DOI 10.2478/sbe-2025-0037
SBE no. 20(2) 2025

ALTMAN Z-SCORE MODELING AND FINANCIAL RISK ANALYSIS: AN EMPIRICAL STUDY ON COMPANIES LISTED ON THE BUCHAREST STOCK EXCHANGE

Cristi SPULBAR
University of Craiova, Romania

Dumitru CINCIULESCU
University of Craiova, Romania

Cezar Catalin ENE
University of Craiova, Romania

Lucian Florin SPULBAR
University of Craiova, Romania

Abstract:

The Altman Z-score model stands out due to its broad applicability and ability to provide a predictive assessment of firms' financial vulnerabilities, being widely used to determine insolvency probability based on specific financial indicators, thus representing a valuable tool for analyzing company performance. Economic volatility, fiscal regulations with low predictability, as well as the particular structure of firms listed on the Romanian capital market (BSE), necessitate rigorous evaluations of financial risk. Although common indicators such as asset profitability or gross margin are frequently included in risk models, other factors like operating expenses or book value per share remain insufficiently explored in local literature. Addressing this research gap, this study quantitatively examines the relationship between the Altman Z-score and selected financial indicators relevant to companies listed on the Bucharest Stock Exchange, aiming to identify key determinants of financial stability and validate the model's applicability in this specific context. Using multiple linear regression on financial data sourced from the TradingView database, the research investigates whether operating expenses, operating income, book value per share, and gross margin significantly influence the Altman Z-score. Methodologically, successive adjustments will enhance model robustness by addressing multicollinearity and autocorrelation, supported by statistical tests verifying model validity and reliability.

Key words: *Altman Z-score, financial risk, insolvency prediction, financial indicators, Bucharest Stock Exchange*

1. Introduction

The analysis of financial risk constitutes a significant area of interest for researchers, investors, economists, and business decision-makers alike. Within a global economic environment characterized by uncertainty and considerable market fluctuations, the identification of factors influencing corporate financial stability has become increasingly important. Among established bankruptcy-risk assessment models, the Altman Z-score is distinguished by its extensive applicability and predictive capability regarding firms' financial vulnerabilities. This model is widely employed to estimate insolvency probability using specific financial indicators, thereby representing a valuable analytical tool for assessing corporate performance.

The literature highlights the relevance of the Altman Z-score across diverse markets and sectors. While extensively calibrated for developed economies, the model's application in emerging markets like Romania requires further examination due to specific local attributes. Previous research confirms that financial indicators such as asset profitability, operating expenses, operational profitability, and capital structure significantly affect corporate performance, although their relationships with the Z-score vary by market. Thus, analyzing firms listed on the Bucharest Stock Exchange can yield insights into the model's suitability in Romania.

In the Romanian market, economic volatility, political-fiscal regulations characterized by low predictability, as well as the specific structure of listed firms, necessitate rigorous assessments of financial risk. In this context, examining the relationship between the Altman Z-score and the financial indicators of Romanian companies becomes essential for a deeper understanding of the mechanisms influencing their financial stability. While certain financial variables, such as return on assets (ROA) or gross margin, are frequently employed in risk evaluation models, the impact of other factors, including operating expenses or book value per share, remains inadequately explored within the local market's academic literature.

This research aims to examine the relationship between the Altman Z-score and key financial indicators—operating expenses, operating income, book value per share, and gross margin—of companies listed on the Bucharest Stock Exchange (BSE). Using multiple linear regression analysis, the study evaluates these indicators' contributions to corporate financial stability and tests the Altman Z-score's applicability in Romania. Unlike previous studies conducted primarily in developed economies, this research specifically targets the Romanian context, providing valuable insights for investors and managers regarding financial risk assessment and laying the groundwork for further refinement of local bankruptcy prediction models.

2. Literature review

Kapounek et al. (2022) analyzed the predictive accuracy of the Altman Z-score model for European private companies, noting superior performance for large firms and identifying liquidity and capital structure as key factors influencing financial stability. They also emphasized that robust institutional frameworks could prolong distress periods, potentially leading to overstated insolvency risks, and recommended adjustments during recessions, when asset value declines increase bankruptcy likelihood. Similarly, Lizarzaburu (2014) indicated that the Z-score model's effectiveness in the Peruvian market depends on firms' financial characteristics and the broader economic context, suggesting that external interventions and financial restructuring efforts necessitate model adaptations to improve predictive accuracy.

From another point of view, Nurul & Zulfiati (2019) analyzed state-owned enterprises listed on the Indonesian Stock Exchange, observing that over 50% were classified as high-risk by the Altman Z-score, yet this was not mirrored in their market valuation due to implicit government backing. Thus, the Z-score's universal applicability might be limited in markets with significant state involvement, potentially overstating bankruptcy risks. Joshi (2020), investigating public-sector banks in India, found Z-scores generally above the 2.9 safety threshold but noted significant variations driven by profitability and asset quality. Specifically, a 1% rise in non-performing loans led to a 3.1% decline in Z-score, while a 1% profit increase boosted the score by 15.31%, highlighting the strong influence of profitability and asset management on financial stability.

Singh & Singla (2021) highlighted that firms with higher Altman Z-scores, indicative of lower bankruptcy risk, provided higher stock returns in India's corporate sector, challenging traditional risk-return assumptions. Their findings confirmed the Z-score's effectiveness in forecasting returns across varying investment horizons, though with differing accuracy levels. In Indonesian manufacturing companies, bankruptcy risk was notably influenced by liquidity (WCTA), operational profitability (EBITTA), and sales efficiency (STA), while retained earnings and market equity had limited impact, emphasizing the need for industry-specific adaptations of the model (Lestari et al., 2022). Additionally, higher managerial and institutional ownership in Bangladesh's financial sector was associated with lower financial distress, whereas foreign ownership increased risk due to governance issues, underscoring the importance of ownership structure reforms (Alam et al., 2024).

A significant positive correlation between the Altman Z-score and return on equity (ROE) was found in the airline industry, indicating that more financially stable firms typically demonstrate higher profitability. Regression analysis showed that improvements in Z-score were directly linked to higher ROE, confirming the usefulness of Z-score as a performance indicator beyond this specific sector, including potentially for firms listed on the Bucharest Stock Exchange (Willey et al., 2023). Similarly, the Altman model was effective in identifying financially distressed insurance firms listed on the Amman Stock Exchange, though accuracy varied with financial structure and sector-specific traits, highlighting its applicability as an early warning tool (Al-Manaseer & Al-Oshaibat, 2018). Altman et al. (2014) emphasized international variability in the model’s accuracy, ranging from approximately 75% overall to above 90% in specific countries. However, they noted limitations of standardized coefficients across different national contexts, recommending recalibration and additional country-specific variables to improve predictive precision, aspects relevant for our current analysis.

In analyzing commercial firms in Colombia, a positive relationship between the Altman Z-score and equity-to-liabilities ratio was identified, implying firms with higher equity experience lower financial distress risk, though liquidity and profitability played secondary, industry-specific roles (Isaac-Roque & Caicedo-Carrero, 2023). Examining conventional versus Islamic insurers, higher Z-scores were observed among Islamic firms, attributed primarily to differences in capital structures and risk management. Notably, asset-based earnings and equity ratios significantly influenced stability, underscoring the impact of business models on Altman outcomes (Nustini & Amiruddin, 2019). Conversely, Marais et al. (2014), assessing industrial firms on the Johannesburg Stock Exchange, found only weak correlations between the Z-score and short-term financial performance indicators like ROA and stock returns, suggesting limited applicability of the Altman model for predicting financial success outside manufacturing contexts, thus emphasizing the necessity for sector-specific model adjustments.

Ene (2023) used regression analysis to explore macroeconomic impacts on non-governmental credit in Romania (2013-2022), finding significant positive relationships of inflation (coefficient 3286.83), unemployment rate (4204.96), and M2 money supply (0.35) on credit dynamics. Spulbar & Ene (2024), employing VAR analysis, confirmed significant interactions between Romania's BET index, inflation rate, monetary policy rate, and exchange rate, emphasizing the role of macroeconomic indicators in predicting financial stability. Elewa (2022) assessed the Altman Z-score's applicability for Egyptian firms, revealing that working capital (WCTA) and operational profitability (EBITTA) strongly predicted bankruptcy, while market equity had limited predictive ability. These studies collectively underline the importance of macroeconomic and financial indicators, supporting our approach to validating the Altman Z-score model in the Romanian context.

3. Methodology

3.1. Theoretical Framework and Research Hypotheses

The selection of variables employed in this analysis aligns with the relevant academic literature and the research objectives, focusing on identifying financial factors influencing corporate stability. The Altman Z-score model was chosen as the dependent variable due to its recognition as one of the foremost predictive frameworks for bankruptcy risk assessment. Additionally, several pertinent financial indicators were integrated as independent variables, namely: Return on Assets (ROA), operating expenses (excluding the cost of goods sold), operating income, net income, book value per share, Return on Equity (ROE), gross margin, Quick ratio, and Current ratio.

The Altman Z-score was originally developed to assess bankruptcy risk specifically within the manufacturing sector and was not initially calibrated for application to service-oriented companies or financial institutions such as banks. The calculation formula for the Z-score is:

$$Z - Score = 1.2A + 1.4B + 3.3C + 0.6D + 1.0E$$

where:

- *A* = Working capital / Total assets, measuring liquidity;
- *B* = Retained earnings / Total assets, assessing long-term financial stability;

- *C* = Earnings before interest and tax / Total assets, indicating operational profitability;
- *D* = Market value of equity / Total liabilities, reflecting the capacity to absorb losses;
- *E* = Revenues / Total assets, evaluating asset efficiency in revenue generation.

Interpreting this model, a Z-score exceeding 3.00 indicates a low probability of bankruptcy, while a score below 1.81 signals a high risk of insolvency. Although this model provides a probabilistic classification method for assessing corporate bankruptcy risk, existing scholarly literature emphasizes that its predictive performance may differ according to industry characteristics, capital structure, and specific economic conditions prevalent in each market. These limitations necessitate further analysis of the selected independent variables to better elucidate their influence on the financial stability of the firms under investigation.

Return on Assets (ROA), calculated as net income divided by average total assets, measures a firm's effectiveness in generating profit from asset utilization. A high ROA suggests efficient asset management, while a low ROA indicates possible operational inefficiencies or revenue difficulties. Since optimal ROA values depend on industry and economic conditions, this study includes ROA as an independent variable to analyze its impact on corporate stability using multiple regression analysis.

Operating Expenses (excluding COGS) comprise indirect costs essential to business operations, such as administrative salaries, rent, marketing, and depreciation. Elevated operating expenses may signal inefficiencies harming profitability, while unusually low levels could reflect insufficient investment. This indicator, included as an independent variable in this study, assesses the impact on corporate stability and bankruptcy risk (Altman Z-score).

Operating income reflects profit from primary business activities, excluding interest, investments, and taxes. It indicates operational efficiency and business sustainability. High operating income implies effective cost management, whereas low or negative values suggest operational problems. This indicator is included in the regression analysis to examine its relationship with corporate financial stability.

Net profit is the final earnings after deducting all costs, including taxes, interest, and dividends. Positive net profit indicates overall financial health and investment capability, whereas negative values highlight potential instability or risk. Interpretation requires context, considering strategic and industry-specific factors. Firms consistently reporting higher net profits typically enjoy better growth and financing opportunities compared to those with persistently low or negative earnings.

Book Value per Share (BVS) is calculated by dividing common shareholders' equity by the number of common shares outstanding, representing the net asset value attributable to each share. Unlike market value, which reflects investor expectations, BVS offers an objective measure of a company's equity value. A BVS higher than the share price may indicate undervalued stock and potential investment opportunities, while a lower BVS compared to market price suggests investor expectations of future growth or intangible factors not captured in financial reports.

Return on Equity (ROE) evaluates how efficiently a company generates profit from shareholders' equity, calculated by dividing net income by average equity. A high ROE suggests effective capital management and strong growth potential, while a low ROE indicates possible inefficiencies or excessive reliance on debt. Interpretation of ROE must consider industry context, as capital-intensive sectors typically have lower values compared to service-oriented or technology firms. Additionally, high leverage can artificially inflate ROE; thus, analyzing it alongside debt ratios and Return on Assets ensures a balanced assessment.

Gross margin is an important financial indicator reflecting a firm's efficiency in managing direct production costs, calculated as the proportion of revenue remaining after deducting these costs. A high gross margin typically signals effective cost control and robust competitive positioning, while a lower margin may indicate higher production costs or intense market pressures. Variations in gross margin require careful interpretation. A stable margin often suggests a strategic pricing approach designed to manage profitability through economic cycles—absorbing cost increases during downturns and moderately raising prices in favorable conditions. However, this strategic adjustment could obscure underlying financial weaknesses, leading the Altman Z-score to underestimate bankruptcy risk due to maintained superficial stability. Conversely, substantial fluctuations in gross margin might highlight operational instability or high sensitivity to external economic changes, potentially increasing vulnerability and bankruptcy risk.

Within this study's regression analysis, a negative relationship between gross margin and Altman Z-score could suggest either strategic pricing adjustments to maintain competitiveness or exposure to operational and market risks. Thus, analyzing gross margin alongside complementary indicators such as operating income, expenses, and asset returns is essential to accurately assess its influence on firm stability.

The Quick Ratio (Acid-Test Ratio) assesses a firm's short-term liquidity using its most liquid assets, excluding inventories, offering a conservative view especially relevant in industries with slow-moving inventories. A Quick Ratio above 1 indicates sufficient liquidity, while values below 1 may raise liquidity concerns. However, optimal Quick Ratio levels vary by sector; industries like retail or manufacturing typically have lower ratios without necessarily facing liquidity issues, whereas service or tech sectors may require higher ratios.

The Current Ratio evaluates a company's short-term liquidity by comparing total current assets to current liabilities. A ratio greater than 1 suggests adequate liquidity, while values below 1 indicate potential financial challenges. Yet, excessively high Current Ratios could signify inefficient resource use, such as excessive cash holdings or inflated inventories, while lower ratios do not always imply distress, especially in industries with stable cash flow or easy financing access.

Based on our focus, econometric hypotheses will be tested, enabling the formulation of substantiated conclusions regarding the relationships among the analyzed variables:

a) Main Hypothesis (H1):

There is a statistically significant relationship between Return on Assets (ROA), operating expenses (excluding COGS), operating income, net profit, book value per share, Return on Equity (ROE), gross margin, Quick Ratio, and Current Ratio, and the Altman Z-score. This hypothesis aims to assess whether these financial factors have a direct impact on the firms' financial stability and bankruptcy risk.

b) Secondary Hypotheses:

- H2: ROA, net profit, and ROE exert a positive effect on the Altman Z-score. An increase in these indicators reflects higher profitability, which should enhance the financial stability of the company.
- H3: Operating expenses (excluding COGS) have a negative effect on the Altman Z-score. An increase in these expenses may negatively impact financial stability by reducing profitability and placing additional pressure on the company's resources.
- H4: Operating income and book value per share positively influence the Altman Z-score. Companies generating higher operating income and possessing solid equity positions exhibit greater financial stability and lower bankruptcy risk.
- H5: Gross margin has an uncertain impact on the Altman Z-score. A relatively stable gross margin may indicate strategic adaptability to economic fluctuations, whereas a sudden increase or decrease may reveal operational vulnerabilities that compromise financial stability.
- H6: Quick Ratio and Current Ratio positively influence the Altman Z-score. Companies maintaining higher levels of liquid assets experience lower insolvency risk due to more effective management of short-term financial obligations.

c) Variable Selection Hypothesis (H7):

From the initial set of financial variables, it is likely that only operating expenses (excluding COGS), operating income, book value per share, and gross margin will be retained in the final regression model, as the other variables either may lack statistical significance or present multicollinearity issues. This hypothesis aims to examine whether a more concise selection of variables preserves the validity of the analysis and provides a robust prediction of the Altman Z-score.

d) Null Hypothesis (H0):

For each of the formulated hypotheses, the corresponding null hypothesis (H0) states that there is no statistically significant relationship between the analyzed financial variables and the Altman Z-score. Econometric testing of these hypotheses will determine if the observed effects are statistically relevant and whether the identified relationships can meaningfully inform interpretations regarding corporate bankruptcy risk.

3.2 Design and Implementation of the Model

The dataset used covers the period from Q1 2018 to Q4 2023, consisting of quarterly data for 14 companies listed on the Bucharest Stock Exchange (BETPlus index components). To enhance robustness and reduce firm-specific variability, the data was transformed by averaging across the entire time series, resulting in 24 quarterly observations per variable. This approach allowed clearer identification of general trends and improved comparability across firms.

The econometric model applies multiple linear regression to quantify the impact of operating expenses, operating income, book value per share, and gross margin on

Altman's Z-score, providing insights into the financial stability and bankruptcy risk of these companies.Financial data for this analysis were sourced from TradingView, a specialized platform known for accurate and up-to-date information on publicly listed companies. Multiple linear regression was employed to test hypotheses and evaluate relationships between selected financial variables and the Altman Z-score, providing clear insights into each variable's effect on the financial stability and bankruptcy risk of the analyzed firms.

Table 1 presents the variables used in the analysis, along with their corresponding measurement units and associated acronyms. Each variable is defined according to the specific financial indicator it measures, with units explicitly indicated to ensure the comparability and interpretability of the results:

Table 1. Variables used, measurement units, and acronyms after transformation

Acronim	Indicator	Unitate de măsură	Acronim după transformări
AZ_score	Altman Z-score	Unitless	AZ_score_YJ
ROA	Return on Assets	Percent (%)	ROA_YJ ROA_QT
OP_E	Operating Expenses (excluding COGS)	Currency (RON)	OP_E_YJ
OP_I	Operating Income	Currency (RON)	OP_I_YJ
NET_IN	Net Income	Currency (RON)	NET_IN_YJ
BVS	Book Value per Share	Currency per share	BVS_YJ
ROE	Return on Equity	Percent (%)	ROE_YJ ROE_QT
GR_M	Gross Margin	Percent (%)	GR_M_YJ
Q_R	Quick Ratio	Unitless	Q_R_YJ
C_R	Current Ratio	Unitless	C_R_YJ

Source: Author's computations

The variables were denoted using intuitive acronyms reflecting each indicator's nature. In cases where statistical transformations were applied, these were indicated using specific suffixes. For instance, variables transformed using the Yeo-Johnson method were marked with the suffix _YJ, while those subjected to quantile transformations were designated with _QT. This naming convention ensures transparency in the analytical process and facilitates tracking adjustments made to the original dataset.

The Yeo-Johnson transformation extends the Box-Cox method, enabling its application to the entire range of real numbers, including variables containing negative or zero values (Yeo & Johnson, 2000). This approach employs a family of power transformations aimed at adjusting data distributions to reduce skewness and enhance normality. Unlike other methods, Yeo-Johnson preserves the advantages of maximum likelihood estimation without requiring artificial shifts of the analyzed variable. The procedure involves determining an optimal parameter, lambda, which maximizes the likelihood of achieving a near-normal distribution. Within this study, applying the Yeo-

Johnson transformation aimed to stabilize variance and enhance the interpretability of relationships between variables, thereby improving subsequent econometric modeling.

The quantile-based transformation is utilized in data analysis to modify a variable's distribution so that it aligns with a predefined distribution, thereby reducing skewness and mitigating the influence of extreme values. This method is frequently applied in econometric models to strengthen the validity of statistical assumptions and to enhance the robustness of estimations (Bogner et al., 2012). Its relevance stems from its capacity to address non-symmetrical distributions and minimize estimation errors in contexts characterized by data heterogeneity (Jawed & Schmidt-Thieme, 2022).

In the present study, quantile transformation was applied to the ROA and ROE variables due to percentage nature, imposing strict lower and upper boundaries that potentially lead to strongly skewed distributions. The academic literature highlights the efficiency of this method in improving the accuracy of statistical models, particularly in economic time series analysis (Bogner et al., 2012; Erdogan, 2023). Furthermore, existing studies confirm the advantages of quantile transformations in achieving symmetric distributions and in reducing the impact of outliers on statistical analyses (Bogner et al., 2012; Erdogan, 2023; Jawed & Schmidt-Thieme, 2022).

The analysis was conducted using Python, leveraging specialized libraries for data processing and econometric modeling. Data manipulation utilized pandas and numpy for efficient handling and numerical operations. Visualization was performed using seaborn for histograms and correlation matrices, and matplotlib for customized graphical interpretations of results.

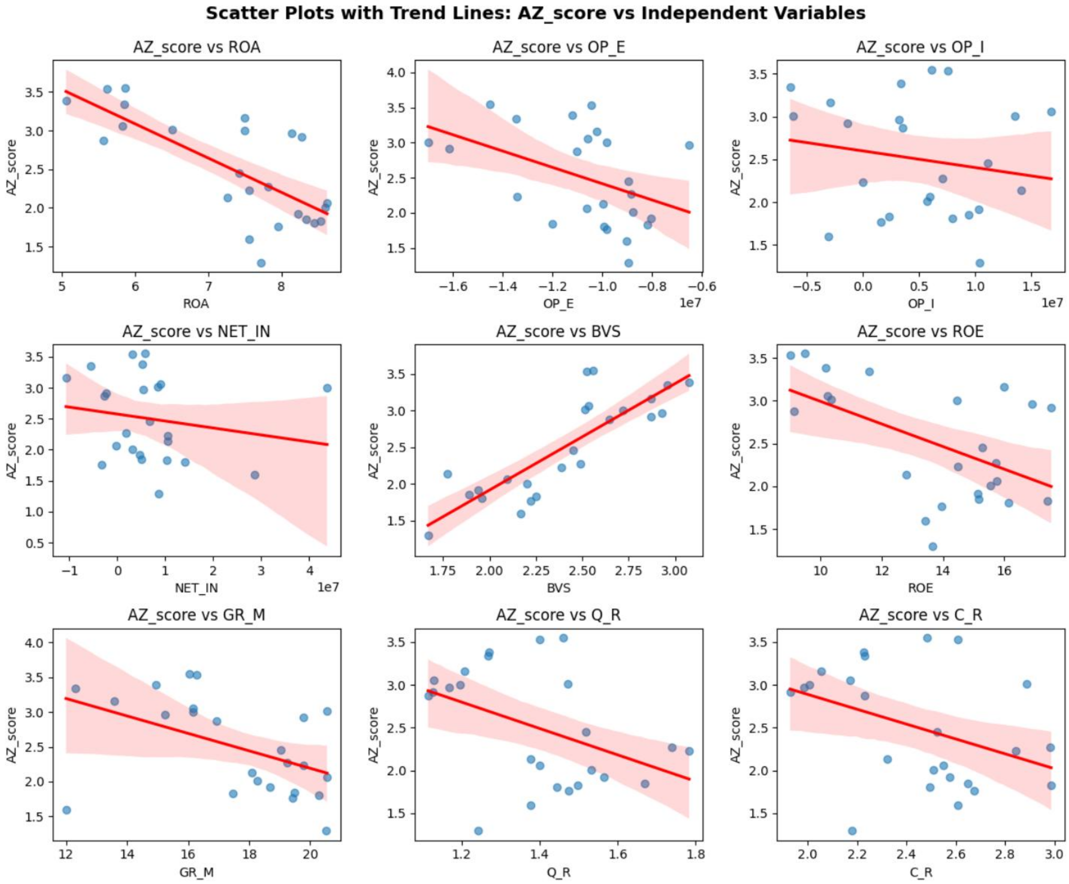
Econometric models were estimated using the statsmodels package, applying Ordinary Least Squares (OLS) regression and tests for heteroscedasticity (Breusch-Pagan, White), autocorrelation (Breusch-Godfrey), and specification (Ramsey RESET). Model evaluation employed metrics such as Mean Squared Error (MSE), Adjusted R^2, and Mean Absolute Error (MAE) via sklearn.metrics, with sklearn.linear_model used to verify estimate stability. Variable transformations to improve normality were performed using the Yeo-Johnson method (scipy.stats) for negative or zero values and the QuantileTransformer (sklearn.preprocessing) for skewed distributions.

4. Empirical Research Results and Their Economic Implications

Regarding the preliminary analysis of the indicators, Fig. 1 illustrates the initial relationships between the Altman Z-score and the independent variables utilized in the analysis, based on raw data processing without applying transformations. It is important to note that these relationships do not account for potential issues such as heteroscedasticity, multicollinearity, or non-Gaussian distributions of variables, which may introduce biases or distortions in interpreting underlying trends.

Firstly, it is notable that ROA exhibits a negative relationship with the Altman Z-score, which contradicts theoretical expectations. Typically, higher asset profitability should correlate with a lower probability of bankruptcy. This anomaly may be explained by sector-specific effects, variations in capital structure, or corporate strategies aimed at tax optimization. Operating expenses (excluding COGS) demonstrate a strong negative relationship with the Z-score, which aligns intuitively, as elevated costs negatively affect profitability and, consequently, the financial stability of the firm. Conversely, operating income displays a positive relationship with the Z-score, confirming that companies generating higher revenues tend to exhibit greater financial stability.

Fig. 1. Scatter plots and relational trends between Altman Z-score and explanatory variables



Source: Author's elaboration based on the research methodology

A strong positive relationship between book value per share (BVS) and Altman Z-score indicates that firms with higher net assets are perceived as more financially stable, aligning with established financial theory. Conversely, gross margin (GR_M) unexpectedly shows a negative relationship with Z-score, suggesting companies may strategically adjust margins during challenging periods, masking financial instability. Additionally, liquidity indicators such as quick ratio (Q_R) and current ratio (C_R) exhibit negative relationships with the Z-score, implying that firms with excessive liquidity may not necessarily have greater stability or productivity.

These preliminary results reveal economically intuitive relationships for certain variables, such as operating expenses and operating income, yet they raise questions regarding the unexpected findings for ROA and gross margin. Given that the data are untransformed and in raw form, these relationships may be affected by issues such as heteroscedasticity, skewed distributions, or sector-specific influences. Consequently, subsequent analysis employing multiple linear regression and appropriate data transformations will be essential to verify the robustness of these relationships.

The analysis of correlations among the independent variables suggests the presence of multicollinearity concerns, as indicated in Fig. 2, potentially affecting the stability of regression estimates. A notably strong relationship is observed between Return on Assets (ROA) and Return on Equity (ROE), implying redundancy in the informational content provided by these variables. Such high correlations could lead to distorted coefficient estimates, complicating the task of isolating the individual impact of each variable on the Altman Z-score.

Fig. 2. Correlation Matrix of Variables Included in the Analysis

	AZ_score	ROA	OP_E	OP_I	NET_IN	BVS	ROE	GR_M	Q_R	C_R
AZ_score	1.000000	-0.728174	-0.437251	-0.179352	-0.181342	0.838374	-0.529291	-0.473757	-0.432689	-0.398398
ROA	-0.728174	1.000000	0.255365	-0.054579	0.095333	-0.505788	0.919237	0.470970	0.355213	0.198440
OP_E	-0.437251	0.255365	1.000000	0.446544	-0.210619	-0.354369	0.184910	0.068258	0.193878	0.329007
OP_I	-0.179352	-0.054579	0.446544	1.000000	-0.107240	-0.503651	-0.224795	0.519580	0.217727	0.256802
NET_IN	-0.181342	0.095333	-0.210619	-0.107240	1.000000	-0.181916	0.021858	-0.090714	0.000736	0.002152
BVS	0.838374	-0.505788	-0.354369	-0.503651	-0.181916	1.000000	-0.207655	-0.541571	-0.449817	-0.409931
ROE	-0.529291	0.919237	0.184910	-0.224795	0.021858	-0.207655	1.000000	0.298148	0.224525	0.034384
GR_M	-0.473757	0.470970	0.068258	0.519580	-0.090714	-0.541571	0.298148	1.000000	0.439266	0.372874
Q_R	-0.432689	0.355213	0.193878	0.217727	0.000736	-0.449817	0.224525	0.439266	1.000000	0.859164
C_R	-0.398398	0.198440	0.329007	0.256802	0.002152	-0.409931	0.034384	0.372874	0.859164	1.000000

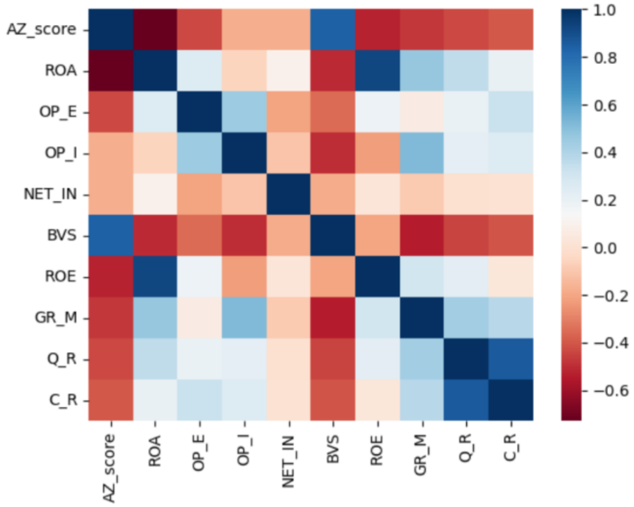
Source: Author's elaboration based on the research methodology

Another problematic relationship emerges between Book Value per Share and Return on Assets, indicating potential conceptual overlap between the equity structure and economic performance of the firms under analysis. Consequently, the simultaneous inclusion of both variables within the econometric model may increase coefficient instability, compromising the validity of subsequent interpretations.

Moreover, Current Ratio and Quick Ratio exhibit strong mutual correlation, which aligns with expectations given the similarity of metrics used for evaluating short-term payment capacity. This redundancy introduces concerns regarding perfect multicollinearity, necessitating careful selection between these variables to prevent numerical issues during the estimation process. Additionally, the negative correlation observed between Altman Z-score and Gross Margin contradicts theoretical expectations but may be explained by firms' strategic adjustments during periods of economic volatility.

This situation indicates that the analysis requires a suitable selection of variables and also a careful interpretation of economic relationships beyond mere statistical associations. To enhance the validity of the model, it is necessary to exclude or transform variables exhibiting high correlations and to perform additional multicollinearity tests, such as examining the Variance Inflation Factors (VIF).

Fig. 3. Heatmap of correlation coefficients among analyzed variables



Source: Author's elaboration based on the research methodology

High Variance Inflation Factors (VIF), as shown in Table 2, confirm significant multicollinearity, particularly for ROA and ROE, which exceed the threshold of 10, indicating redundancy. BVS also displays high VIF values, suggesting strong links to profitability and equity measures.

Table 2. Variance Inflation Factor (VIF) values before data processing

VIF before data processing	
Const	790.963961
AZ_score	12.178972
ROA	25.356082
OP_E	4.325350
OP_I	6.692308
NET_IN	1.419523
BVS	14.184129
ROE	19.781455
GR_M	4.621839
Q_R	5.639836
C_R	6.111835
dtype: float64	

Source: Author's elaboration based on the research methodology

Altman Z-score's elevated VIF values imply potential redundancy, given it is a composite indicator. Additionally, moderate VIF values for Current and Quick Ratios indicate redundancy due to conceptual overlap. Addressing these issues requires eliminating redundant variables, such as choosing between ROA or ROE, and employing transformations or combining variables to reduce multicollinearity.

To address multicollinearity and improve data distribution, transformations suited to each variable type were applied. The Yeo-Johnson method was used for Altman Z-score, operating expenses, operating income, net income, book value per share, and gross margin, effectively correcting skewness and improving normality without requiring strictly positive values. For percentage-based variables such as return on assets (ROA) and return on equity (ROE), a Quantile Transformer was applied, maintaining uniform distribution and reducing the impact of extreme values. This approach enabled the construction of a model wherein the influence of each independent variable on the Altman Z-score became clearer, reducing the distortions caused by initially uneven distributions.

The results derived from the multiple linear regression indicate a statistically robust model, as demonstrated by Table 3, with an R-squared of 0.947 and an adjusted R-squared of 0.913. These values suggest that the model explains a substantial proportion of the variability in the Altman Z-score. However, a critical evaluation of the coefficients and their statistical significance necessitates further adjustments to optimize the model.

Firstly, it is observed that net income (NET_IN_YJ), quick ratio (Q_R_YJ), and current ratio (C_R_YJ) have p-values exceeding 0.05, indicating that these variables are not statistically significant. The inclusion of these variables in the model may introduce noise into the estimations and potentially compromise the validity of the results. Consequently, these variables will be excluded to achieve a more refined and precise model.

Secondly, the analysis of the Durbin-Watson statistic reveals a value of 1.932, suggesting the absence of autocorrelation in the residuals, a positive attribute regarding the model's validity. However, the condition number (Cond. No.) of 5.57 is relatively high, indicating potential residual collinearity issues, albeit not to an alarming degree.

Table 3. Estimation of the OLS Regression Model with HAC Correction for Heteroscedasticity and Autocorrelation

OLS Regression Results			
Dep. Variable:	AZ_score_YJ	R-squared:	0.947
Model:	OLS	Adj. R-squared:	0.913
Method:	Least Squares	F-statistic:	70.51
Date:	Sun, 23 Feb 2025	Prob (F-statistic):	4.14e-10
Time:	23:40:44	Log-Likelihood:	-22.525
No. Observations:	24	AIC:	-25.05
Df Residuals:	14	BIC:	-13.27
Df Model:	9		
Covariance Type:	HAC		

	coef	**std err**	**z**	**P>|z|**	**0.025**	**0.975**
const	1.8676	0.019	96.125	0.000	1.830	1.906
ROA_QT	0.0912	0.027	3.353	0.001	0.038	0.145
OP_E_YJ	-0.1282	0.025	-5.147	0.000	-0.177	-0.079
OP_I_YJ	0.1912	0.047	4.077	0.000	0.099	0.283
NET_IN_YJ	-0.0104	0.011	-0.940	0.347	-0.032	0.011

BVS_YJ	0.4063	0.029	14.218	0.000	0.350	0.462
ROE_QT	-0.1150	0.031	-3.653	0.000	-0.177	-0.053
GR_M_YJ	-0.0746	0.035	-2.137	0.033	-0.143	-0.006
Q_R_YJ	0.0498	0.042	1.179	0.238	-0.033	0.133
C_R_YJ	-0.0654	0.042	-1.561	0.119	-0.147	0.017

Omnibus:	2.068	Durbin-Watson:	1.932
Prob(Omnibus):	0.356	Jarque-Bera (JB):	1.092
Skew:	-0.086	Prob(JB):	0.579
Kurtosis:	1.955	Cond. No.:	5.57

Notes:
[1] Standard Errors are heteroscedasticity and autocorrelation robust (HAC) using 1 lags and without small sample correction

Source: Author's elaboration based on the research methodology

Additionally, it is noted that ROA_QT, OP_E_YJ, OP_I_YJ, BVS_YJ, ROE_QT, and GR_M_YJ are statistically significant variables, with p-values below 0.05, confirming their relevance in explaining a company's probability of insolvency. However, the signs of the coefficients must be interpreted economically, as certain relationships may initially appear counterintuitive.

Therefore, refining the model by removing insignificant variables and reassessing the relationships among the remaining independent variables will enhance the accuracy of estimates and validate the econometric hypotheses formulated, as will be demonstrated in the subsequent analysis.

The resulting model, presented in Table 4, exhibits notable improvements over previous iterations from both statistical and economic interpretative perspectives. The adjusted R-squared coefficient is 0.921, indicating a strong explanatory power of the independent variables regarding variations in the Altman Z-score. Additionally, the F-statistic test (74.08, $p < 0.001$) confirms the overall statistical significance of the model.

Regarding the significance of coefficients, all included variables are relevant at a confidence level of at least 95%, confirming the robustness of the estimates. Return on Assets (ROA) shows a significant positive relationship with the Z-score, suggesting that firms that more efficiently utilize their assets are less likely to encounter financial distress. Operating expenses (excluding COGS) (OP_E_YJ) exhibit a negative coefficient, indicating that higher operational costs can weaken a company's financial stability—an economically intuitive outcome. Conversely, Operating income (OP_I_YJ) has a positive effect, highlighting the importance of operational earnings in maintaining solvency.

Table 4. Estimation of the OLS regression model with HAC correction for heteroscedasticity and autocorrelation after removing insignificant variables.

OLS Regression Results			
Dep. Variable:	AZ_score_YJ	R-squared:	0.941
Model:	OLS	Adj. R-squared:	0.921
Method:	Least Squares	F-statistic:	74.08
Date:	Sun, 23 Feb 2025	Prob (F-statistic):	3.04e-11

Time:	23:50:34	Log-Likelihood:	21.266
No. Observations:	24	AIC:	-28.53
Df Residuals:	17	BIC:	-20.29
Df Model:	6		
Covariance Type:	HAC		

	coef	std err	z	P>|z|	0.025	0.975
const	1.8676	0.022	86.654	0.000	1.825	1.910
ROA_QT	0.0892	0.028	3.168	0.002	0.034	0.144
OP_E_YJ	-0.1366	0.026	-5.240	0.000	-0.188	-0.085
OP_I_YJ	0.1964	0.053	3.688	0.000	0.092	0.301
BVS_YJ	0.4072	0.034	12.064	0.000	0.341	0.473
ROE_QT	-0.0998	0.033	-3.068	0.002	-0.164	-0.036
GR_M_YJ	-0.0832	0.042	-1.999	0.046	-0.165	-0.002

Omnibus:	0.258	Durbin-Watson:	1.732
Prob(Omnibus):	0.879	Jarque-Bera (JB):	0.438
Skew:	-0.157	Prob(JB):	0.803
Kurtosis:	2.417	Cond. No.:	3.43

Notes:
[1] Standard Errors are heteroscedasticity and autocorrelation robust (HAC) using 1 lags and without small sample correction

Source: Author's elaboration based on the research methodology

Book Value per Share (BVS_YJ), with a coefficient of 0.4072, indicates a direct relationship between the book value of shares and a company's financial stability, aligning with established financial theory. The negative coefficient for Return on Equity (ROE) (-0.0998) suggests that firms with higher shareholder profitability might have increased exposure to financial risks, potentially due to higher leverage or riskier investments. Gross Margin (GR_M_YJ), significant at the 5% threshold (p = 0.046), displays a negative coefficient (-0.0832), implying that firms maintaining elevated gross margins do not necessarily exhibit enhanced financial stability. This could reflect strategic margin adjustments undertaken by companies during economic downturns.

Regarding the statistical evaluation of the model, the Durbin-Watson statistic (1.732) does not indicate significant autocorrelation in the residuals, which is favorable for the validity of inferences. The Omnibus and Jarque-Bera (JB) statistics confirm that the residuals are approximately normally distributed, and the collinearity index (Cond. No. = 3.43) indicates that multicollinearity issues have been significantly mitigated by the applied transformations.

However, despite the acceptable values returned by the OLS model, additional tests were performed to verify the accuracy of the model. The estimated model raises several methodological and econometric concerns that require detailed critical analysis.

Table 5. Detection of Heteroscedasticity: Breusch-Pagan and White Tests.

Breusch-Pagan Test Results:
{'LM Statistic': 16.44, 'LM-Test p-value': 0.01, 'F-Statistic': 6.17, 'F-Test p-value': 0.0}
White's Test Results:
{'LM Statistic': 24.0, 'LM-Test p-value': 0.4, 'F-Statistic': nan, 'F-Test p-value': nan}

Source: Author's elaboration based on the research methodology

Firstly, the issue of heteroscedasticity is confirmed by the Breusch-Pagan test presented in Table 5, which reports a p-value of 0.01, indicating that the variance of the errors is not constant across the range of the independent variables. Thus, there is sufficient evidence to reject the null hypothesis and conclude that the model exhibits heteroscedasticity. This condition can result in inefficient estimators and incorrectly calculated standard errors, thereby affecting the validity of statistical inferences. Although the White test does not confirm heteroscedasticity, its results are influenced by the presence of NaN values, raising questions about the robustness of this test in the context of our data.

Subsequently, we will exclude the Return on Equity (ROE) variable from the analysis, as it does not meet economic foundations and introduces problems of multicollinearity and informational redundancy in the econometric model. Its calculation, defined as the ratio between net income and shareholder equity, directly incorporates net income as the numerator, explaining the perfect collinearity observed in the initial descriptive analysis. This collinearity suggests that ROE does not add new information to the model but rather introduces redundancy, affecting the stability of the estimates.

Furthermore, the inclusion of ROE in the regression may introduce distortions in the interpretation of the results, given that the model already incorporates components related to profitability and financial stability. Specifically, operational profit elements and shareholder equity are already factored into the Altman Z-score calculation.

The interpretation of the econometric model obtained, illustrated in Table 6, should be performed from both statistical and economic perspectives, taking into consideration the robustness of the coefficients, their statistical significance, and the direction of the estimated relationships.

The final model exhibits a coefficient of determination (R-squared) of 0.907, indicating that the selected explanatory variables successfully account for approximately 90.7% of the variation in the Altman Z-score, reflecting strong explanatory power. The adjusted R-squared of 0.881 further confirms the model's stability and demonstrates that the included variables provide significant explanatory value. Statistically, all coefficients associated with the relevant independent variables are significant at conventional confidence levels (particularly at $p < 0.05$), except for ROA, which displays a p-value of 0.069, slightly exceeding the conventional threshold of significance at 5%. This result suggests that ROA might have a less robust impact on the Z-score, although the direction of the relationship remains consistent with theoretical expectations.

Regarding the direction of economic relationships, operating expenses (OP_E_YJ) display a negative coefficient (-0.1517, $p < 0.05$), confirming that an increase in these expenses tends to reduce the Z-score, thus indicating a deterioration in financial stability.

This relationship is economically intuitive, as companies facing higher operating expenses, without a proportional increase in revenues, may significantly diminish their financial safety margin. Conversely, operating income (OP_I_YJ) demonstrates a positive effect (0.2309, $p < 0.05$), suggesting that increased operating income enhances financial stability, confirming that firms generating higher operating revenues are less susceptible to bankruptcy risk.

Table 6. Estimation of the OLS regression model with HAC correction for heteroskedasticity and autocorrelation after removing the ROE variable.

OLS Regression Results			
Dep. Variable:	AZ_score_YJ	R-squared:	0.907
Model:	OLS	Adj. R-squared:	0.881
Method:	Least Squares	F-statistic:	169.7
Date:	Mon, 24 Feb 2025	Prob (F-statistic):	1.72e-14
Time:	01:08:13	Log-Likelihood:	15.717
No. Observations:	24	AIC:	-19.43
Df Residuals:	18	BIC:	-12.37
Df Model:	5		
Covariance Type:	HAC		

	coef	std err	z	P>|z|	0.025	0.975
const	1.8676	0.024	78.884	0.000	1.821	1.914
ROA_QT	0.0517	0.028	1.820	0.069	-0.004	0.107
OP_E_YJ	-0.1517	0.030	-5.141	0.000	-0.210	-0.094
OP_I_YJ	0.2309	0.056	4.098	0.000	0.120	0.341
BVS_YJ	0.3726	0.032	11.632	0.000	0.310	0.435
GR_M_YJ	-0.1305	0.042	-3.097	0.002	-0.213	-0.048

Omnibus:	4.212	Durbin-Watson:	2.262
Prob(Omnibus):	0.122	Jarque-Bera (JB):	2.612
Skew:	0.379	Prob(JB):	0.271
Kurtosis:	4.428	Cond. No.:	3.32

Notes:
[1] Standard Errors are heteroscedasticity and autocorrelation robust (HAC) using 1 lags and without small sample correction

Source: Author's elaboration based on the research methodology

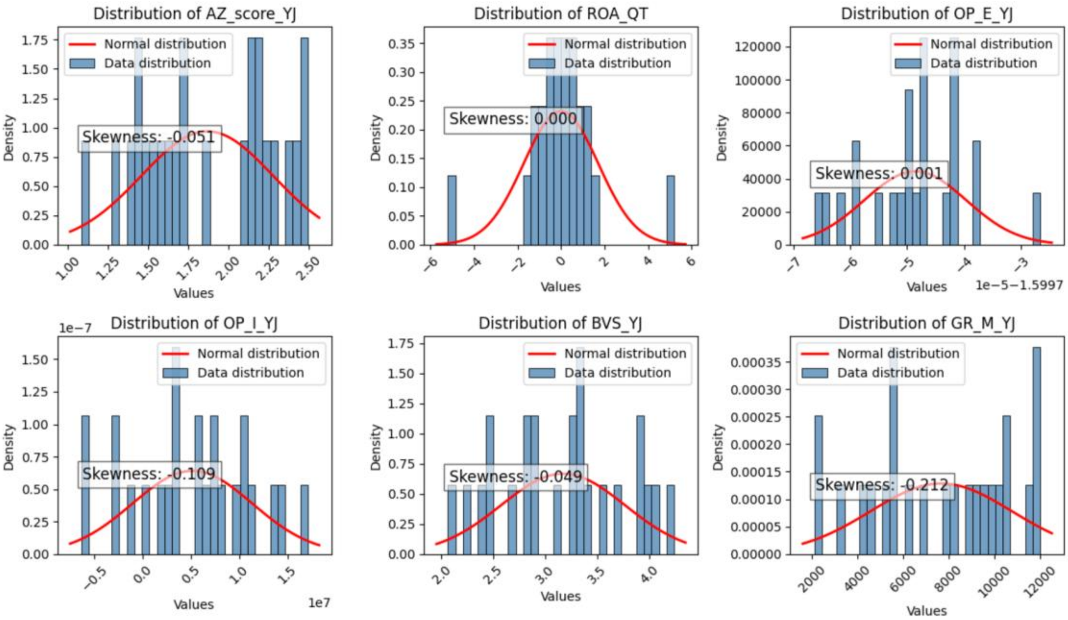
Book Value per Share (BVS_YJ) demonstrates a highly significant positive association (coefficient of 0.3726, $p < 0.05$), aligning with existing literature, as a higher level of net assets per share typically reflects enhanced financial solidity. Similarly, Gross Margin (GR_M_YJ) exhibits a negative coefficient (-0.1305, $p < 0.05$), indicating that, paradoxically, a higher gross margin is associated with a lower Z-score. This relationship may result from companies strategically adjusting margins during challenging periods, thereby maintaining apparent stability in profitability, yet concealing underlying structural financial vulnerabilities.

Regarding Return on Assets (ROA_QT), its positive coefficient (0.0517) and near-significant p-value (p = 0.069) suggest that higher profitability levels might contribute to an elevated Z-score; however, the impact is not distinctly defined within this model.

The analysis of transformed variables reveals significant improvements in their normality, an important factor for ensuring the validity of estimates derived from multiple linear regression.

Firstly, according to Fig. 4, skewness tests indicate values close to zero for the majority of variables, suggesting a significant reduction in initial asymmetry. For instance, ROA_QT exhibits a skewness of 0.000, confirming a near-perfect symmetrical distribution, while AZ_score_YJ (-0.051), OP_E_YJ (0.001), and BVS_YJ (-0.049) also display minimal deviations from normality. These findings demonstrate the effectiveness of the applied transformations (Yeo-Johnson, Quantile Transformer) in correcting distributional issues.

Fig. 4. Analysis of the distribution of variables used in the regression model



Source: Author's elaboration based on the research methodology

Secondly, the overlay of theoretical normal distributions (represented by the red curve) onto the histograms indicates that the transformed variables closely approximate Gaussian distributions. This aspect is essential for the validity of statistical tests applied within the OLS regression framework, as the assumption of residual normality depends significantly on balanced distributions of explanatory variables. Although GR_M_YJ (-0.212) and OP_I_YJ (-0.109) exhibit slight deviations from normality, their values remain sufficiently close to zero to not raise substantial methodological concerns. These results reflect considerable improvement in the statistical properties of the variables, thus ensuring a robust and reliable estimation of the econometric model.

For White’s Test, depicted in Table 7, the obtained p-value (p = 0.458) significantly exceeds the standard significance level of 0.05. Consequently, the null hypothesis—

asserting constant variance of the residuals—is not rejected. This result indicates that the model does not suffer from heteroscedasticity, a condition that, if present, would undermine the precision of estimations and compromise the validity of t-statistical tests. Similarly, the Breusch-Pagan Test yields a p-value of 0.1077, also surpassing the 0.05 significance threshold.

The Ramsey RESET Test results indicate an F-statistic of 2.05 and a corresponding p-value of 0.1704, implying that there is insufficient evidence to reject the null hypothesis of correct model specification.

Therefore, the functional form of the regression is valid, and the model does not require additional adjustments related to omitted relevant variables or nonlinear modeling. This outcome confirms that the applied transformations and the selection of explanatory variables have been executed correctly, without clear evidence of specification errors.

Table 7. Results of White, Breusch-Pagan and Ramsey tests for detecting heteroscedasticity.

0.45802973953224113	0.7085805953507782
For the **White's** Test The p-value was **0.458** We fail to reject the null hypthoesis, so there is no heterosecdasticity.	
0.10771650268114032	0.1028384788687727
For the **Breusch-Pagan's** Test The p-value was **0.1077** We fail to reject the null hypthoesis, so there is no heterosecdasticity.	
Ramsey RESET Test: (F-stat, p-value): <F test: F=2.05, p=0.17, df_denom=17, df_num=1>	

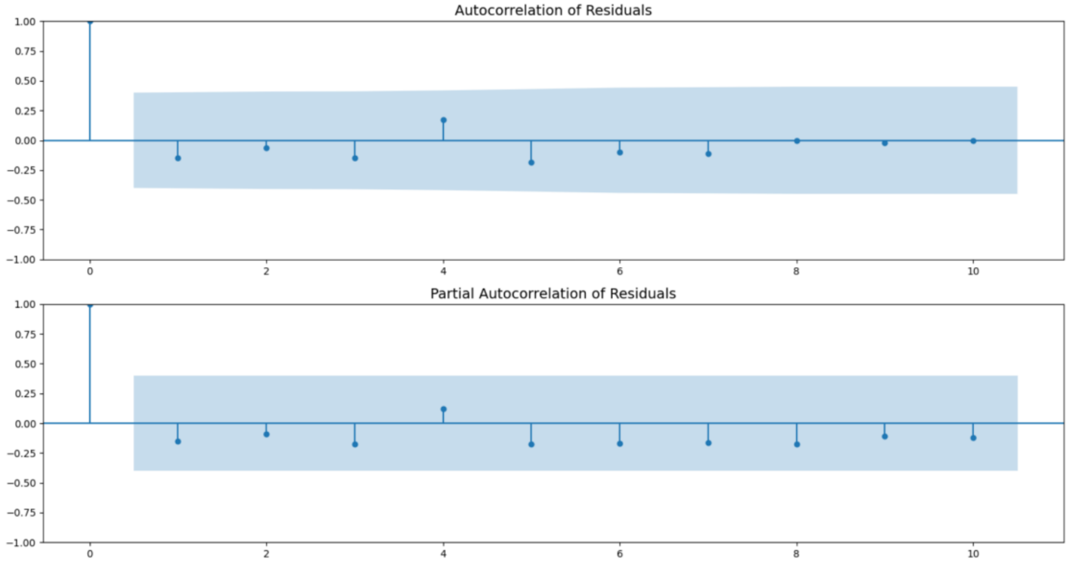
Source: Author's elaboration based on the research methodology

The results of the Breusch-Godfrey test indicate an LM statistic of 1.38 with a p-value of 0.50, while the F-test yields an F-statistic of 0.49 with a p-value of 0.62. Both p-values significantly exceed the 0.05 threshold, indicating that we cannot reject the null hypothesis of no autocorrelation in the errors. This conclusion is favorable to the model, as it suggests that the residuals are independent and do not exhibit a systematic structure that could introduce estimation errors.

The ACF and PACF plots, shown in Fig. 5, confirm the results of the Breusch-Godfrey test, namely, that there is no significant autocorrelation in the residuals. All lags fall within the confidence interval, indicating the absence of an autocorrelated structure in the errors. If autocorrelation had been present, significant bars would have appeared beyond this region.

From a statistical perspective, the model does not exhibit systematic temporal dependency in residuals, indicating the absence of correlations between residual values at different time points. This outcome is advantageous, as it suggests that residuals are randomly distributed, confirming the appropriate specification of the model in this regard. Both tests and visual representations support the hypothesis that the model is robust concerning residual autocorrelation.

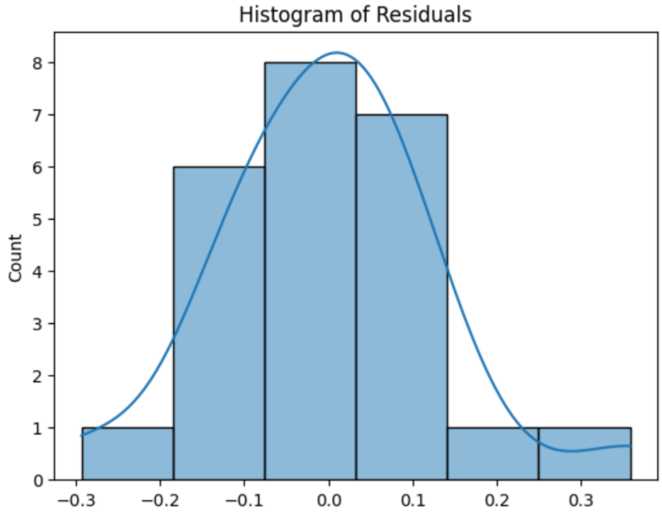
Fig. 5. Autocorrelation and Partial Autocorrelation of Residuals



Source: Author's elaboration based on the research methodology

The histogram of residuals (Fig. 6) indicates an approximately normal distribution with a slight negative skewness, suggesting residual values are somewhat extended toward lower extremes. This minor deviation does not significantly impact the model's validity, as the majority of observations are concentrated around zero, and the overall shape of the distribution closely resembles a Gaussian curve.

Fig. 6. Histogram of residuals



Source: Author's elaboration based on the research methodology

The distribution of residuals is critical for verifying the normality assumption of errors, a prerequisite for valid statistical inference in linear regression. A strong skewness or excessive kurtosis in residuals would indicate potential model misspecification, omitted variables, or a nonlinear relationship between included predictors and the dependent variable. However, the current analysis suggests that the model does not suffer from such severe shortcomings.

Additionally, the validity of statistical significance tests, such as t-tests for individual coefficients, relies on the assumption of normally distributed errors. Given that the histogram does not reveal substantial deviations from normality, it can be inferred that the coefficient estimates are robust and that the inferences derived from the model are reliable.

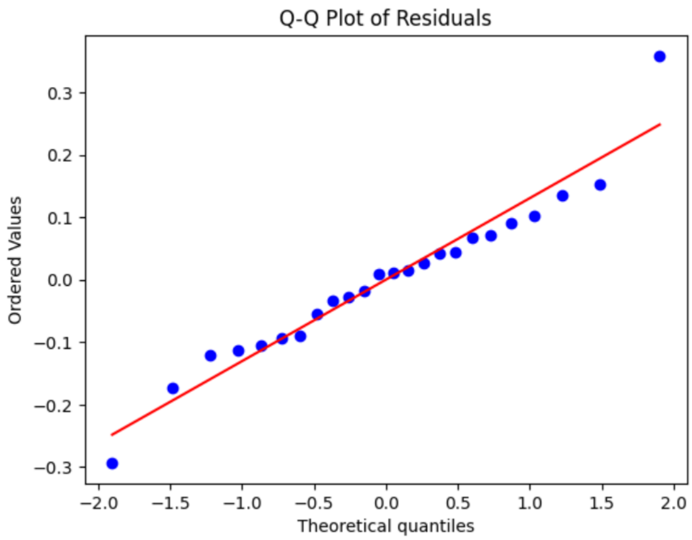
Also, the relative symmetry of the distribution ensures that the conditional mean of errors is zero, a fundamental criterion for the consistency of estimates obtained through Ordinary Least Squares (OLS).

The quantile-quantile (Q-Q) plot of residuals (Fig. 7) provides a visual assessment of the conformity between the residuals' distribution and a theoretical normal distribution. In this instance, the data points align relatively well along the reference diagonal, indicating that the residuals are approximately normally distributed.

Minor deviations observed at the extremes, particularly at the upper end of the graph, suggest the presence of values slightly departing from the assumption of normality, yet not to an extent that would indicate a major structural issue.

Distribution of residuals represents an important aspect for validating statistical inferences derived from linear regression models, as significant deviations from normality may compromise the accuracy of significance tests for regression coefficients. In this instance, the distribution is sufficiently close to normality, ensuring that the results of significance tests remain robust.

Fig. 7. Q-Q Plot of Residuals

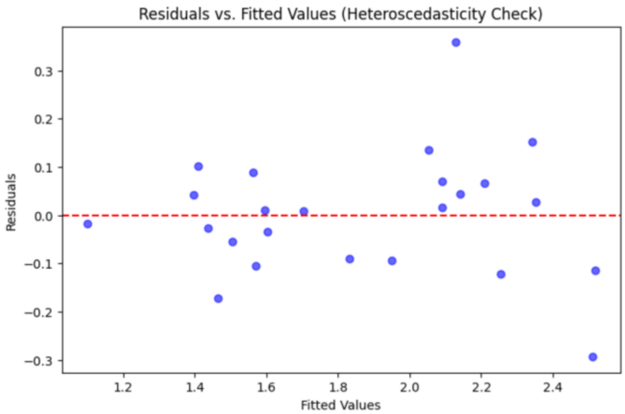


Source: Author's elaboration based on the research methodology

The plot of residuals against fitted values allows for a visual assessment of potential heteroscedasticity in the regression model. In a properly specified model, residuals should be randomly distributed around the horizontal reference line, without forming any discernible pattern or systematic trend. In this case, the data points appear relatively uniformly scattered, without any clear trend of increasing or decreasing variance in relation to the fitted values, indicating a likely absence of heteroscedasticity.

This observation is further supported by the formal test results for heteroscedasticity. The Breusch-Pagan test yields a statistic of 9.0340 with a p-value of 0.1077, while the White test indicates a statistic of 19.9984 with a p-value of 0.4580. Both tests produce p-values exceeding the conventional significance threshold of 0.05, which implies that the null hypothesis of homoscedasticity cannot be rejected. Consequently, these findings suggest that the variance of the residuals does not systematically vary with the fitted values, thereby providing no clear evidence of heteroscedasticity within the model.

Fig. 8. Plot of Residuals versus Fitted Values (Heteroscedasticity Check)



Source: Author's elaboration based on the research methodology

The absence of heteroscedasticity is an important characteristic for the validity of statistical inferences, as it allows the use of coefficient estimates without necessitating adjustments for non-constant standard errors. In conclusion, both the visual inspection and statistical tests suggest that the model satisfies the assumption of constant variance of the residuals, thereby reinforcing the reliability of the obtained estimates.

5. Discussion

The empirical findings underscore the pivotal roles of profitability, cost management, and capital structure in determining financial stability for Romanian listed firms. In our regression model, operating income and book value per share emerged as significant positive contributors to the Altman Z-score, while operating expenses and gross margin exhibited negative effects. These results align with a broad body of literature emphasizing that firms with stronger core earnings and equity positions tend to be more financially stable, whereas high cost structures can undermine stability (Kapounek et al., 2022; Elewa, 2022). The model's high explanatory power (adjusted $R^2 = 0.881$) and robust diagnostics further suggest that these variables collectively capture the primary determinants of insolvency risk in this context, consistent with the theoretical composition of Altman's Z-score model (Altman et al., 2014).

The positive impact of operating income on the Z-score confirms that strong operational profitability enhances a firm's solvency position. This finding is supported by prior studies showing that higher earnings (EBIT or ROA) improve Altman Z-scores and reduce default risk. For instance, Elewa (2022) found that operational profitability (EBIT/TA) was a powerful predictor of bankruptcy avoidance in Egyptian companies. Similarly, Willey et al. (2023) reported a direct link between rising Z-scores and higher return on equity in the airline industry, underlining that financially stable firms tend to exhibit superior profitability. The marginal significance of ROA in our model ($p = 0.069$) suggests that asset efficiency contributes to stability as well, albeit overlapping with other profit measures. This is in line with evidence from emerging markets that profitability metrics are among the most reliable distress indicators (Singh & Singla, 2021; Lestari et al., 2022). Overall, our results reinforce the view that robust earnings generation is fundamental to sustaining a high Altman Z-score and low bankruptcy risk.

Our analysis also highlights the importance of capital structure for financial stability. The book value per share's positive coefficient indicates that firms with larger net asset values (relative to shares) are perceived as more stable. This reflects the protective effect of a strong equity base and lower leverage on insolvency risk. Prior research supports this relationship: a positive association between Altman Z-scores and equity ratios has been documented in various markets. For example, Isaac-Roque and Caicedo-Carrero (2023) observed that Colombian firms with higher equity-to-liabilities ratios achieved higher Z-scores, implying greater resilience against financial distress. Likewise, Kapounek et al. (2022), in a European study, identified capital structure as a key factor influencing stability, where well-capitalized firms enjoyed better Z-score outcomes. Our findings concur with these studies, affirming that a solid equity cushion (as signaled by high book value per share or similar ratios) enhances a company's ability to absorb losses and contributes to financial soundness. Notably, this contrasts with some evidence in other emerging contexts – for instance, Elewa (2022) reported that market-based equity measures had limited predictive power in Egypt – suggesting that the relevance of book equity vs. market equity can vary by market. In Romania's case, the positive effect of book value per share may indicate that tangible net worth is a particularly trusted indicator of stability in a developing market where market valuations are more volatile or less informative.

The negative coefficient for operating expenses aligns perfectly with theoretical expectations and prior studies: higher operating costs erode profit margins and increase insolvency risk. By increasing expenses, firms reduce their retained earnings and EBIT, which are core components of the Z-score, thus weakening their financial position. This relationship is economically intuitive and supported by literature noting that rising operating costs or thinner margins heighten bankruptcy risk (Khajavi & Ghoohestani, 2015, as cited in Baciu et al. 2021). Our findings corroborate the hypothesis (H3) that cost efficiency is crucial for financial stability – companies maintaining leaner cost structures tend to score higher on the Altman Z-scale, reflecting lower distress probability.

Perhaps the most intriguing result is the negative impact of gross margin on the Z-score, an unexpected finding that deviates from conventional wisdom. Typically, a higher gross profit margin signals better pricing power and profitability, which should bolster financial health. Prior research generally associates strong gross or operating margins with reduced insolvency risk (Khajavi & Ghoohestani, 2015). In our sample, however, gross margin is inversely related to the Z-score. One plausible explanation is rooted in strategic behavior during economic volatility: Romanian firms sacrifice margins to preserve liquidity and market share in difficult times, thereby sustaining their overall stability. In other words, companies facing economic stress might deliberately lower prices (and hence gross margins) to generate sales cash flow, allowing them to avoid distress; such firms would show lower margins yet higher Altman Z-scores, whereas firms that maintain higher margins could be those unable or unwilling to adjust pricing, potentially suffering revenue losses that weaken their financial stability. This perspective is consistent with our context-specific interpretation that strategic margin adjustments during challenging periods can mask or mitigate financial vulnerabilities (as noted in our results). Another contributing factor could be industry composition: firms in traditionally high-margin industries might carry greater business risk or fixed costs, whereas firms in low-margin industries often have steadier cash flows. Thus, across a mixed sample, higher gross margins might correlate with more volatile or risk-prone sectors, leading to a counterintuitive negative correlation with stability. Such nuanced behavior of gross margin highlights the importance of context. It echoes Altman's observation that coefficient effects can vary internationally and across sectors, warranting local calibration of risk models (Altman et al., 2014). In sum, while gross margin is generally viewed as a positive factor, our findings suggest that in the Romanian market context it may sometimes act as a double-edged sword – that financial indicators cannot be interpreted in isolation of firm strategy and economic environment.

Contrary to some expectations, the traditional liquidity ratios (quick ratio and current ratio) were not significant predictors of the Z-score in our final model. This does not necessarily mean liquidity is unimportant; rather, it suggests that once profitability and equity strength are accounted for, additional variation from common liquidity metrics was negligible for these firms. In Altman's original model, a liquidity component (working capital/total assets) is indeed important (Altman et al., 2014), and other studies on emerging markets have found liquidity ratios to be significant in distress prediction (Kapounek et al., 2022; Lestari et al., 2022). Our results indicate that Romanian companies with high Altman Z-scores did not systematically have higher quick or current ratios. In fact, preliminary analysis even showed a weak negative association between those liquidity ratios and Z-scores, implying that extremely high liquidity might be associated with lower productivity or growth opportunities (a phenomenon where excess idle assets could signal inefficiency). A similar outcome was observed by Sunaryo (2021) in a Southeast Asian retail context, where current ratio had no significant effect on financial distress once other factors were considered. It appears that for Romanian firms, profitability and capital buffers trump short-term liquidity in explaining solvency risk. Firms with sound earnings can manage their short-term obligations through internal cash generation or external credit lines, diminishing the incremental predictive value of static liquidity ratios. Moreover, since our sample excludes financial firms and spans mostly established companies, most likely maintain adequate liquidity as a baseline, meaning variation in quick/current ratios may not reflect impending trouble unless extreme. Thus, the exclusion of quick and current ratios from the final model underscores the primacy of fundamental performance metrics over superficial liquidity in assessing financial stability – a finding that refines our understanding of Altman Z-score drivers in this context.

Overall, these findings both support and extend the existing literature on bankruptcy prediction and financial stability. The positive effects of profitability and equity strength corroborate a wide range of studies across developed and emerging markets which conclude that high earnings capacity and low leverage are cornerstone attributes of financially stable firms (Altman et al., 2014; Willey et al., 2023; Elewa, 2022). Meanwhile, the lack of influence of liquidity ratios and the inverse gross margin effect highlight how contextual factors and firm behaviors can modulate classic risk indicators. Prior research has noted that the Altman Z-score model may require adaptation for different environments – for example, adjusting coefficients or adding variables to reflect local conditions (Altman et al., 2014; Marais et al. 2014). Our study provides a concrete example: in the Bucharest Stock Exchange milieu, aggressive competition and market volatility may lead to unique patterns (such as margin reductions to ensure survival) that diverge from textbook expectations. This suggests that practitioners and researchers should interpret Z-score components with an understanding of industry and regional dynamics.

6. Conclusions

The findings confirm that selected financial indicators significantly influence the Altman Z-score, with strong explanatory power (adjusted R-squared = 0.881). Operating income (0.2309, $p < 0.05$) and book value per share (0.3726, $p < 0.05$) positively impact financial stability, while operating expenses (-0.1517, $p < 0.05$) and gross margin (-0.1305, $p < 0.05$) negatively influence it. The statistical robustness of the model is validated through various tests, confirming correct specification, absence of heteroscedasticity and autocorrelation, and normally distributed residuals.

Return on assets (ROA_QT) shows a marginally significant positive relationship (0.0517, $p = 0.069$), indicating asset efficiency may support stability, though moderated by other factors. The negative impact of operating expenses aligns with expectations, underscoring vulnerability to financial distress. Conversely, operating income demonstrates the expected positive influence on stability. The positive coefficient of book value per share confirms its role in absorbing economic shocks. However, the unexpected negative correlation of gross margin suggests that strategic margin adjustments during economic downturns might obscure actual financial stability.

The regression model confirmed significant relationships between selected financial indicators and the Altman Z-score for Romanian listed firms, supporting the main hypothesis (H1). Partial support emerged for H2, with return on assets (ROA) showing a marginal positive relationship (0.0517, $p = 0.069$), though net income and ROE were excluded due to multicollinearity. H3 was supported, showing operating expenses negatively affecting stability (-0.1517, $p < 0.05$). H4 was confirmed, as operating income

(0.2309, $p < 0.05$) and book value per share (0.3726, $p < 0.05$) positively impacted stability. Hypothesis H5 was contradicted by the negative gross margin effect (-0.1305, $p < 0.05$), possibly reflecting strategic adjustments during volatility. Liquidity measures (H6) were insignificant, while H7 was confirmed by selecting operating expenses, operating income, book value per share, and gross margin as key predictors. The null hypothesis (H0) was rejected, validating the model and highlighting the importance of assessing financial stability determinants for Romanian companies.

The obtained findings confirm that the Altman Z-score model is significantly influenced by selected financial indicators, demonstrating a high explanatory power with an adjusted R-squared of 0.881. This indicates a robust relationship between the Altman Z-score and the chosen variables. Among these, operating income and book value per share exhibited a positive impact on firms' financial stability, while operating expenses and gross margin had negative effects.

The results suggest a potential positive but marginally significant relationship between Return on Assets and financial stability, possibly influenced by capital structure or industry conditions. Operating expenses negatively impact financial stability, indicating higher vulnerability to financial distress, while operating income positively affects the Altman Z-score, underscoring its role in mitigating bankruptcy risk. Additionally, a higher book value per share enhances financial stability, reflecting improved resilience to economic shocks.

Although a higher gross margin is theoretically associated with stability, our findings indicate a negative relationship with the Altman Z-score, possibly due to firms strategically adjusting margins during challenging periods to remain competitive. This underscores the complexity of factors influencing bankruptcy risk and emphasizes the importance of detailed economic and strategic context analysis. Additionally, the results validate the econometric model used, reinforcing the need for comprehensive assessments of financial stability determinants for companies listed on the Bucharest Stock Exchange.

6. References

Altman, E. I., Iwanicz-Drozdowska, M., Laitinen, E. K., & Suvas, A. (2014). Distressed firm and bankruptcy prediction in an international context: A review and empirical analysis of Altman’s Z-score model. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2536340

Al-Manaseer, S. R., & Al-Oshaibat, S. D. (2018). Validity of Altman Z-score model to predict financial failure: Evidence from Jordan. *International Journal of Economics and Finance*, *10*(8), 181–189. https://doi.org/10.5539/ijef.v10n8p181

Alam, S., Das, S. K., Dipa, U. R., & Hossain, S. Z. (2024). Predicting financial distress through ownership pattern: Dynamics of financial resilience of Bangladesh. *Future Business Journal, 10*(91). https://doi.org/10.1186/s43093-024-00379-5

Bogner, K., Pappenberger, F., & Cloke, H. L. (2012). The normal quantile transformation and its application in a flood forecasting system. *Hydrology and Earth System Sciences, 16*, 1085–1094.

Baciu, R., Petre, B., & Simon, A. (2021). Insolvency risk. Application of Altman Z-score to the auto parts sector in Romania. International Journal of Innovation and Economic Development**, 7**(4), 37–48. https://doi.org/10.18775/ijied.1849-7551-7020.2015.74.2003

Elewa, M. M. (2022). Using Altman Z-Score models for predicting financial distress for companies – The case of Egypt. *Alexandria Journal of Accounting Research, 6*(1), 1–28. https://doi.org/10.5465/amr.2003.10196754

Erdogan, A. I. (2023). Drivers of SME growth: Quantile regression evidence from developing countries. *International Journal of Economics and Finance, 15*(2), 45–62.

Ene, C. C. (2023). Econometric Insights into Non-Governmental Credit Fluctuations: A Case Study of Romania. *Ovidius University Annals, Economic Sciences Series*, *23*(2), 694-699.

Isaac-Roque, D., & Caicedo-Carrero, A. (2023). Relationship between the Altman Z-Score model and the Z-Score financial indicators. *Retos Revista de Ciencias de la Administración y Economía, 13*(25), 127–146. https://doi.org/10.17163/ret.n25.2023.09

Joshi, M. K. (2020). Financial performance analysis of select Indian public sector banks using Altman's Z-score model. *Smart Journal of Business Management Studies, 16*(2), 74–87. https://doi.org/10.5958/2321-2012.2020.00018.4

Jawed, S., & Schmidt-Thieme, L. (2022). FQFormer: A fully quantile transformer for time series forecasting. *Proceedings of MILETS 2022*, 1–12.

Khajavi, S., & Ghoohestani, A. (2015). Relationship of financial ratios with bankruptcy probability. *Iranian Journal of Management Studies*, 8(2), 159–180.

Kapounek, S., Hanousek, J., & Bílý, F. (2022). Predikční schopnost Altmanova Z-skóre evropských soukromých společností. *Politická ekonomie, 70*(3), 265–287. https://doi.org/10.18267/j.polek.1353

Lizarzaburu, E. R. (2014). Analysis of Altman Z-score in the Peruvian market. Universidad & Empresa, 16(26), 141–158. https://doi.org/10.12804/rev.univ.empresa.26.2014.05

Lestari, E. P., Fatimah, F., & Sunaryo, D. (2022). Analysis of the effect of the Altman Z-score method on financial distress. *International Journal of Educational Research & Social Sciences, 3*(1). https://doi.org/10.51601/ijersc.v3i1.254

Marais, A., Soni, S., & Chitakunye, P. (2014). The ability of the Altman Z-score to predict the relative success of industrial companies listed on the Johannesburg Stock Exchange. *Journal of Contemporary Management, 11*, 451–469.

Nustini, Y., & Amiruddin, A. R. (2019). Altman model for measuring financial distress: Comparative analysis between sharia and conventional insurance companies. *Journal of Contemporary Accounting, 1*(3), 161–172. https://doi.org/10.20885/jca.vol1.iss3.art4

Nurul, F., & Zulfiati, L. (2019). Financial distress analysis with Altman Z Score method and value of SOEs listed on BEI. *Advances in Economics, Business and Management Research, 73*, 47–51.

Sunaryo, D. (2021). Analysis of current ratio, debt to assets ratio and gross profit margin on financial distress with moderated share prices in retail companies. *International Journal of Educational Research & Social Sciences*, 2(1), 23–33. https://doi.org/10.51601/ijersc.v2i1.39

Singh, G., & Singla, R. (2021). Default risk and stock returns: Evidence from Indian corporate sector. *Vision*, 1–13. https://doi.org/10.1177/09722629211003358

Spulbar, C., & Ene, C. C. (2024). The Empirical Approach of the Interplay of Macroeconomic Variables and the Dynamics of the Financial Market in Romania. *Revista de Stiinte Politice*, (82), 55-69.

Willey, T., Edwards, S., & Bhagwat, Y. (2023). An investigation of the Altman Z-Score measure and return on equity (ROE) of firms in the airline industry. *Archives of Business Research, 11*(12), 96–102. https://doi.org/10.14738/abr.1112.16059

Yeo, I. K., & Johnson, R. A. (2000). A new family of power transformations to improve normality or symmetry. *Biometrika, 87*(4), 954–959.