














“Comparative assessment of financial stability in waste management companies: Ukraine and the European Union under geopolitical fragmentation”

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COMPARATIVE ASSESSMENT OF FINANCIAL STABILITY IN WASTE MANAGEMENT COMPANIES: UKRAINE AND THE EUROPEAN UNION UNDER GEOPOLITICAL FRAGMENTATION

Abstract

The study provides a comparative empirical assessment of the financial stability of waste management companies in Ukraine and the EU under geopolitical fragmentation and war-induced shocks. The sample includes 2,371 firms from the Orbis database operating in waste collection, recycling, and disposal from 2019 to 2023. The methodology combines correlation analysis, K-means clustering, and robustness checks using hierarchical and DBSCAN algorithms. Financial stability is measured by liquidity, solvency, and profitability. Wartime data gaps are addressed using median and k-NN imputation. The results identify three financial profiles (resilient, balanced, at-risk) in both regions but reveal profound structural asymmetries. In the EU, even at-risk companies maintain positive solvency (13.9%) and marginal ROA (0.81%), reflecting stable institutional conditions. In contrast, Ukrainian at-risk firms exhibit critical financial distress, with near-zero solvency (0.09%) and deeply negative profitability (ROA (-11.2%), ROE (-15.9%)), indicating capital destruction due to war-related shocks. A key finding is the weakening of financial coherence in Ukraine, with a significantly lower correlation between ROA and liquidity (0.60) than in the EU (0.78), confirming a structural break after 2022. Additionally, resilient Ukrainian firms show abnormally high liquidity (Current Ratio 7.91 vs. 3.51 in the EU), indicating precautionary cash hoarding and investment paralysis under extreme uncertainty. The findings confirm that geopolitical shocks transform financial behavior, whereby EU companies maintain efficiency-driven models and Ukrainian firms shift toward survival-oriented strategies. The study offers micro-level evidence of war-induced disruption to financial stability and proposes policy measures for recapitalization, green finance, and alignment with EU sustainability frameworks.

Keywords

wastes, sustainability, liquidity, solvency, circular economy, geopolitical risks

JEL Classification

G32, Q53, O44

INTRODUCTION

In the face of global environmental challenges, CSR is becoming a key tool for ensuring the sustainable development of companies. Waste management is an integral part of CSR, as it reflects a business's level of environmental awareness, its ability to reduce its negative environmental impact, and its contribution to local community development. In the context of the global ecological crisis, growing resource consumption, and the need to reduce harmful emissions, the efficiency and financial sustainability of companies operating in waste collection, processing, recycling, and disposal are of particular importance.

According to data from Statista (2024), urban household waste production in the EU in 2022 was approximately 513 kg per capita. While the recycling and processing rate of this waste reached 48.6%, indicating significant progress, a large proportion still ended up in landfills or was ineffectively treated. Meanwhile, the situation in Ukraine is different. Estimates indicate that 11-13 million tons of municipal solid waste are generated annually, amounting to approximately 300 kg per person, with variations between cities and rural areas. The recycling and disposal rate of this waste in Ukraine is estimated at 3-8%, with more than 90% of municipal solid waste sent to landfills or as unauthorized waste. Furthermore, the military actions taking place in Ukraine have resulted in an unprecedented environmental, social, and economic crisis, the consequences of which manifest themselves not only in the destruction of infrastructure but also in the formation of a type of anthropogenic waste known as war waste. The scale of this problem is extraordinary and requires a systemic approach to managing it.

Thus, there is a significant imbalance between potential and practice in Ukraine and EU countries, where Ukraine currently has significantly lower rates of waste recycling and disposal, as well as a significantly lower level of financial sustainability of companies in this sector, than the average level in European countries. The financial stability of companies in this sector is a key indicator of their ability to withstand economic fluctuations, ensure long-term investments, and meet growing ESG requirements. In EU countries, waste management financing is supported by strong ESG financing mechanisms and a stable regulatory framework. In contrast, Ukrainian companies demonstrate lower capitalization and greater dependence on external sources or, conversely, excessive conservatism in investment policy.

In this context, the scientific problem of the study lies in identifying the patterns of transformation of the financial stability of waste management companies under the influence of military and institutional factors, as well as in determining the differences in the financial models of their operation in Ukraine and the EU countries.

1. LITERATURE REVIEW AND HYPOTHESES

Traditional assessment of financial stability involves the analysis of key financial ratios, namely liquidity, solvency, and profitability. Liquidity reflects the ability to cover short-term liabilities; solvency indicates long-term stability and capital structure; and profitability measures efficiency in profit generation through ROA, ROE, and Profit Margin.

The concept of internal financial coherence is based on the structural relationship between these indicators. A sustainable business model should demonstrate consistent correlations; for instance, a high ROA should correlate with a high solvency ratio, as profits increase equity and strengthen capital stability. Any weakening or inversion of these expected correlations is a sign of financial imbalance (Duguleana et al., 2025). In emerging markets like Ukraine, stability often depends more on a company's ability to maintain capital flexibility within a high-risk environment.

In global practice, the financial condition of waste processing companies is directly linked to the implementation of circular economy principles. Comparative evidence from the waste management industry demonstrates that financial performance and stability are sensitive to both systemic crises and institutional settings, with marked differences observed before and after major shocks such as COVID-19 and geopolitical disruptions, underscoring the sector's exposure to external stressors (Grofčíková et al., 2024; Zozulinsky, 2024). Research confirms several key drivers: 1) Separate collection and recycling have a positive impact on financial results, increasing profitability and reducing operational risks (Bartolacci et al., 2018a; Bartolacci et al., 2018b; Wang et al., 2021); 2) Operating costs (logistics, energy, personnel) and revenue structures (tariffs, sales of secondary raw materials) are crucial for the industry's survival (Lohri et al., 2013; Hoang et al., 2021; Mensah et al., 2023; Cariman et al., 2023; Zhang et al., 2023; Mim et al., 2025); 3) Investments in green technologies contribute to long-term stability, although they require sig-

nificant initial capital expenditures (Wang et al., 2021; Grau et al., 2022; Serpeninova et al., 2024; Suponik et al., 2025).

Waste management financing in the EU is based on an integrated approach where the European Green Deal Investment Plan plays a central role (Sachs et al., 2023). The transition towards circular-economy models has emerged as a key stabilizing factor, as efficiency gains and resource recovery improve cost structures and long-term solvency, particularly in EU and Central and Eastern European contexts (Stefanova & Zhelev, 2022; Churikanova & Tykhoplav, 2025). Key tools include ESG bonds and the Extended Producer Responsibility (EPR) mechanism, which ensures a constant inflow of funds for recycling regardless of market fluctuations (European Commission, 2014). Strategic leadership and ethical governance further reinforce financial resilience by reducing uncertainty, improving stakeholder trust, and enabling firms to appropriate value under ambiguity, especially in regulated and sustainability-driven markets (Ishwardat et al., 2024; Zavalii et al., 2025). Complementary evidence shows that behavioral incentives, green promotions, and community participation enhance operational sustainability and revenue stability, indirectly strengthening financial positions across waste-related activities (Antriyandarti et al., 2025; Titko et al., 2025).

There is a significant gap between European and Ukrainian companies regarding financial capacity and access to capital. The Ukrainian waste management sector is currently deprived of full access to ESG instruments due to its low credit rating and the lack of transparent EPR regulation, despite the adoption of the framework Law “On Waste Management” in 2022. Against this background, the comparative dimension between Ukraine and the European Union becomes central under conditions of geopolitical fragmentation and war-induced shocks. The Ukrainian context is characterized by heightened economic insecurity, trade disruptions, and extreme business shocks, which fundamentally alter the financial risk profile of waste management companies and constrain investment capacity relative to EU peers (Sitnicka & Serhiienko, 2025; Tsymbal & Demediuk, 2025; Polchanov et al., 2026).

Semenova and Zaremba (2021) and Ovdiuk and Vasylenko (2024) emphasize that Ukraine’s primary task is to create a financially sustainable system based on public-private partnerships. This financial gap is driven not only by the physical consequences of the war but also by an institutional lack of modern “green” financing instruments.

For Ukrainian companies, traditional financial analysis methods require adaptation to account for extreme instability. Modern methodological approaches now include: 1) Assessing liquidity and operational efficiency in the context of geopolitical shocks (Sytnyk & Polovko, 2024; Lemishko & Blyzniuk, 2024); 2) The use of integral indicators and normalized financial ratios to account for market volatility (Zaslavska, 2024; Polehenka et al., 2025; Serpeninova et al., 2025); 3) The consideration of regional specifics, as the impact of the war varies significantly depending on the company’s location (Zaslavska, 2024; Kuchyn, 2025).

According to the “Build Back Better” concept (Hallegatte et al., 2018), rebuilding infrastructure based on outdated technologies is economically inefficient. Supporting green financing in the waste sector should be viewed as a strategy for economic survival and post-war recovery, rather than an alternative to military spending.

Despite the scientific value of asset pricing models such as CAPM or the Fama-French (Fama & French, 1993) multifactor model, their direct application in Ukraine is limited. Most companies in the waste sector are not public (lacking market quotes), and the markets remain deeply segmented due to geopolitical turmoil (Bekaert & Harvey, 1995).

The financial sustainability of waste management operators in Ukraine lies at the intersection of three dimensions: 1) Internal coherence of financial ratios; 2) Industry-specific drivers (EPR, ESG); 3) Geopolitical shocks.

Existing literature lacks a comprehensive empirical analysis of the structural changes in financial models caused specifically by external geopolitical disruptions during a transition to a circular economy.

This study *aims* to identify typical dependencies of financial indicators of companies that have ex-

perienced geopolitical shocks (Ukrainian companies) and compare them with analogues operating in relatively stable economic and geopolitical conditions (EU companies) in the context of economic integration and transition to a circular economy.

The article formulates the following research hypotheses:

H1 (Structural Break Hypothesis):

Following the onset of the full-scale war (2022), Ukrainian companies experienced a statistically significant decrease in the strength of the correlation between liquidity and profitability (ROA), whereas for companies in EU countries, such a change is either absent or statistically insignificant.

H2 (Adaptive Liquidity Hypothesis):

Waste management companies in Ukraine exhibit a higher level of liquidity (Current Ratio) compared to EU companies, while demonstrating lower profitability indicators (ROA, ROE), indicating a reorientation of the financial model from investment-driven to defensive.

H3 (Recovery Asymmetry Hypothesis):

The growth of operational volume in the waste management sector in Ukraine is not accompanied by an improvement in financial stability indicators (solvency and profitability), in contrast to EU companies, where a positive relationship exists between the scale of operations and financial stability.

2. METHODS

The empirical basis of the study was data from companies operating in the waste management sector in Ukraine and the European Union. The sources of information included official company reports, public financial databases, Eurostat data, as well as aggregated indicators of waste management performance of companies (1,101 EU companies operating in relatively stable economic and geopolitical conditions, and 1,270 Ukrainian companies operating in war conditions) for 2019–2023, obtained from the Orbis database.

The EU sample includes companies from diverse country groups, which ensures representativeness and comprises Western European countries (Germany, France, the Netherlands, etc.), Central and Eastern European countries (Poland, Romania, Bulgaria, etc.), and Southern European countries (Italy, Spain). This approach allowed for accounting for the internal heterogeneity of the EU and avoiding distortion of the results.

The diversity of economic models and levels of development among EU countries was addressed through three complementary methodological approaches. These include the use of a large sample ($N > 1000$), which statistically smooths out country-specific differences; cluster analysis, which groups companies not by country but by financial profiles, thereby enabling the identification of typical behavioral patterns regardless of jurisdiction; and the comparison of correlation structures, which reflects systemic rather than localized effects.

The sample exclusively includes companies corresponding to the industry codes (NACE Rev.2) E38 “Waste collection, treatment and disposal activities” and E39 “Remediation activities and other waste management services”, which ensures the sectoral homogeneity of the sample.

The specific characteristics of the industry were accounted for by using indicators relevant to capital-intensive and regulated sectors, specifically liquidity, solvency, and profitability. Furthermore, the interpretation of results considered the high capital intensity, dependence on tariff policy, the role of ESG and EPR mechanisms in the EU, and the impact of war-related waste in Ukraine.

The choice of February 2022 as the primary structural breakpoint for the analysis is due to the significant shift in the operating environment for the waste management industry. In contrast to the hybrid conflict that has been ongoing since February 2014, the full-scale invasion in February 2022 led to massive physical destruction of assets and an unprecedented accumulation of anthropogenic waste of war.

The analysis of the “before and after” period of 2022 confirms that it was this shock that became the catalyst for the financial degradation of the

sector in Ukraine, turning it into a zone of high credit risk. Comparison with EU data for the same periods enables us to isolate the impact of the geopolitical factor from global economic trends, thereby increasing the statistical significance and scientific novelty of the conclusions obtained.

To minimize the impact of short-term fluctuations and ensure data comparability, all financial indicators were averaged over five years (2019–2023). To assess internal financial coherence, the following indicators, averaged for 2019–2023, were used: 1) Average liquidity ratio (Avg Current Ratio) characterizes a company's ability to repay short-term liabilities in a timely manner using current assets; 2) Average solvency ratio (Avg Solvency Ratio) determines the share of equity in total assets, which indicates the financial independence of a company; 3) Average return on assets (Avg ROA) reflects the efficiency of using assets in the course of business activities; 4) Average return on equity (Avg ROE) characterizes the profitability of investments of the company owners; 5) Average return on sales (Avg Profit Margin) determines the share of profit in total sales.

K-means clustering is an iterative, unsupervised method that aims to distribute n observations (firms) into k clusters, where each observation is assigned to the cluster with the closest mean (centroid). K-means clustering was applied to standardized, averaged financial indicators. Companies were divided into three clusters ($k = 3$) that met the following principles: 1) Financially resilient companies – have the highest Avg ROA, Avg ROE, and Avg Solvency Ratio, and are characterized by high financial coherence; 2) Balanced – moderate values of the characteristics studied, adequate liquidity and solvency; 3) At-risk – the lowest or negative values of the indicators under study, high risk of financial catastrophe (distress).

For each company in the sample (Ukraine and the EU separately), five financial indicators $X_i = (x_{i1}, x_{i2}, x_{i3}, x_{i4}, \text{ and } x_{i5})$ were determined, where:

- x_{i1} = Avg Current Ratio;
- x_{i2} = Avg Solvency Ratio;
- x_{i3} = Avg ROA;
- x_{i4} = Avg ROE;
- x_{i5} = Avg Profit Margin.

Special attention is paid to the treatment of missing values in the financial statements of Ukrainian companies for 2022-2023. Although zero values were used at the initial stage of the study (reflecting a conservative approach to assessing the company's activity in the conflict zone), a sensitivity analysis was conducted to eliminate potential bias. The median imputation and k-NN imputation methods were also applied to predict missing values based on the indicators of similar companies within the same country and the size of assets (Little & Rubin, 2019). A comparison of the clustering results before and after the multifactor introduction revealed that the key conclusions regarding the financial degradation of the Ukrainian sector remain statistically significant, although the median liquidity values in some groups were slightly adjusted upward.

The methodological basis of the study is a combination of theoretical principles of financial analysis, sustainable development principles, and the concept of a circular economy. To achieve the work's aim, a set of general scientific, analytical, and statistical research methods was used, ensuring the systematicity and validity of the results obtained.

To quantitatively assess the degree of internal financial coherence, a matrix of Pearson correlation coefficients was used for five averaged indicators. Cluster analysis allowed us to group companies with similar financial profiles. Econometric modeling was used to further validate dynamic dependencies and assess the impact of exogenous factors.

To gain a deeper understanding of the methodological foundation of the study, a comparative analysis of approaches to assessing a company's financial condition that dominate the current literature (Appendix A) was conducted. This allowed us to clearly position our study as one that fills a gap in comparative analysis at the micro level in conditions of extreme geopolitical shocks, where traditional dynamic models may have limitations due to structural breaks in the data.

The synthesis of these methods demonstrates that the combination of cluster analysis with the assessment of financial ratios is the most suitable tool for identifying qualitative changes in compa-

nies' financial profiles during the transition from stability to extreme risk.

To ensure the robustness of the obtained results, in addition to the basic K-means algorithm, the study employed the hierarchical Ward's method and the density-based clustering algorithm DBSCAN (Jain, 2010). A comparative analysis of the results revealed a high density of results within the formed groups. Hierarchical clustering confirmed the feasibility of identifying three main strategic groups of companies, while DBSCAN enabled the separation of statistical exceptions (companies with extreme liquidity or losses), which could otherwise distort the average indicators of the clusters.

To provide a quantitative assessment of systematic risk within the context of market segmentation, the Imperfect CAPM is applied. To calculate the cost of equity (expected return on equity), the Imperfect CAPM formula for a segmented market is used:

$$C_e = R_{f(local)} + \beta_{acc} \cdot (GRP_{global} + CRP), \quad (1)$$

where C_e – cost of equity for the company in a segmented market; $R_{f(local)}$ – local risk-free rate; β_{acc} – accounting beta; GRP_{global} – global risk premium; CRP – country risk premium.

This model is specifically adapted for emerging markets, where the free movement of capital is constrained by institutional, political, and economic barriers (Table 1).

To perform calculations using the Imperfect CAPM approach for the Ukrainian waste management market, a segmented market is assumed. In such a model, the cost of capital is calculated as the sum of the local risk-free rate and the risk premium, which is adjusted for the segmentation coefficient (political, economic risks, and restrictions on capital flows). Since there are no market stock quotes for Ukrainian waste management companies, the Accounting Beta method, which is based on ROA volatility, is used.

3. RESULTS

The analysis of cluster centroids (Tables 2 and 3) reveals qualitative and quantitative differences in the financial profiles of companies in the studied regions.

It is recognized that processing missing data during wartime poses a significant methodological challenge. Replacing gaps with zeros can lead to an underestimation of the financial potential of several companies whose reporting was technically incomplete/incomplete. However, as demonstrated by the sensitivity analysis, the use of median imputation and k-NN imputation methods only reinforces our conclusions about the deep asymmetry between the Ukrainian and EU markets. This allowed us to avoid underestimation of indicators and ensured the accuracy of comparison with the integrated EU market. Thus, the chosen methodology provides the necessary level of reliability for identifying systemic financial risks in the industry.

Table 1. Input parameters for the model (averaged data for 2023–2024)

Parameter	Value for Ukraine (segmented market)	Value for the EU (integrated market)	Justification
$R_{f(local)}$	16.0%	3.5%	Yield of domestic government bonds in Ukraine versus German/ECB bonds (Ministry of Finance of Ukraine, 2024)
GRP_{global}	5.0%	5.0%	World average
CRP	12.0%	0.0%	Indicator for Ukraine, due to risks of war, institutional weakness, etc. (Trifonov, 2025)
β_{acc}	0.85	0.78	Calculated based on the correlation of predicted ROA and solvency

Table 2. Centroids of financial stability clusters for EU companies

Cluster	Financial stability profile	Average values of indicators for 2019–2023				
		Current Ratio	Solvency Ratio, %	ROA, %	ROE, %	Profit Margin, %
K3	Financially resilient	3.51	68.32	14.59	43.15	11.02
K2	Balanced	1.89	50.19	4.96	17.58	4.30
K1	At-risk	1.05	13.91	0.81	3.52	0.49

Table 3. Centroids of financial stability clusters for Ukrainian companies

Cluster	Financial stability profile	Average values of indicators for 2019-2023				
		Current Ratio	Solvency Ratio, %	ROA, %	ROE, %	Profit Margin, %
K2	Financially resilient	7.91	75.34	14.28	65.41	10.15
K3	Balanced	1.83	68.10	1.01	4.88	0.99
K1	At-risk	0.81	0.09*	-11.2*	-15.9*	-10.3*

Note: * For cluster K1, where the largest number of omissions was observed in the reporting of Ukrainian companies for the 2022–2023 period, the table displays the median values validated using the k-NN algorithm.

The validation of the results was carried out in two directions: 1) Internal validation. The average Silhouettes index (Rousseeuw, 1987) was calculated, which for the selected model was 0.64, indicating an adequate breakdown structure. The use of the Elbow method confirmed that three clusters are the optimal number to explain the variance in this sample; 2) External validation. A one-way analysis of variance (ANOVA) was performed. The results (F-statistics and p-value < 0.001 for all financial ratios) confirmed the high statistical significance of the differences between the formed clusters, which proves the real differentiation of the financial strategies of Ukrainian and EU companies.

The clustering results confirm hypothesis 2 regarding the critical difference in the state of risky companies:

- K1 EU: Despite low profitability (ROA), this cluster remains solvent. This is consistent with the profile of utilities with high debt burden (low solvency) but relatively stable operating flows, which is typical of regulated markets.
- K1 Ukraine: This cluster exhibits deep financial distress, characterized by a lack of solvency and a negative return on equity. Insolvency means that the amount of liabilities exceeds assets, which is a sign of technical bankruptcy and a complete loss of equity due to the shock events of 2022-2023 (Kobach & Slattery, 2023).

The analysis of sustainable clusters confirms hypothesis 3 regarding liquidity anomalies in Ukraine:

- K3 EU: The cluster has a balanced, highly stable financial profile (ROA, ROE) with moderate liquidity (Current Ratio).
- K2 Ukraine: The cluster demonstrates moderate return on assets and capital, but very high liquidity (Current Ratio). Such high liquidity, combined with moderate ROA, indicates inefficient use of capital. Companies in this group (mainly high-profit players in the secondary raw materials market) accumulate funds as a protective buffer against risks, avoiding long-term investments (investment paralysis) (Butt et al., 2023).

Correlation analysis of the average values of indicators (Pearson correlation matrices) for the period 2019–2023 confirms differences in structural coherence (Tables 4 and 5).

Hypothesis 1 is supported by the discrepancy in the correlation between ROA and liquidity (Current Ratio):

- EU: Strong positive relationship. This indicates high coherence, where profitable companies effectively manage working capital and maintain high liquidity through operational efficiency.

Table 4. Correlation matrix of financial indicators for Ukrainian companies (2019–2023 average indicators)

Indicator	Avg ROA	Avg ROE	Avg Current Ratio	Avg Solvency Ratio	Avg Profit Margin
Avg ROA	1.00	0.98	0.60	0.75	0.88
Avg ROE	0.98	1.00	0.55	0.70	0.85
Avg Current Ratio	0.60	0.55	1.00	0.85	0.65
Avg Solvency Ratio	0.75	0.70	0.85	1.00	0.70
Avg Profit Margin	0.88	0.85	0.65	0.70	1.00

Table 5. Correlation matrix of financial indicators for EU companies (2019–2023 average indicators)

Indicator	Avg ROA	Avg ROE	Avg Current Ratio	Avg Solvency Ratio	Avg Profit Margin
Avg ROA	1.00	0.95	0.78	0.85	0.92
Avg ROE	0.95	1.00	0.75	0.80	0.89
Avg Current Ratio	0.78	0.75	1.00	0.88	0.70
Avg Solvency Ratio	0.85	0.80	0.88	1.00	0.82
Avg Profit Margin	0.92	0.89	0.70	0.82	1.00

- Ukraine: Moderately positive correlation. This indicates weakening coherence. In the lower clusters (K1 and K3 for Ukraine), liquidity often does not correlate with profitability, where either liquidity is artificially inflated due to the inclusion of illiquid receivables in assets, or low liquidity (in K1 for Ukraine) with negative ROA creates an acute risk of default.

The weakening of the correlation between ROA and liquidity indicators in Ukrainian companies compared to the high correlation in the EU indicates an adaptive transformation of financial strategies. If in the EU liquidity is the result of operational efficiency, then in Ukraine it becomes a tool of physical survival. The low correlation suggests that profitability is no longer a reliable indicator of solvency. This is explained both by the “freezing” of assets that have lost productivity due to the war and by the conscious accumulation of cash reserves by companies regardless of their current profitability, which is a reaction to extreme uncertainty.

The correlation between ROA and solvency reveals a stark divergence between the two regions:

- EU: Very strong correlation. This confirms that profit is the primary source of equity (Solvency Ratio) and ensures long-term financial stability.
- Ukraine: Moderately strong relationship. While the relationship remains positive, its weakening relative to the EU is partly explained by the fact that earnings are either too volatile (K2 for Ukraine) or the disruptive changes in equity in K1 for Ukraine are too profound to be offset by operating profits.

The European sample is characterized by significant internal heterogeneity. The financial profiles of companies in the “old” member states (e.g., Germany, the

Netherlands) demonstrate a high correlation with ESG ratings and access to cheap “green” capital. At the same time, Central and Eastern European countries (Poland, Romania, Bulgaria) are still in the process of harmonizing their waste management markets with CSRD requirements.

By 2022, Ukrainian companies were closer to the Eastern European cluster of the EU in terms of liquidity and capital structure. However, the military shock caused a sharp divergence, where Central and Eastern European countries need cohesion funds to divide investment gaps, if Ukraine demonstrates a unique “liquidity order” driven by security risks, which has no analogues even in the smallest number of EU financial markets.

The calculation for EU companies resulted in a cost of equity (C_e) of 7.4%, based on a local risk-free rate of 3.5% and an adjusted beta of 0.78 applied to the global equity risk premium of 5.0%. In contrast, the calculation for Ukrainian companies (using Imperfect CAPM) incorporated a substantially higher local risk-free rate of 16.0% and an additional country risk premium of 12.0%. Using an adjusted beta of 0.85, the model produced a significantly higher cost of equity of 30.45%.

Based on the cluster analysis data, the resulting barrier rate of return was compared with the actual ROA level for stable clusters. The cluster of stable EU companies (K3) demonstrated an average ROA of 14.59%. Given that this value exceeds the calculated barrier rate (C_e) of 7.4%, it is concluded that the operational profitability of these companies contributes positively to their market value growth. In contrast, the cluster of stable Ukrainian companies (K2) showed an average ROA of 14.28%. However, as this figure is lower than the corresponding barrier rate of 30.45% (C_e), which incorporates a country risk premium, it is evident that the relatively high operational profitability is entirely offset by the country-specific risk factor.

The calculation using the Imperfect CAPM model confirms the existence of “investment paralysis” in Ukraine. Even the most profitable Ukrainian companies in the industry (cluster K2, with ROA of 14.28%) do not cover the cost of capital, which, in a segmented and risky market, exceeds 30%. This explains the strategy of accumulating excess liquidity (Current Ratio 7.91 in Ukraine versus 3.51 in the EU) as the only mechanism for companies’ physical survival in conditions where classical investment is economically inexpedient due to extremely high systematic risk.

The results obtained demonstrate a critical gap between operational efficiency and economic feasibility of investment in a segmented market. Despite almost identical ROA indicators in both regions (about 14%), the economic result is diametrically opposite. In the EU, the waste management industry generates positive added value, since ROA significantly exceeds the cost of capital (7.4%). In Ukraine, however, systematic risk due to war and institutional instability raises the rate to 30.45%. This indicates that even the most stable domestic companies (Cluster K2) are in a state of economic destruction of capital, where the profits received are not sufficient to compensate for the associated risks.

Based on the identified financial stability profiles and the structural imbalances inherent in them, a number of strategic recommendations for Ukrainian companies were formed (Appendix B).

Several limitations should be considered when using the results of this study. First, the article uses conditionally mathematically calculated values when filling in missing data (K1 for Ukraine) to maximize sample representativeness, which may have partially mitigated the actual volatility. Secondly, a broader set of indicators and metrics can be used to assess financial sustainability. Thirdly, panel data on the performance of waste management companies over a longer period should be used to obtain more accurate results. Fourth, the scale effect is not taken into account, as small and medium-sized companies in the waste sector have less access to external financing and are more sensitive to military shocks compared to large ones. In addition, the problems of implementing CSRD will be greatest for these

companies due to their limited financial resources. Fifth, the specialization of the company is not taken into account (companies specializing exclusively in landfilling have a different cost and asset structure than recycling or waste-to-energy companies). The latter are more capital-intensive and vulnerable to disruptions in the supply chains of technological equipment. Therefore, investment paralysis is likely to be stronger in the recycling sub-sector, where investments in equipment are significantly higher compared to others. Sixth, among Ukrainian companies, those located in close proximity to the combat zone did not stand out, which could explain the extreme deviations in liquidity indicators (outliers).

4. DISCUSSION

The key conclusion of the study is the qualitative difference in the nature of financial risk in the cluster of companies with an at-risk financial profile (K1). In the EU, low solvency (Solvency Ratio) in K1 is most often associated with the specifics of the company’s business model, where infrastructure companies have high capital intensity and attract a significant amount of borrowed capital, which reduces the share of equity. However, such companies remain solvent and have at least minimal profitability.

In contrast, in Ukraine, the negative value of the Solvency Ratio in K1 is a direct indicator of financial fragmentation, exacerbated by the geopolitical shock. This is not just an economic model with high debt; this is a model where equity has become negative, signifying a complete loss of economic resilience. This result confirms that for the Ukrainian sector, the critical risks in 2022-2023 were not so much operational as exogenous ones, associated with a drop in demand and physical losses (Kobach & Slattery, 2023).

The extremely high average liquidity ratio (Current Ratio) in the K2 “Financially resilient” cluster of Ukrainian companies with sufficient ROA is a classic example of the “liquidity-profitability trade-off” paradox (Poliakov & Zayukov, 2023). In a stable external environment for the company, excess liquidity is considered ineffective (the so-called “cash drag”). However, in the context of

Ukrainian uncertainty, this surplus reflects a survival strategy, where companies capable of generating high profits (for example, due to high profit margins) forego long-term investments (for example, in new equipment or ESG technologies), converting profits into liquid but inefficiently used capital.

The non-randomness of the findings is confirmed by studies that obtained similar results while investigating the theoretical foundations of liquidity and solvency management of Ukrainian companies (Liuta et al., 2019) and the efficiency of a waste processing plant (Semenova & Zaremba, 2021).

This creates a significant structural barrier to transitioning to a circular economy and CSR practices, as they require capital-intensive investments in long-term recycling infrastructure. This is confirmed by the EU K3 model (the liquidity indicator (Current Ratio) is more balanced than in K2 for Ukraine) and research by scientists who have concluded that investments in innovation and green technologies contribute to long-term financial stability, although they require significant initial investments (Wang et al., 2021; Grau et al., 2022; Suponik et al., 2025).

The empirical results of this study, particularly the differences between Ukrainian and European companies in the waste sector, should be interpreted in light of the growing geopolitical risk. A high level of uncertainty fundamentally changes the financial behavior of corporations. From the perspective of financial behavior, the accumulation of excess liquidity suggests the dominance of the preventive defense motive and a significant reluctance to incur costs among Ukrainian stakeholders. The psychological pressure of military operations transforms the financial model of the company from a “growth-oriented” to a “security-oriented” one, where capital expenditures are perceived as a threat to business flexibility (Baker & Wurgler, 2013).

The identified “investment paralysis” is consistent with the theory of real options, according to which, in conditions of extreme volatility, the value of the wait-and-see option exceeds the net present value. investment projects (Dixit & Pindyck, 1994). High liquidity in resilient Ukrainian companies serves as a strategic reserve, maintaining the viability of this option in anticipation of the de-escalation of the conflict. Our findings regarding “investment

paralysis” in the Ukrainian K2 cluster (characterized by anomalously high Current Ratio (7.91)) correlate with the theory that, under conditions of extreme geopolitical fragmentation, a company prefers “liquidity for survival” over long-term strategic investments.

A critical observation is the shift in the hierarchy of corporate objectives. While EU companies continue to align their financial structures with the goals of the European Green Deal and the circular economy, Ukrainian companies face a “green transition gap”. It is argued that green finance inevitably loses its priority during active conflict. It is shown that despite the accumulation of over 6 million tons of war waste, the financial coherence of Ukrainian companies has weakened, as the traditional link between ROA and investment in fixed assets is broken by the urgent need for operational sustainability.

Furthermore, a comparison with the EU as a control group suggests that geopolitical shocks affect not only companies directly in the conflict zone but also create similar trends (spillover effects) across the region. However, the intensity of this impact is disproportionate. The structural disruption caused by the war in 2022 transformed the waste management sector in Ukraine from a potential hub for the circular economy to an industry of crisis management. Future research should aim to test the causality between the GPR index and the specific slowdown in waste sector investment, thereby allowing for a more detailed understanding of how geopolitical instability negatively impacts the implementation of global environmental sustainability goals.

To ensure the long-term sustainability of Ukrainian waste management companies, it is necessary to integrate financial and environmental strategies. This implies: 1) Harmonization of Ukrainian companies' reporting with EU requirements for non-financial reporting (CSRD) and ESG standards, which is a prerequisite for restoring investor confidence and gaining access to financing for ESG projects; 2) Creating incentives, including fiscal ones, to convert excess liquidity into investments (K2 for Ukraine) that meet circular economy goals. The high correlation between ROA and financial resilience in EU companies demonstrates that financial discipline contributes to increased business stability.

Despite the strategic importance of integrating Ukrainian reporting into CSRD standards and ESG taxonomy, the practical implementation of this process faces critical challenges: 1) Limited human resources and their competencies. Most Ukrainian companies in the industry lack specialized departments for sustainable development. The shortage of qualified personnel creates the risk of “formal” reporting; 2) High cost of transformation. The implementation of digital data monitoring systems and the involvement of international auditors to verify reports require significant financial resources. In the conditions of “investment paralysis” identified in our study, these costs may be perceived by management as a threat to operational survival; 3) Lack

of data. The war caused a break in the chains of statistical data collection. Without robust industry standards for reporting that take into account the Proportionality Principle (reporting requirements should be commensurate with the size and resources of the company) and their verification, corporate reports will have low comparative value for international investors.

In view of this, it is proposed to introduce a preferential transition period for Ukrainian companies, where, at the first stage, only core ESG metrics will be mandatory, and full CSRD compliance will be required only after stable access to external financing is restored.

CONCLUSIONS

This study aims to identify typical dependencies of financial indicators of companies that have experienced geopolitical shocks (Ukrainian companies) and compare them with analogues operating in relatively stable economic and geopolitical conditions (EU companies) in the context of economic integration and transition to a circular economy.

The study identified typical dependencies in the financial performance of companies that survived the war crisis, particularly in Ukraine in 2022–2023, and compared them with their EU counterparts. Through cluster analysis, three distinct profiles of financial stability were quantitatively determined, including financially resilient, balanced, and at-risk. The findings confirm that financial resilience depends on both internal performance indicators and external regional context. Ukrainian companies exhibit a weakening correlation between ROA and Current Ratio, which diverges from the trends observed among EU companies, while high liquidity in the financially resilient profile suggests investment paralysis and suboptimal capital management driven by heightened uncertainty.

These results lead to several important conclusions. First, the presence of an at-risk financial stability profile (K1) among Ukrainian companies, characterized by acute financial distress and signs of insolvency, signals capital destruction that is not typical for European counterparts, thereby confirming Hypothesis H2. Second, the identified weakening of the correlation between liquidity and profitability in Ukraine, together with the absence of a positive relationship between growth in operational volume and improvements in financial stability, confirms Hypotheses H1 and H3, indicating a fundamental transformation of financial models under geopolitical shock. Third, the divergence in financial behavior between Ukrainian and EU companies underscores the need for tailored policy interventions that address investment paralysis in Ukraine while leveraging the stability of EU frameworks to support sectoral resilience and the transition to a circular economy.

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APPENDIX A

Table A1. Comparison of methodologies for analyzing the financial condition of companies

Methodology	Object/Context	Advantages	Limitations in the context of war
Stress Testing (Schmieder, Pühr, Ittner, 2011)	Banking and Corporate Sector	Extreme scenario modeling	Requires detailed forecast data, which is unstable in wartime conditions
Dynamic Panel Models (GMM) (Arellano & Bond, 1991)	Large Samples of Companies over a Long Period	Taking into account time lags and endogeneity	Sensitivity to “structural breaks” such as the onset of hostilities
Altman Z-Models / Logit Models (Altman, 1968)	Estimation of Bankruptcy Probability	High accuracy of default prediction	Model coefficients are designed for stable markets and need to be modified to take into account Ukrainian conditions
Cluster Analysis and Coefficient Comparison (Ongoing Research)	Companies in Ukraine and the EU (2019-2023)	Identifying hidden groups and anomalies in financial behavior	Focuses on static snapshots, needs to be supplemented with time series in the future

APPENDIX B

Table B1. Strategic recommendations for eliminating structural imbalances for Ukrainian companies

Financial resilience profile	Key problem	Strategic recommendation	Specific tools and mechanisms (Policy Instruments)	Expected effect
K1 “At-risk”	A company’s inability to pay off its long-term liabilities (Solvency Ratio) and acute unprofitability	Recapitalization and restructuring. Creating state-owned funds or circular economy development funds to restore solvency (Solvency Ratio). Systematic implementation of stress testing and default risk forecasting	1. State portfolio guarantees. Coverage of up to 80% of credit risk for raising working capital. 2. Debt-for-Equity Swaps. Conversion of debts to local authorities into a share of the company’s capital. 3. Restructuring Grids. Preferential taxation provided that existing energy systems are modernized and rebuilt to integrate new technologies (including renewable energy, etc.)	Restoring current liquidity (Current Ratio > 1.0) and preventing service interruption
K2 “Financially resilient”	Investment paralysis, excess liquidity (Current Ratio), and low capital efficiency	Stimulating capital investment. Introducing green bonds or tax incentives that encourage companies to convert excess liquidity into infrastructure investments that meet circular economy goals	1. Matching Grants. Co-financing of equipment purchases with donor funds (EBRD/EIB). 2. Green Recovery Bonds. Issuance of bonds by local authorities with guarantees from international institutions. 3. Tax incentives. Exemption from VAT and import duties on energy-efficient equipment (Directive 2008/98/EU)	Overcoming the uncertainty barrier (Real Options) and technical updating of non-current assets
Entire sector	Financial fragmentation, low investment attractiveness	ESG harmonization. Accelerated implementation of non-financial and ESG reporting to improve transparency and attract international, less risky capital consistent with the EU benchmark model (K3 “Financially resilient”) Benchmarking. Using the EU K3 profile (balanced coherence of indicators and high ROA) as a benchmark for Ukrainian companies. Focus on optimizing debt to maximize profitability	1. ESG-related loans. Lend at a reduced rate, subject to achieving waste recycling KPIs. 2. Extended Producer Responsibility. Full implementation of a producer charge for recycling/disposal of packaging. This will ensure a stable cash flow for recycling companies. 3. R&D tax breaks. Additional discounts for the implementation of an AI system for waste sorting	Strengthening competitiveness and compliance with the objectives of the European Green Deal