A Conceptual Framework for Post-COVID Financial Distress Prediction Using Fuzzy Inference Systems in Emerging Markets

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ABSTRACT

Financial distress prediction has traditionally been based on linear, ratio-driven models that assume stable economic conditions and clear financial signals. However, the COVID-19 pandemic introduced significant uncertainty and uneven recovery patterns, particularly in emerging markets, which challenge these assumptions. In response, this study proposes a conceptual framework for post-COVID financial distress prediction using a Fuzzy Inference System (FIS). Drawing on financial distress theory, decision science, and fuzzy logic, this paper reinterprets key financial ratios—such as profitability, liquidity, leverage, and efficiency—not as precise values, but as flexible and linguistically meaningful indicators. These indicators are then integrated into a rule-based fuzzy inference system to generate a more nuanced assessment of financial distress risk. From a theoretical perspective, the proposed framework shows how fuzzy inference can better capture non-linearity, uncertainty, and the complex interactions between financial variables—areas where traditional linear models often fall short. This study contributes to the financial distress literature by introducing an uncertainty-aware framework that connects corporate finance with intelligent decision-making systems. It also lays a strong foundation for future empirical testing and offers practical insights for regulators, investors, and managers navigating post-crisis environments.

Keywords: Financial distress; Fuzzy inference system; Conceptual framework; post-COVID recovery; Emerging markets

INTRODUCTION

Forecasting financial trouble is a primary focus of corporate finance research due to its significant ramifications for investors, regulators, and the sustainability of firms. Traditional prediction models, on the other hand, were mostly based on the ideas that linkages are linear, the economy is stable, and financial signals are clear. These assumptions get weaker and weaker when there is a lot of systemic upheaval. The COVID-19 pandemic, for example, brought to unprecedented levels of uncertainty, volatility, and sectoral asymmetry in corporate financial settings. This would create a very complex economy that existing methods of prediction would have a hard time predicting (Yunus et al., 2021a).

During the post-COVID recovery phase, companies take different paths to adjust, which makes static ratio-based methods less useful for showing how distress changes over time. Financial indicators can emit ambiguous and contradictory signals, complicating binary classifications and rigid threshold methodologies. Even with these constraints, a lot of the current research, especially in emerging markets, still uses traditional linear frameworks.

Emerging markets have heightened complexity in predicting financial crises due to inherent structural market inefficiencies and increased susceptibility to economic instability (Marzuki et al., 2025). Malaysia is an example of such a country whereby despite its consistent economic growth and periodical budgetary interventions, data shows a rising pattern of bankruptcies.

This paper responds to this gap by developing a conceptual framework for financial distress prediction based on Fuzzy Inference Systems (FIS). By reconceptualising financial ratios as linguistically interpretable and inherently imprecise signals, the framework embeds uncertainty directly into the decision process. Rather than proposing an empirical model, this study advances a theoretically grounded structure that aligns financial distress assessment with human reasoning under uncertainty, offering a more adaptive foundation for post-crisis risk evaluation.

The objective of this paper is therefore conceptual: to articulate how FIS can serve as an alternative theoretical foundation for financial distress prediction in post-crisis environments, particularly within emerging markets.

Financial Distress as a Dynamic and Uncertain Phenomenon

Financial distress is commonly defined as a state in which a corporation struggles to meet its financial obligations (Yazdanfar & Öhman, 2020). It is increasingly being recognised as a dynamic process rather than a discrete event. It reflects a gradual erosion of a firm's financial resilience, driven by interacting pressures on profitability, liquidity, leverage, and operational efficiency. During crisis and recovery periods, these dimensions rarely deteriorate in isolation, producing complex and non-linear distress trajectories. In the field of research, this is frequently referred to as the "red zone" before a business encounters difficulties such as bankruptcy or insolvency, particularly if they fail to take prompt action (Hashim et al., 2024). It is more often a gradual downward spiral driven by poor internal choices or external economic setbacks than an overnight failure.

Recurring symptoms have been found by researchers to be early indicators of distress. These include continued cases of negative earnings, heavy debt burdens, and unstable cash flows which affect the ability of a business to pay its short-term liabilities (Zuhud et al., 2022a). Furthermore, a reducing asset turnover and decrease in quick ratio is usually used as a key indicator of a company's loss of operational efficiency. These financial weaknesses are rampant during periods of macroeconomic instability such as the COVID-19 pandemic which had a significant impact on corporate performance globally (Ismail et al., 2021b).

During periods of economic stability, financial ratios may reasonably approximate firm performance. In contrast, crisis and recovery periods introduce volatility, feedback effects, and abrupt structural shifts. Under these conditions, identical ratio values may carry different meanings across firms, industries, and time horizons. For example, high leverage may signal aggressive growth in one context but imminent distress in another.

Post-COVID economic conditions amplify this complexity. Firms may simultaneously experience revenue recovery and liquidity constraints, or operational efficiency gains alongside elevated leverage. Under such circumstances, identical financial ratios may signal fundamentally different risk profiles across firms and sectors. Consequently, financial distress should be conceptualised as a continuum of risk shaped by contextual uncertainty rather than a binary state determined by fixed thresholds.

Empirical research conducted in Malaysia reveal that the impact of financial distress varied considerably across businesses during the COVID-19 epidemic. Manufacturing enterprises were adversely affected by supply chain disruptions, production delays, and labour shortages. This resulted in a deteriorated financial ratio and heightened bankruptcy risk (Gunawan & Putra, 2021). Nevertheless, the insurance business faced its own set of issues including the escalation of claim volumes, elevated underwriting risk, and fluctuating investment returns within unpredictable financial markets (Yunus et al., 2021).

Accordingly, financial distress should be conceptualised not as a fixed classification outcome but as a continuum of risk, shaped by interacting financial dimensions under uncertainty.

Limitations of Traditional Financial Distress Models

Conventional financial distress prediction models are grounded in three implicit assumptions: linearity, stability, and precision (Altman, 1968). First, they assume linear relationships between financial ratios and distress outcomes. Second, they presume stable economic conditions in which historical relationships remain valid. Third, they treat financial indicators as precise numerical values with clear interpretive boundaries.

These assumptions are increasingly untenable in post-crisis environments. Financial relationships often become non-linear during periods of stress, with small changes in liquidity or leverage producing disproportionately large effects on firm viability. Moreover, crisis conditions invalidate historical benchmarks, reducing the relevance of pre-pandemic calibration.

Perhaps most critically, traditional models fail to capture interpretive ambiguity. Financial ratios are subject to accounting discretion, reporting delays, and contextual variation. Treating such indicators as exact signals ignores their inherently fuzzy nature. As a result, reliance on purely linear aggregation methods may lead to misclassification, delayed warnings, and reduced explanatory power during periods when accurate assessment is most needed.

The Z-Score has been extensively utilized by Malaysian companies listed on Bursa Malaysia, particularly for assessing solvency levels and providing early warnings on PN17 status. The assessments of PN17 companies regularly indicate that a company will ultimately be classified inside this financial distress state (Hashim, 2021). This demonstrates the model's utility as a primary screening instrument for conducting safety assessments and credit risk evaluations. The Z-Score has historically served as a tool for financial analysts to detect a firm's deteriorating financial condition and to forecast distress across multiple industries, owing to its simplicity and quantitative objectivity (Zuhud et al., 2022).

Despite its demonstrated popularity, the Altman Z-Score possesses significant limitations in addressing periods of economic uncertainty. The model is predicated on the assumption that financial environments and the linear relationships among the variables remain stable. Nevertheless, the COVID-19 pandemic showed that this assumption is erroneous. As a result, market shocks and unexpected liquidity constraints led to fast alterations in financial ratios, diminishing the responsiveness of conventional Z-Score evaluations to swiftly changing distress trends (Ismail & Mahussin, 2021).

Fuzzy Logic as a Decision-Theoretic Foundation

Fuzzy logic is a well-known intelligent computational paradigm that aims to solve decision-making problems that involve uncertainty, imprecision, and vagueness—situations where binary or traditional statistical methods often fall short (Tang et al., 2021; Shinde-Pawar et al., 2022; Sahu et al., 2024). Fuzzy logic, in contrast to classical logic, facilitates the representation of partial membership and linguistic reasoning, so enabling the assessment of complicated phenomena in a manner that more accurately mirrors human cognitive processes.

Prior studies across diverse application domains demonstrate the suitability of fuzzy inference systems (FIS) for integrating expert knowledge and handling ambiguous information. For example, fuzzy-based frameworks have been applied in environmental risk assessment, healthcare decision support, and safety management, where precise numerical boundaries are difficult to define (Zulkiflee & Idris, 2024). These studies consistently emphasise that FIS aligns with human reasoning by enabling inference under incomplete or uncertain information, thereby supporting more flexible and interpretable decision outcomes.

More recently, fuzzy logic has been extended to financial decision-making contexts, where corporate conditions evolve dynamically and financial indicators often convey imprecise signals. Studies applying FIS to financial distress and bankruptcy assessment highlight its ability to accommodate changing financial environments and interpret qualitative and quantitative risk factors in an integrated manner (Judijanto & Riandari, 2024). Collectively, this body of literature supports the theoretical relevance of fuzzy logic as an uncertainty-aware reasoning framework, providing a strong conceptual foundation for its application in post-crisis financial distress assessment.

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Development of the Conceptual Framework

Conceptual Constructs

The proposed framework incorporates four core financial dimensions that are widely recognised in the financial distress literature: profitability, liquidity, leverage, and efficiency. Profitability reflects a firm's capacity to generate earnings from its asset base, while liquidity captures short-term solvency and the ability to meet immediate financial obligations. Leverage represents the extent of debt financing and associated financial risk exposure, and efficiency indicates how effectively a firm utilises its resources to generate revenue. Within the framework, these dimensions are not treated as deterministic indicators but as imprecise financial signals that require interpretation under conditions of uncertainty.

Profitability constitutes a crucial internal factor influencing financial difficulty. A prolonged decrease in earnings frequently indicates fundamental financial problems, such operational inefficiencies, diminished demand, or elevated expenses. Companies with inadequate profitability are less capable of producing sufficient cash flow to manage debt or reinvest in their operations, hence substantially heightening the risk of financial trouble (Ohlson, 1980). Profitability can be evaluated using key indicators including return on assets (ROA), return on equity (ROE), and operating profit margins, where diminished values suggest possible distress (Altman, 1968).

Liquidity plays a central role in financial distress assessment by capturing a firm's ability to meet short-term obligations as they fall due. Liquidity Ratios are financial measurements that assess a company's capacity to fulfil its short-term obligations and effectively manage its current assets and liabilities (Saleem & Rehman, 2011). Insufficient liquidity constrains operational flexibility and increases dependence on external financing, thereby elevating distress risk.

It is commonly acknowledged that leverage is a significant source of financial risk and a substantial contributor to financial misery, especially in challenging economic times. The leverage ratio measures the extent to which the company is financed by debt (Fahmi, 2020). High leverage makes organizations more vulnerable to shocks by increasing fixed financial commitments and making them more sensitive to changes in earnings. Leverage and the chance of financial difficulty are positively correlated, according to empirical data, with highly leveraged companies showing less resilience during downturns.

Efficiency captures how effectively a firm utilises its resources to generate revenue and sustain operational performance. Inefficient resource utilisation often signals structural weaknesses that precede financial distress, such as declining asset turnover, rising operating costs, or managerial inefficiencies. Recent empirical studies highlight that deteriorating efficiency ratios tend to emerge well before firms enter formal distress or bankruptcy.

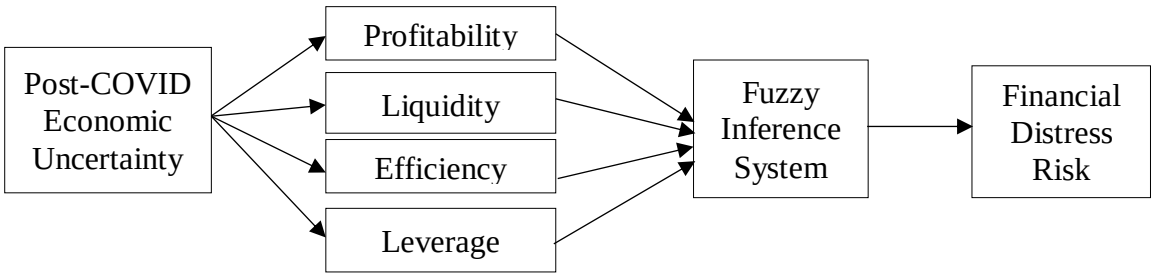

Figure 1: The proposed research framework for post-COVID financial distress prediction

Figure 1 illustrates the proposed research framework for post-COVID financial distress assessment. Post-COVID economic uncertainty is conceptualised as a contextual condition influencing firms' financial performance dimensions, namely profitability, liquidity, efficiency, and leverage. These dimensions are treated as imprecise financial signals that are linguistically interpreted and integrated through a fuzzy inference system. The framework produces an overall assessment of financial distress risk, reflecting the non-linear and uncertainty-sensitive nature of post-crisis financial environments.

Implications

Theoretical Implications

This paper contributes to financial distress literature by reframing distress prediction as a problem of uncertainty-aware decision-making rather than purely statistical classification. By integrating fuzzy logic into financial analysis, the framework extends traditional theories that assume precision and stability. It also bridges finance and intelligent systems research, offering a multidisciplinary perspective on corporate risk assessment.

Practical Implications

For practitioners, the framework offers a foundation for developing early-warning systems that align more closely with managerial reasoning. Regulators may use such systems to complement existing screening tools, particularly during periods of systemic stress. Investors and analysts can benefit from enhanced interpretability and context-sensitive assessments of financial health.

Future Research Directions

Future studies may empirically validate the proposed framework using firm-level data across industries and countries. Comparative analyses between fuzzy-based models and traditional statistical approaches would further establish predictive performance. Additionally, hybrid frameworks integrating fuzzy logic with machine learning techniques present promising avenues for advancing financial distress prediction under uncertainty.

CONCLUSION

The post-COVID economic landscape has exposed fundamental limitations in traditional financial distress prediction models that rely on linear aggregation and fixed thresholds. In environments characterised by uncertainty, volatility, and uneven recovery, financial indicators rarely convey unambiguous signals, necessitating more adaptive and interpretive assessment frameworks.

This paper develops a conceptual framework that positions Fuzzy Inference Systems as a theoretically appropriate foundation for post-crisis financial distress prediction. By reconceptualising financial ratios as imprecise signals and embedding linguistic reasoning within a rule-based inference structure, the framework captures non-linear interactions and contextual dependencies that are overlooked by conventional models.

The proposed framework contributes to theory by extending financial distress research into uncertainty-aware decision-making and by integrating insights from fuzzy logic and intelligent systems into corporate finance. Practically, it provides a foundation for developing early-warning tools that align more closely with managerial reasoning and regulatory needs in emerging markets.

Future research is encouraged to empirically validate the framework across sectors and jurisdictions, compare its predictive performance against traditional approaches, and explore hybrid fuzzy–machine learning extensions. Such efforts would further strengthen the role of fuzzy-based frameworks in advancing financial distress prediction under conditions of systemic uncertainty.

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