

Altman's Z"-score for Slovak construction companies: Do company size and ownership matter?

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Abstract

Research background: Since the construction sector accounts for a significant part of the Slovak economy, it is crucial to monitor and understand the financial performance of companies within this industry. Although Altman's model for predicting financial distress is widely used, there is limited evidence from Slovakia, particularly regarding how company size and ownership affect its predictions.

Purpose of the article: The paper examines how firm size and ownership influence different types of financial distress in Slovakia's construction sector, using Altman's model. It also examines whether these factors can serve as reliable indicators of a company's long-term financial stability.

Methods: For the purpose of this study, a set of 30,147 Slovak construction companies for the year 2023 was compiled. Each company has been subsequently classified into one of three categories: safe, grey, or distress zone, based on Altman's Z"-score methodology. Consequently, the differences in the resulting scores with respect to the companies' size and ownership were examined using statistical hypothesis testing.

Findings & Value added: The analysis revealed that domestic and foreign companies differ significantly in their Altman's Z"-scores, with foreign companies showing higher values, indicating stronger financial stability and lower distress risk. On the contrary, small, medium, and large companies exhibit a similar distribution of Z"-scores, suggesting that company size does not play a crucial role in determining financial health.

Keywords: Altman Z"-score; construction sector; firm size; ownership

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1. Introduction

The financial health of companies is a crucial issue in modern economies due to its significant influence on investment, employment, and overall economic stability. The construction sector is a



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large and expanding global industry; however, it is particularly vulnerable to financial difficulties and economic fluctuations (Wang et al., 2024). Construction projects are unique, long-term, and require substantial capital, often involving complex processes with numerous stakeholders. Consequently, the construction sector is known for its high rate of business insolvencies (Prebanic and Vukomanovic, 2023). In Slovakia, where the construction sector plays a vital role in the country's economic development, this issue is particularly pressing (Gajdosikova et al., 2022). The Slovak construction industry is highly cyclical and sensitive to macroeconomic changes, such as fluctuations in GDP growth, interest rates, and public infrastructure spending (Coface, 2024). This highlights the importance of this research, as understanding and predicting the financial difficulties of Slovak construction companies is both an economic necessity and a complex research challenge.

The capacity to predict financial difficulties in companies is crucial for stakeholders to mitigate risks and prevent severe financial consequences (Zhao et al., 2024). Early warning models for bankruptcy are essential instruments for investors and creditors as they identify companies in trouble early, allowing for preventive measures to avoid collapse. In practice, predicting difficulties helps implement early warning systems and mitigates the proliferation of risk (Huang et al., 2023). For creditors and investors, this reduces the risk of major losses while increasing the likelihood of delivering planned infrastructure to the authorities (Ates and Eirgash, 2025).

Over the past few decades, researchers have developed several quantitative models to assess the financial health of companies and predict their potential failures (Jones, 2023). Beaver (1966) demonstrated that individual accounting indicators can differentiate between companies that fail and those that survive, laying the groundwork for later approaches. Building on this, Altman (1968) combined multiple indicators in his Z-score using multivariate discriminant analysis, resulting in a significant improvement in predictive accuracy (Duricova et al., 2025).

Altman's Z-score classifies companies into safe, grey, or distress zones based on their bankruptcy risk. The original Z-score was developed using a sample of US manufacturing firms, and it proved to be highly accurate. It combines five key financial metrics – profitability, liquidity, leverage, solvency, and activity ratios – into a linear formula, effectively summarising a company's financial health. Firms exhibiting excessively low Z-scores are likely at a high risk of bankruptcy, while those with high scores are considered financially healthy (Altman, 1968). Over time, Altman and others adapted the Z-score model for different contexts. In 1983, they introduced the Z'-score for privately held firms, and in 1995, the Z''-score for non-manufacturing and emerging market companies. These versions adjust the original set of variables and coefficients, such as removing the market value of equity for private firms or recalibrating for different accounting standards to improve prediction accuracy beyond the original sample (Cao, 2016).

However, despite its widespread acclaim, several questions have been raised about the effectiveness of the Z-score model when applied outside its initial context. Research findings are mixed regarding the performance of Altman's model in other countries and industries (Cindik and Armutlulu, 2021). On the one hand, Altman's recent comprehensive analysis of 34 countries, mostly in Europe, reported that the Z-score model performs satisfactorily in most countries, with an overall prediction accuracy of about 75%, and that customising the model with country-specific data can improve accuracy to over 90% (Altman et al., 2017). This indicates that the model's primary approach remains effective across various environments. On the other hand, some evidence suggests that the Z-score's performance may decline in the absence of localisation or adjustments (Altman, 2018). This view is supported by other studies (Braunsberger and Aschauer, 2025; Du et al., 2025; Wang et al., 2024). For example, Toudas et al. (2024) found that the accuracy of Altman's Z-score decreases over extended time frames and is lower than that of other models when applied to Greek construction companies. Similarly, Rahman and Zhu (2024) confirmed, using a sample of Chinese construction companies, that while the Z-score provides a useful benchmark, machine learning methods tend to achieve higher accuracy. Moreover, factors unique to local economies can reduce

the accuracy of the original model. For instance, a Slovak study demonstrated that Altman's Z-score required customisation to account for local economic conditions, as macroeconomic variables such as inflation and interest rates impacted its predictive accuracy (Duricova et al., 2025). Building on such region-specific research, recent studies from Central and Eastern Europe have introduced both updated models and modern techniques. Kliestik et al. (2018) developed a financial distress prediction model specifically for the V4 countries, using data from Czechia, Hungary, Poland, and Slovakia. In another study, Valaskova et al. (2023) achieved over 88% classification accuracy for enterprises in the V4 economies by employing a tailored multivariate discriminant model, identifying total indebtedness as a particularly influential predictor of financial distress in the post-pandemic period.

Furthermore, an under-examined facet in the literature is how firm-specific characteristics, such as size and ownership structure, may influence the predictive performance of these models (Wang and Guedes, 2025). Firm size affects financial stability because small companies often face higher bankruptcy risks than larger firms due to their limited diversification and weaker access to financing (Rashid et al., 2024). Conversely, very large companies might benefit from the "too big to fail" phenomenon, as they can receive external support or have more resources to withstand economic downturns (Li et al., 2024). This view is also shared by Postiglione et al. (2025), who highlight that a company's size is a key factor, as smaller companies may report higher volatility in their indicators, reducing the reliability of the Z-score, while larger companies tend to produce more stable results. The ownership structure can also play an important role. Companies that are part of foreign multinationals or have strong institutional owners may benefit from resource advantages that enhance their resilience. In contrast, purely domestic firms, especially those that are owner-managed or family-owned, might be more vulnerable to local market fluctuations and financing constraints (Kampouris et al., 2022). Similarly, Maquieira et al. (2024) note that ownership structure can influence outcomes, as family businesses vary in their financial strategies and approaches to risk.

Despite the development of new approaches, traditional statistical techniques such as discriminant analysis and logistic regression remain commonly used tools for assessing bankruptcy risks. Recently, there has been increased use of machine learning methods, which often achieve higher predictive accuracy compared to traditional models (Prusak, 2020). Recent research on bankruptcy prediction demonstrates a synthesis of conventional financial ratio models and modern machine learning techniques. Thus, the Altman Z-score model, introduced in 1968, remains a widely adopted standard for evaluating companies' financial health (Jayawardana et al., 2025).

This study aims to examine the applicability of Altman's model for predicting financial distress in the Slovak construction industry, considering the potential impact of company size and ownership structure on the Z-scores derived from the model. By including these factors in the analysis, the study seeks not only to evaluate the overall effectiveness of Altman's model but also to determine whether its performance is affected by specific company characteristics.

The rest of the article is organised as follows. The Methodology section outlines the research design and analytical framework, the Results section presents the primary empirical findings, the Discussion section interprets these findings within a broader context, and the Conclusion section summarises the key contributions, practical implications, and directions for future research.

2. Methodology

This paper uses the adjusted Altman's model for non-manufacturing firms and emerging markets to estimate the Altman's Z-scores of the companies examined. This formula was chosen because the sample included construction companies, which typically do not belong to the manufacturing sector, and whose financial structures are better represented by this modification of the model.

$$Z'' = 3.25 + 6.56X_1 + 3.26X_2 + 6.72X_3 + 1.05X_4 \quad (1)$$

where X_1 is (current assets-current liabilities)/total assets,
 X_2 is retained earnings/total assets,
 X_3 is earnings before interest and taxes/total assets,
 X_4 is book value of equity/total liabilities.

Based on the estimated Z"-scores, companies are classified into three categories: the safe zone ($Z'' > 2.6$; financially stable), the grey zone ($1.1 \leq Z'' \leq 2.6$; uncertain or ambiguous financial health), and the distress zone ($Z'' < 1.1$; high risk of financial failure) (Altman, 2018).

In this study, we utilised data from the Moody's Orbis database, which provides standardised financial statements and ownership information for companies across various countries. The dataset includes data on 30,147 Slovak construction companies in 2023. In the Slovak statistical classification of economic activities (NACE) system, the analysed companies fall under section F and include divisions 41, 42, and 43. Ownership details were used to distinguish between domestic and foreign companies, and their sizes were categorised based on their turnover and employment into small, medium-sized, and large enterprises.

Table 1 shows the distribution of firms by ownership and size. It is evident that most firms are domestically owned, accounting for 94.7% of the total. Regarding company size, small firms dominate the business landscape, representing 99.3% of all enterprises. Overall, the data indicate that the business sector is primarily composed of small and domestically owned firms.

Table 1: Distribution of firms by ownership and size

Variable	Values	Frequency	Percent
Ownership	Domestic	28,559	94.7
	Foreign	1,588	5.3
Company size	Small	29,939	99.3
	Medium-sized	171	0.6
	Large	37	0.1

Source: own elaboration

Table 2 summarises the descriptive statistics of the financial indicators used in the analysis, specifically the Altman model variables (X_1 – X_4). The statistics are presented for the entire sample of Slovak construction companies in the total column, as well as for subgroups defined by company size and ownership. This table provides a comprehensive overview of each indicator, enabling a comparison of financial characteristics among different categories of companies.

To analyse the statistical differences in financial distress classifications, the study employed non-parametric tests, which are suitable for analysing skewed financial data. The Kruskal–Wallis test was used to assess whether the distributions of Altman's scores vary across size and ownership categories. It is a highly effective method for testing the null hypothesis that multiple independent groups originate from the same population or have identical medians or distributions (Biancardi et al., 2023). At the same time, the Median test was used to determine whether the central tendency across groups significantly differed among the groups, with the null hypothesis positing that they are equal (Markulik et al., 2024). All statistical tests were evaluated based on their p-value, with the null hypothesis rejected if the p-value was below the 0.05 significance level. IBM SPSS Statistics 26 was employed to conduct the data analysis.

3. Results

This section presents the findings from applying Altman's Z"-score to the dataset of 30,147 Slovak construction companies in 2023, along with the results of statistical tests examining differences based on firm size and ownership.

Table 2: Descriptive statistics of Altman's model variables

	Variable	Min	Max	Mean	Median	Std. Deviation
Domestic	X_1	-30,324	3,000	-4.6	0.3	235
	X_2	-22,660	12,499	-5.4	0.04	223
	X_3	-45,657	3,600	-1.9	0.04	272
	X_4	-6,156	45,495	26	0.5	449
Foreign	X_1	-788	38	-1.9	0.4	31
	X_2	-2,476	28	-4.6	0.02	71
	X_3	-231	8	-0.3	0.02	6.5
	X_4	-647	19,679	42	0.6	563
Small	X_1	-30,324	3,000	-4.5	0.3	229
	X_2	-22,660	12,499	-5.4	0.04	218
	X_3	-45,657	3,600	-1.8	0.04	265
	X_4	-6,156	45,495	27.1	0.5	458
Medium-sized	X_1	-1	1	0.3	0.3	0.4
	X_2	-1.9	0.8	0.1	0.02	0.3
	X_3	-0.3	0.9	0.08	0.03	0.1
	X_4	-0.2	51	1.7	0.3	4.8
Large	X_1	-0.2	0.9	0.3	0.4	0.3
	X_2	-1.9	0.5	0.02	0.01	0.4
	X_3	0	0.5	0.05	0.02	0.09
	X_4	0	1,068	29.9	0.4	175
Total	X_1	-30,324	3,000	-4.5	0.3	229
	X_2	-22,660	12,499	-5.3	0.04	218
	X_3	-45,657	3,600	-1.8	0.04	265
	X_4	-6,156	45,495	26.9	0.5	457

Source: own elaboration

As the first step of the analysis, Altman's model (1) mentioned above was used to estimate their Z"-scores, and then they were classified into one of three financial condition categories. Tables 3 and 4 show the distribution of companies based on their size or ownership, along with predictions from Altman's model, categorising companies into distress, grey, and safe zones. The percentages indicate the proportion of companies within each size or ownership category, not the total sample of 30,147 companies.

Table 3: Distribution of firms by company size and financial zone

	Small	Medium-sized	Large	Total
Distress zone	5,231 (17.5%)	9 (5.3%)	1 (2.7%)	5,241 (17.4%)
Grey zone	1,577 (5.3%)	6 (3.5%)	1 (2.7%)	1,584 (5.2%)
Safe zone	23,131 (77.2%)	156 (91.2%)	35 (94.6%)	23,322 (77.4%)
Total	29,939 (100%)	171 (100%)	37 (100%)	30,147 (100%)

Source: own elaboration

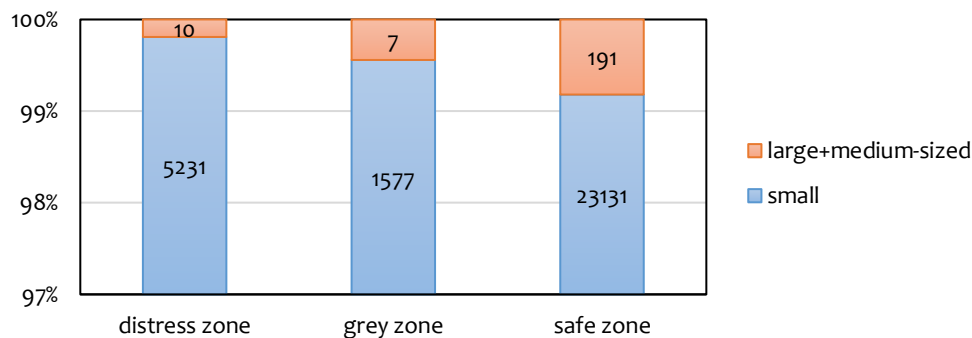
Table 4: Distribution of firms by ownership structure and financial zone

	Domestic	Foreign	Total
Distress zone	4,964 (17.4%)	277 (17.4%)	5,241 (17.4%)
Grey zone	1,523 (5.3%)	61 (3.9%)	1,584 (5.2%)
Safe zone	22,072 (77.3%)	1,250 (78.7%)	23,322 (77.4%)
Total	28,559 (100%)	1,588 (100%)	30,147 (100%)

Source: own elaboration

The sample includes slightly over thirty thousand construction companies. As shown in Table 3, the construction sector is primarily composed of small businesses. Figure 1 clearly shows that small businesses make up almost the entire sample across all three zones. Medium-sized and large firms represent only a small portion, especially in the distress and grey zones. Since there was only one large firm in each of these two zones, their presence was too small to be visible on the graph. As a result, the medium and large categories were combined into a single group.

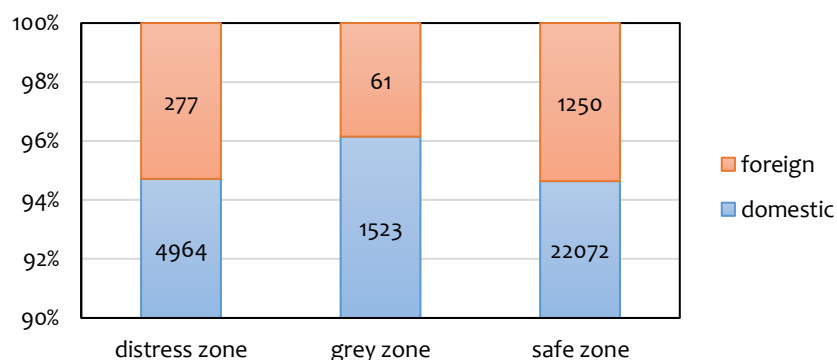
Figure 1: Distribution of Slovak construction firms across Altman zones by company size



Source: own elaboration

Figure 2 illustrates the distribution of companies within identical Altman zones, categorised by ownership structure. In all three zones, domestic companies significantly outnumber foreign ones, although the gap is narrower than in the size-based classification. Foreign companies are present in each zone, but they make up a relatively small share, with their largest presence in the safe zone.

Figure 2: Distribution of Slovak construction firms across Altman zones by ownership



Source: own elaboration

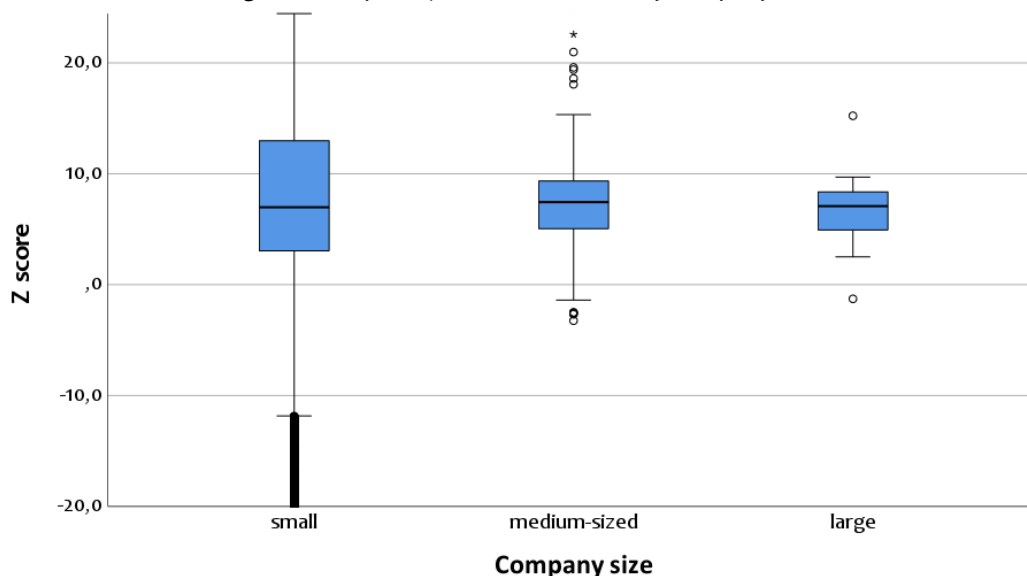
The boxplot in Figure 3 illustrates the distribution of Altman's Z"-scores by company size. Small firms exhibit the greatest spread, with whiskers extending from strongly negative to high positive values along with several extreme outliers (marked by stars in the boxplot). Their median exceeds zero, indicating that the typical value is relatively favourable, yet the variability is substantial. Medium-sized firms exhibit a narrower range, with the majority of data points clustered around the median and a few outliers. Large firms display the smallest interquartile range and reduced total dispersion, indicating more consistent results.

To enhance the clarity of these patterns, the y-axis was constricted, as the initial range, driven by the very large number of small firms and their extreme values, severely compressed the boxes to the point of near invisibility. The adjusted scale enhanced readability while keeping the relative positions of the medians and the comparison of the spread across size groups.

Figure 4 illustrates the distribution of Altman's Z"-score values by ownership. The shapes of the boxes for domestic and foreign companies are very similar, with comparable medians and interquartile ranges. Both groups displayed a wide range of values and numerous outliers. The interquartile ranges are similar, but domestic companies have more extreme outliers. As with the previous chart, the y-axis scale was adjusted to make the boxes visible, as extreme values would otherwise compress them and obscure the central distributions.

After conducting a graphical analysis, we examined the differences in Altman's scores across different ownership categories of companies. The results from both the Median and Kruskal-Wallis tests confirmed statistically significant differences (p-value less than 0.05) in the Z"-scores based

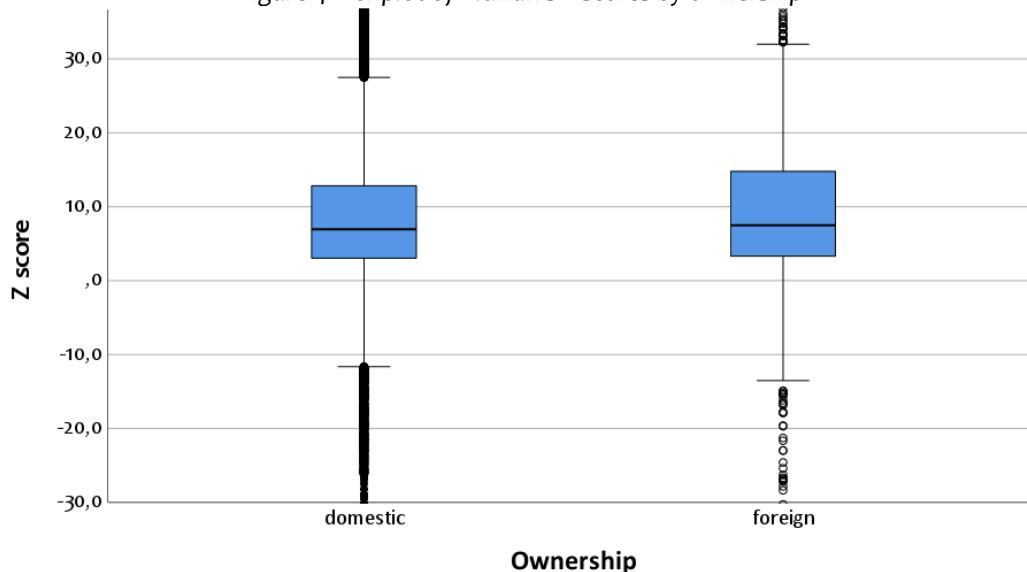
Figure 3: Boxplot of Altman's Z-scores by company size



Source: own elaboration

on ownership. This indicates that the distribution of Altman's scores varies between domestic and foreign companies.

Figure 4: Boxplot of Altman's Z-scores by ownership



Source: own elaboration

Table 5: Nonparametric test results by company size

	Null Hypothesis	Test	Sig.
1	The medians of Z-scores are the same across categories of ownership.	Independent-Samples Median Test	0.025
2	The distribution of Z-scores is the same across categories of ownership.	Independent-Samples Kruskal-Wallis Test	0.006

Source: own elaboration

Furthermore, we analysed the differences between small, medium-sized, and large companies. In this case, neither the Median test ($p = 0.140$) nor the Kruskal-Wallis test ($p = 0.987$) showed

statistically significant differences. Therefore, the null hypothesis of equal medians and distributions cannot be rejected, indicating that company size does not significantly affect Altman's Z"-score or the financial health of construction companies. This finding is also supported by the graphical outputs, which show that the distributions of Altman Z"-scores for small, medium-sized, and large companies display a very similar pattern. The results of these tests are shown in Table 6.

Table 6: Nonparametric test results by ownership

	Null Hypothesis	Test	Sig.
1	The medians of Z-score are the same across categories of company size.	Independent-Samples Median Test	0.140
2	The distribution of Z-score is the same across categories of company size.	Independent-Samples Kruskal-Wallis Test	0.987

Source: own elaboration

4. Discussion

The purpose of this discussion is to interpret and critically evaluate the results obtained from analysing the Altman Z"-score for Slovak construction companies, with particular attention to the influence of company size and ownership structure.

The results of this study confirm that foreign construction companies in Slovakia are, on average, financially healthier than their domestic counterparts, as evidenced by the significantly higher Altman Z"-scores of foreign construction companies, which indicate the financial health of companies. These firms' higher Z"-scores are consistent with the global advantage hypothesis, which posits that foreign investors bring benefits such as advanced management practices, technology, and stricter governance, thereby strengthening the firm's stability (Aldousari et al., 2025). In addition, foreign ownership often reduces financial constraints, which is consistent with a recent international study by Kampouris et al. (2022), which found that foreign ownership is a strong predictor of a company's ability to obtain credit. Nguyen (2025), moreover, documents a positive association between foreign ownership and a larger amount of commercial loans provided, which is likely related to foreign-owned firms' better access to capital. Conversely, domestic companies, many of which are smaller family businesses, may be more vulnerable due to limited financing options or less diversified operations, which is reflected in their lower Z"-scores. It appears that foreign ownership, through both financial backing and managerial expertise, provides a buffer against distress in the Slovak construction context.

Conversely, company size has not been identified in this study as a significant variable for discrimination regarding the companies' Z"-score. In other words, large construction companies were not systematically safer than small and medium-sized companies in terms of financial distress risk. This result is noteworthy because classical financial theory and some previous studies often associate larger firm size with lower bankruptcy risk due to economies of scale, diversification, and better access to resources (Le et al., 2024). It could be said that research focusing on company size yields mixed findings. Our conclusion is shared by Kamilah and Indira (2025), who also argue that company size has no significant impact on financial distress. They emphasise that larger firms require greater oversight and have higher operating costs. However, if management fails to control these costs effectively, the likelihood of financial distress may actually increase. From this perspective, the financial distress of large companies does not stem solely from their size, but rather from management's inability to effectively manage resources and debt. On the other hand, Bimantio and Nur (2023) found that size affects financial distress only indirectly as a moderator of the impact of indebtedness in the Indonesian construction sector, suggesting an inconsistent effect of size. Another recent analysis by Meiliana et al. (2024) showed that larger companies have a statistically significantly lower risk of financial distress, which contradicts our finding that size plays an insignificant role. Similarly, Febiana et al. (2024) demonstrated that firm size can moderate the impact of certain financial indicators on the emergence of financial problems, and therefore,

this factor cannot be completely ignored. Overall, this suggests that while the benefits of foreign ownership are fairly consistently confirmed in the literature, in line with the findings of this study, the impact of firm size remains more complex and context-dependent.

The failure of large construction contractors in various countries confirms that size alone does not ensure stability. Our findings corroborate this view, as size did not guarantee immunity within the construction sector in Slovakia. It may also be relevant that Altman's Z"-score is based on relative financial indicators rather than absolute values, so that well-managed small firms can achieve Z"-scores comparable to those of large firms. In other words, smaller construction companies can be just as financially resilient as larger ones; therefore, risk needs to be assessed based on differentiated indicators that go beyond just the company's size.

These findings possess several important implications. First, the robust performance of foreign-owned firms suggests that practices or resources associated with foreign ownership are beneficial to financial health. Therefore, public institutions and regulatory authorities could consider strategies to facilitate the transfer of knowledge from foreign to domestic firms, or to establish an environment that facilitates easier access to capital and expertise for domestic companies. Lenders and investors should not assume that a large firm is automatically safe. Analysis should focus on financial fundamentals and management rather than size alone, given that even market-leading construction firms can get into trouble. Moreover, domestic companies in the construction sector may need to enhance their financial planning and risk management to reduce the performance disparity with their foreign competitors. They could emulate management practices to improve their Z"-score. Furthermore, the absence of a size effect signals to managers that smaller companies are not inherently destined for financial weakness; with effective financial management, they may achieve stability similar to that of larger companies.

5. Conclusions

The aim of this study was to examine how firm size and ownership distinguish various types of financial distress in Slovakia's construction sector, using Altman's model for identifying the companies' financial state. The analysis of a sample of domestic and foreign companies of various sizes provides valuable insights into how ownership and size impact the resilience of companies in the unstable construction industry.

Despite its contributions, this study has some limitations that restrict the generalizability of the results. Firstly, the analysis focuses on a single sector of construction in a single country, so the conclusions may not apply to other industries or regions where market dynamics differ. Secondly, the reliance on Altman's Z"-score model as the only indicator of financial distress is another limitation. Recent research warns that such models may require local calibration according to conditions specific to a given sector or country (Matanga and Holman, 2024). It is also worth noting that the Z"-score captures only quantitative financial indicators and may overlook qualitative factors, such as management quality or project risk level, which also affect a company's distress.

Future research could extend this study with international comparisons of Altman's Z"-score or other models of financial distress, particularly in Central and Eastern Europe, to determine whether the advantage of foreign ownership and the non-significant impact of size observed in Slovakia are specific to the context or more universal in nature. Further research could also focus on other industries in Slovakia, as industry characteristics may influence the dynamics of financial distress. It would also be interesting to explore in more depth which aspects of foreign ownership, such as parent company support, management practices, or access to international capital, lead to better outcomes, while also identifying domestic firms that achieve resilience through alternative strategies.

Author contributions

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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Data Availability Statement

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to licensing restrictions on the Moody's Orbis database (formerly Bureau van Dijk), which is a subscription-based commercial dataset.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of generative AI and AI-assisted technologies in the writing process

The authors declare that no generative AI or AI-assisted technologies were used in the writing or preparation of this manuscript.

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