derived based on:

X_1 = net result / total assets;

X_2 = working capital / total assets;

X_3 = current assets / total assets;

X_4 = current assets / sales revenue;

X_5 = long-term liabilities / total assets and

X_6 = log (total assets).

Dragana Bešlić developed a model for assessing the probability of bankruptcy, utilizing logit analysis. The study encompassed 130 companies that were active in the Republic of Serbia from 2010 to 2011, representing small, medium, and large companies across various sectors. The model achieved an average accuracy rate of 92.1% in predicting

bankruptcy within the training sample and 87.8% on the test sample (Bešlić, 2016):

$$DB = 3.834 + 0.141X_1 - 3.671X_2 - 0.045X_3 + 0.001X_4 - 1.547X_5 + 5.006X_6$$

The calculation of indicators for this model followed the methodology outlined in:

X_1 = long-term assets / (long-term liabilities + total equity);

X_2 = initial equity (capital) / total assets;

X_3 = total liabilities / (net result + depreciation);

X_4 = sales revenue / average inventories;

X_5 = sales revenue / average short-term operating receivables and

X_6 = funds provided by operations / average total assets.

Ivica Pervan developed a logit analysis-based model for predicting bankruptcy one year before its occurrence, utilizing a sample of 258 small and medium-sized enterprises from the manufacturing sector. The companies examined operated within the Republic of Croatia. The model initially demonstrated a successful prediction rate of 87.9% in identifying bankruptcy cases (Pervan, 2017):

$$P = 2.969 - 0.031X_1 - 0.480X_2 - 0.089X_3$$

The formulation of indicators used in this model was carried out according to:

X_1 = earnings before interest and taxes / total income;

X_2 = current assets / short-term liabilities and

X_3 = book value of equity / total assets.

The probability of bankruptcy, as determined by the tested logit models, is obtained through the application of the following formula (adapted from Tekić et al., 2021):

$$P_i\,(\text{Bankruptcy}) = \frac{1}{1 + e^{-(O;\, VB;\, DB;\, P)}}$$

Where are:

O, VB, DB and P - values obtained by models;

e - natural logarithm (2.718281828459) and

P_i - the probability of bankruptcy.

A calculated value of P_i greater than 0.5 indicates that the company is at risk, reflecting a high probability of bankruptcy. Conversely, if the conditional probability associated with the calculated value P_i is less than or equal to 0.5, the company is classified as

stable, suggesting no immediate risk of bankruptcy.

The overall predictive accuracy, which constitutes an essential aspect of the model, was derived using the formula (adapted from Kušter, 2023):

$$Overall\ accuracy\ (\%) = \frac{AB+AS}{AB+FB+AS+FS} * 100$$

Where are:

AB-accurate bankrupt company;

FB-false bankrupt company;

AS-accurate stable company and

FS-false stable company.

When assessing the likelihood of company bankruptcy using predictive models, certain classification errors may also arise. A type I error represents the percentage of at-risk companies incorrectly classified as stable by the model, whereas a type II error indicates the percentage of stable companies erroneously classified as at risk (Vavrek et al., 2019).

Results and discussion

The evaluation of the adequacy of utilizing individual models for assessing the likelihood of initiating bankruptcy proceedings begins with a descriptive statistical analysis of the outcomes produced by these models. This analysis encompasses financially stable agricultural companies and those for which bankruptcy proceedings have been initiated, as presented in Table 1.

Table 1. Descriptive statistics for applied models in agricultural companies

Elements	Models									
	VB		DB		P		Z'		Ohlson	
	bankrupt	stable	bankrupt	stable	bankrupt	stable	bankrupt	stable	bankrupt	stable
Mean	0.92	0.22	0.46	0.28	0.83	0.45	3.21	17.16	0.80	0.17
Median	1	0.06	0.11	0	0.92	0.62	0.92	10.10	0.94	0.04
Standard deviation	0.12	0.30	0.50	0.44	0.31	0.39	10.19	14.94	0.31	0.32
Minimum	0.68	0	0	0	0	0	-3.31	2.21	0.06	0
Maximum	1	0.77	1	0.98	0.95	0.93	30.10	43.03	1	1
Cutt of	>0.50	<0.50	>0.50	<0.50	>0.50	<0.50	<1.23	>1.23	>0.50	<0.50
Sample	9	9	9	9	9	9	9	9	9	9

Source: Authors' calculations based on data from financial reports, Business Register Agency

The median values for bankrupt companies indicate that the VB, P, Z', and Ohlson models generally classified the operations of the analyzed firms as at risk, reflecting a high probability of bankruptcy. Conversely, the median values associated with financially stable companies suggest that the VB, DB, Z', and Ohlson models effectively assessed the bankruptcy risk. Furthermore, the results about the standard deviation of the Z' score reveal a significant disparity in bankruptcy risk between stable and at-risk companies. The other models employed logit analysis, producing values ranging from 0 to 1 with minimal standard deviation.

The evaluation of the adequacy of the analyzed models for agricultural companies, as assessed through overall model performance and the incidence of type I and type II errors, is presented in Table 2.

Table 2. Evaluation of the adequacy of individual model utilization in agricultural companies

Elements	Models				
	VB	DB	P	Z'	Ohlson
AB	9	4	8	7	8
FB	0	5	1	2	1
AS	7	6	4	9	8
FS	2	3	5	0	1
Overall accuracy (%)	88.89	55.56	66.67	88.89	88.89
Error type I (%)	0	27.78	5.56	11.11	5.56
Error type II (%)	11.11	16.67	27.78	0	5.56
AB-accurate bankrupt; FB-false bankrupt; AS-accurate stable; FS-false stable					

Source: Authors' calculations

Based on the results presented in Table 2, it can be concluded that the VB model effectively identified bankrupt agriculture companies while achieving a perfect assessment with no type I errors. Sandin and Porporato (2008) highlight that type I errors represent a tangible loss for shareholders, bankers and other stakeholders, whereas type II errors are associated with opportunity costs. The VB model exhibited a type II error rate of 11.11%, incorrectly classifying 2 out of 9 stable companies as bankrupt ones. In contrast, the DB model displayed the highest type I error rate at 27.78%, misclassifying 5 out of 9 bankrupt companies as stable and without risk. The highest error rate II (27.78%) has model P. In comparison, the Ohlson and Altman Z' score models exhibited generally lower error rates than the aforementioned models, which is noteworthy given that they were formulated for economic contexts that differ significantly from that of the Republic of Serbia. Notably, Altman's Z' score successfully evaluated all analyzed stable companies, achieving a type II error rate of 0%.

Descriptive statistics about the outcomes of the applied models for both stable and bankrupt companies in the food sector are presented in Table 3.

Table 3. Descriptive statistics for applied models in food processing companies

Elements	Models									
	VB		DB		P		Z'		Ohlson	
	bankrupt	stable	bankrupt	stable	bankrupt	stable	bankrupt	stable	bankrupt	stable
Mean	0.95	0.25	0.60	0.28	0.93	0.44	-0.58	8.85	0.88	0.21
Median	1	0.09	0.91	0	0.94	0.38	-0.02	8.01	0.97	0.07
Standard deviation	0.11	0.34	0.46	0.42	0.02	0.37	3.41	5.71	0.27	0.32
Minimum	0.64	0	0	0	0.86	0	-10.02	2.98	0.03	0.01
Maximum	1	1	1	0.97	0.95	0.93	5.14	25.27	1	0.92
Cutt of	>0.50	<0.50	>0.50	<0.50	>0.50	<0.50	<1.23	>1.23	>0.50	<0.50
Sample	12	12	12	12	12	12	12	12	12	12

Source: Authors' calculations based on data from financial reports, Business Register Agency

The median values for bankrupt companies indicate that the models employed in this study generally classified the business operations of the analyzed enterprises as financially vulnerable, reflecting a heightened probability of bankruptcy. This suggests that the predictive models used were sensitive to the financial patterns typically associated with distressed companies. Additionally, the median values recorded for financially stable companies further demonstrate the effectiveness of the models in accurately identifying enterprises with low bankruptcy risk. This distinction reinforces the discriminatory power of the tested models in differentiating between solvent and insolvent entities. Furthermore, the analysis of standard deviation values for Altman's Z' score reveals a pronounced variability between the two groups, underscoring a significant separation between stable and bankrupt companies. These findings confirm that the Z' score not only captures central tendencies effectively but also reflects the dispersion of risk across the analyzed companies, thus supporting the model's robustness in practical applications.

The assessment of the adequacy of the analyzed models for companies in the food sector, based on overall model performance and the incidence of type I and type II errors, is presented in Table 4.

Table 4. Evaluation of the adequacy of individual model utilization in food processing companies

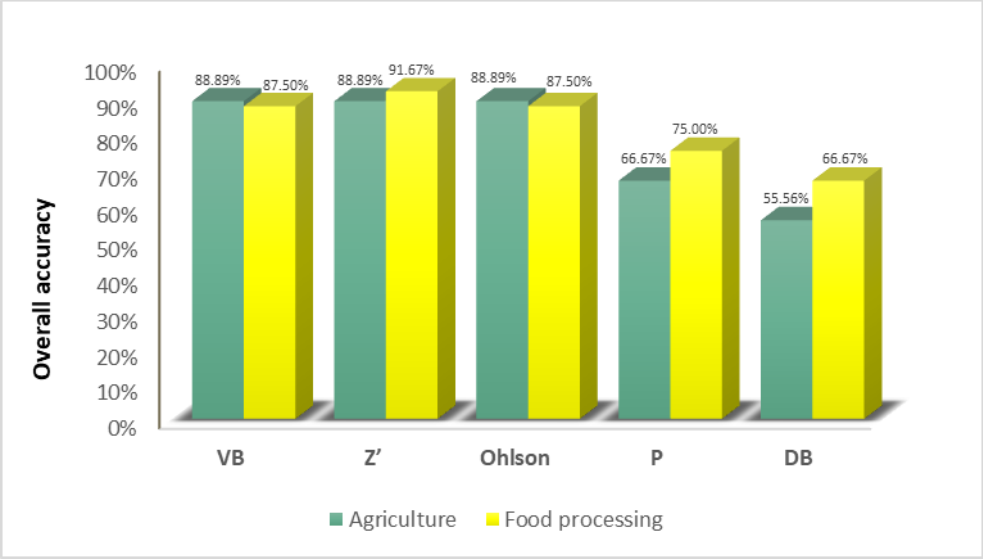
Elements	Models				
	VB	DB	P	Z'	Ohlson
AB	12	7	12	10	11
FB	0	5	0	2	1
AS	9	9	6	12	10
FS	3	3	6	0	2
Overall accuracy (%)	87.50	66.67	75	91.67	87.50
Error type I (%)	0	20.83	0	8.33	4.17
Error type II (%)	12.50	12.50	25	0	8.33
AB-accurate bankrupt; FB-false bankrupt; AH-accurate stable; FS-false stable					

Source: Authors' calculations

Based on the results presented in Table 4, it can be concluded that the VB and P models were the most effective in classifying bankrupt companies, as they successfully evaluated all enterprises that had initiated bankruptcy proceedings. The Z' score also effectively identified all stable companies from the food sector, indicating a complete absence of type II error. Conversely, the DB model exhibited the highest type I error rate at 20.83%, misclassifying 5 out of 12 bankrupt companies as stable and without bankruptcy risk. Additionally, the P model recorded the highest type II error rate at 25%.

A comparative analysis of the overall accuracy of the analyzed models for agricultural and food companies is presented in Figure 1.

Figure 1. The overall accuracy of individual models in analyzing the initiating of bankruptcy proceedings



Source: Authors' calculations

In assessing the likelihood of initiating bankruptcy proceedings for agricultural companies, the VB, Z' and Ohlson models exhibit the highest levels of accuracy. Although these models share identical overall accuracy scores of 88.89% in classifying companies financial integrity, the VB model holds a slight advantage due to the absence of Type I error. When examining the results for food processing companies, it is evident that the same models are the most effective for classification, with Altman's Z' score achieving the highest accuracy rate of 91.67%. While Stanišić et al. (2013) did not focus exclusively on agricultural and food companies, they also concluded that Altman's Z' score is applicable for analyzing the potential for bankruptcy proceedings in the Republic of Serbia. In contrast, Muminović et al. (2011) and Mizdraković and Bokić (2016) highlighted the limitations of using this model. The influence of varying economic dynamics and sectoral differences on the performance of specific models is demonstrated through the results of the DB model. Initially, this general model

exhibited an average accuracy rate of 92.1% on the development sample and 87.8% on the test sample in 2016. However, the findings of this study indicate a notable decrease in the model's predictive accuracy, which dropped to 55.56% for agricultural and 66.67% for food processing companies. This reduction suggests that the model may have limitations when applied to current sector-specific conditions.

Conclusions

The study focuses on assessing the appropriateness of implementing various models for bankruptcy prediction. Specifically, it examines Altman's Z'-score, Ohlson, VB, DB, and P models using a sample comprising both financially stable and bankrupt companies within the agricultural and food sectors. Through an analysis of the performance of these models across different sectors, this research aims to enhance the understanding of their predictive capabilities and to identify which models provide the most reliable estimates of bankruptcy risk.

The findings of this research indicate that the VB model was the most effective in assessing the financial stability of agricultural companies. Although this model was originally developed for the processing industry, analysis suggests it is adaptable to the unique financial indicators of the agricultural sector. Conversely, Altman's Z' score emerged as the most suitable model for companies in the food processing industry. Based on the conducted analysis, the research hypothesis stating that the applied models successfully forecasted bankruptcy within the analyzed agricultural and food processing companies is confirmed. However, these conclusions should be interpreted with caution due to the limited sample size, which may not fully reflect the broader structure of the analyzed industries. A larger and more diverse sample would facilitate a more robust statistical analysis and could yield different insights regarding the effectiveness of the analyzed models. Furthermore, the exclusive focus on two sectors constrains the comparability of the results. Broadening the scope of future research to cover multiple industries could significantly improve the understanding of how different models perform in varying economic contexts. Another limitation arises from the reliance on historical financial data, which may not adequately reflect current trends. Economic conditions, regulatory changes, and technological advancements can significantly influence bankruptcy risk, yet these factors were not incorporated into the implemented models. Future models could have a wider array of variables, including macroeconomic indicators, industry-specific risks, and qualitative factors. Moreover, the rapid advancement of artificial intelligence and machine learning presents opportunities to enhance bankruptcy prediction models. The integration of advanced analytical techniques could improve predictive accuracy and responsiveness to dynamic economic climate. Future research could also include hybrid models that combine traditional financial metrics with machine learning algorithms, potentially resulting in more sophisticated and adaptable bankruptcy prediction tools. Furthermore, while the study assessed the accuracy of the chosen models, the practical implementation was

not thoroughly discussed due to the scale constraints of the research. Understanding how these models can be effectively implemented in practice, such as risk assessments conducted by company management, represents a significant area for future research. The findings of this research offer valuable implications for policymakers, financial professionals, and the scientific community. For policymakers, the demonstrated effectiveness of sector-specific models such as the VB and Altman Z' score highlights the need to support the development and application of tailored risk assessment tools in regulatory and economic planning frameworks. Financial professionals, including investors and creditors, may leverage these insights to enhance early warning systems and improve decision-making processes related to credit risk and financial sustainability. For the academic community, the study underscores the importance of advancing predictive methodologies and integrating interdisciplinary approaches. In conclusion, this research offers a comprehensive assessment of bankruptcy prediction models within the agricultural and food industry sectors, providing valuable insights into the effectiveness of the VB and Altman Z' score models. Ultimately, as economies evolve, refining these models will be essential for aiding businesses and investors in making informed decisions, thereby enhancing financial stability and mitigating the risks associated with bankruptcy.

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Conflict of interests

The authors declare no conflict of interest.

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