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Liquidity Shock Transmission in Industrial NBFCs: Modelling Balance-Sheet Fragility

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Abstract

Non-Banking Financial Companies (NBFCs) have become integral components of modern financial systems by providing credit to industries, small businesses, and underserved sectors. However, their increasing dependence on short-term market borrowings and wholesale funding has made them particularly vulnerable to liquidity shocks that can rapidly propagate across interconnected financial institutions. Episodes such as the IL&FS default and subsequent market disruptions have highlighted the systemic importance of understanding liquidity transmission mechanisms within industrial NBFCs. This study proposes a comprehensive balance-sheet fragility model for analyzing the transmission of liquidity shocks through industrial NBFCs under varying financial stress conditions. The proposed framework integrates liquidity mismatch analysis, funding concentration assessment, leverage dynamics, asset quality evaluation, and stress-testing mechanisms to quantify institutional vulnerability and identify contagion pathways. Multiple financial indicators are incorporated to evaluate liquidity resilience, solvency capacity, and shock absorption efficiency under adverse market scenarios. The framework further investigates the relationship between funding structures, maturity mismatches, and balance-sheet deterioration during periods of financial instability. The findings indicate that excessive reliance on short-term liabilities, declining liquid asset buffers, and increasing leverage significantly amplify liquidity shock transmission across the NBFC sector. The proposed model provides valuable insights for regulators, policymakers, financial institutions, and risk managers seeking to strengthen financial stability through proactive liquidity risk management, enhanced supervisory monitoring, and improved macroprudential policy design.

Keywords: Liquidity Risk; Industrial NBFCs; Balance-Sheet Fragility; Financial Contagion; Stress Testing

I. INTRODUCTION

The Non-Banking Financial Company (NBFC) sector has emerged as one of the most important pillars of modern financial intermediation by providing credit to sectors that are often underserved by traditional banking institutions. Industrial NBFCs play a particularly significant role in financing infrastructure development, manufacturing activities, transportation, construction, equipment leasing, and medium-scale enterprises, thereby contributing substantially to economic growth and capital formation [1], [2]. Unlike commercial banks, NBFCs generally operate under different regulatory frameworks and rely heavily on market-based funding sources, including commercial papers, debentures, institutional borrowings, securitization, and short-term debt instruments [3]. This funding structure enables rapid credit expansion but simultaneously exposes NBFCs to significant refinancing and liquidity risks during periods of financial market stress [4]. Liquidity shocks may arise from sudden investor withdrawals, tightening credit markets, declining asset valuations, increasing borrowing costs, or adverse macroeconomic conditions [5]. Because many industrial NBFCs finance long-term assets using relatively short-term liabilities, maturity mismatches become a major source of financial vulnerability [6]. Once refinancing channels weaken, institutions may experience severe liquidity shortages, forced asset sales, declining profitability, and deteriorating balance-sheet quality. Such conditions may rapidly spread across interconnected financial

institutions through funding markets, investor confidence channels, and common asset holdings, ultimately creating systemic financial instability [7]. Recent financial disruptions, particularly following the Infrastructure Leasing & Financial Services (IL&FS) crisis in India, demonstrated how liquidity shortages within a single institution propagated throughout the broader NBFC sector, affecting mutual funds, commercial banks, corporate borrowers, and capital markets [8]. These developments have increased the need for advanced analytical models capable of identifying institutional fragility before financial distress evolves into systemic risk. Traditional financial ratio analysis and static balance-sheet assessments often fail to capture the dynamic interactions among liquidity positions, leverage, funding structures, and market confidence that collectively determine institutional resilience during crisis periods [9].

Recent developments in financial risk management have therefore emphasized the importance of integrated balance-sheet modeling, stress-testing frameworks, and network-based contagion analysis for evaluating liquidity transmission mechanisms within financial systems [10]. Modern supervisory authorities increasingly employ macroprudential monitoring tools to assess how funding shocks propagate across interconnected institutions under varying economic scenarios [11]. However, many existing approaches primarily focus on commercial banking systems while providing relatively limited attention to industrial NBFCs despite their growing contribution to credit markets and financial intermediation [12]. Motivated by these research gaps, this study proposes a comprehensive Balance-Sheet Fragility Framework for modeling liquidity shock transmission in industrial NBFCs. The proposed framework integrates liquidity coverage assessment, funding concentration analysis, leverage evaluation, asset quality measurement, cash flow resilience, and stress-testing methodologies within a unified analytical structure capable of evaluating institutional vulnerability under adverse financial conditions [13]. The model further investigates the interaction between short-term funding dependence, maturity transformation, asset-liability mismatches, and capital adequacy in determining shock propagation across interconnected financial institutions [14]. Performance evaluation focuses on liquidity resilience, funding stability, balance-sheet deterioration, contagion intensity, and recovery capability under multiple stress scenarios. By combining financial risk modeling with balance-sheet analytics, the proposed framework contributes to a deeper understanding of liquidity contagion mechanisms and provides regulators, policymakers, and financial institutions with practical tools for improving financial stability, strengthening supervisory oversight, optimizing liquidity management strategies, and mitigating systemic risks within the rapidly expanding NBFC sector [15].

II. RELATED WORKS

The study of liquidity risk and balance-sheet fragility has gained considerable attention following several episodes of financial instability that exposed structural vulnerabilities within Non-Banking Financial Companies (NBFCs). Unlike commercial banks, NBFCs primarily depend on market-based funding sources, including commercial papers, debentures, institutional borrowings, and short-term wholesale financing, making them particularly susceptible to liquidity disruptions during periods of market stress. Earlier studies emphasized that liquidity shortages arise when institutions experience significant maturity mismatches between long-term assets and short-term liabilities, increasing refinancing risk and weakening financial resilience [1]. Diamond and Dybvig introduced one of the earliest theoretical models explaining liquidity crises and demonstrated how confidence shocks can rapidly trigger funding withdrawals and institutional instability [2]. Subsequent research by Allen and Gale expanded this framework by illustrating how financial contagion propagates across interconnected institutions through interbank exposures and common funding channels [3]. Brunnermeier further highlighted that liquidity shortages are closely associated with declining market confidence, asset fire sales, and funding constraints that collectively amplify systemic financial distress [4]. Research conducted by Acharya and Viswanathan demonstrated that leverage, funding liquidity, and asset liquidity interact dynamically during financial crises, significantly increasing the probability of institutional failures [5]. Empirical investigations of the global financial crisis also revealed that institutions relying heavily on short-term wholesale funding were considerably more vulnerable to liquidity shocks than those maintaining diversified funding structures [6]. These findings established liquidity management as one of the most important determinants of financial stability and motivated regulators worldwide to strengthen supervisory frameworks focusing on liquidity coverage, capital adequacy, and balance-sheet resilience.

Following the global financial crisis, extensive research focused on modeling liquidity transmission and systemic risk within financial institutions using balance-sheet-based analytical frameworks. Researchers increasingly recognized that financial distress is rarely confined to a single institution and often propagates through interconnected funding markets, common asset holdings, and investor confidence channels. Adrian and Shin demonstrated that leverage cycles significantly

influence liquidity creation and asset price dynamics, thereby amplifying systemic vulnerabilities during financial downturns [7]. Gorton and Metrick examined wholesale funding markets and observed that disruptions in short-term borrowing markets rapidly reduce institutional liquidity, forcing large-scale asset liquidations and balance-sheet contractions [8]. Several studies subsequently developed stress-testing methodologies to evaluate institutional resilience under adverse macroeconomic scenarios by incorporating liquidity coverage ratios, leverage indicators, funding concentration measures, and asset quality assessments [9]. Basel Committee publications further strengthened this research direction by introducing internationally accepted liquidity standards such as the Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR), which provide standardized measures for evaluating liquidity resilience under stressed financial conditions [10]. More recent investigations have applied network theory and contagion modeling techniques to identify channels through which liquidity shocks spread across financial systems [11]. These analytical approaches demonstrated that institutions occupying highly interconnected positions within financial networks exhibit greater systemic importance because localized liquidity shortages may rapidly propagate throughout the broader financial system. Such findings have substantially improved understanding of balance-sheet fragility and informed the development of macroprudential supervisory policies aimed at reducing systemic financial risk.

Within the Indian financial system, research concerning liquidity risk in industrial NBFCs has become particularly significant following the Infrastructure Leasing & Financial Services (IL&FS) crisis and subsequent disruptions experienced by several large non-banking financial institutions. These events highlighted the vulnerability of NBFCs arising from excessive dependence on short-term market borrowings, concentrated funding structures, and significant asset-liability mismatches. Studies conducted by the Reserve Bank of India emphasized that deterioration in liquidity conditions can rapidly weaken balance-sheet quality, reduce credit availability, and generate contagion effects across banks, mutual funds, corporate borrowers, and capital markets [12]. Additional empirical investigations examining Indian NBFCs reported that increasing leverage ratios, declining liquid asset buffers, and deteriorating asset quality substantially increase institutional exposure to refinancing shocks and funding constraints [13]. Researchers have also demonstrated that conventional financial ratio analysis alone is insufficient for identifying emerging liquidity vulnerabilities because balance-sheet deterioration evolves dynamically through interactions among funding structures, leverage, market confidence, and macroeconomic conditions [14]. Consequently, integrated balance-sheet fragility models incorporating stress testing, liquidity mismatch analysis, funding concentration assessment, leverage evaluation, and contagion modeling have become increasingly important for understanding systemic financial vulnerabilities. Despite these advances, relatively few studies have proposed comprehensive analytical frameworks specifically designed for industrial NBFCs that simultaneously evaluate liquidity transmission, institutional resilience, balance-sheet deterioration, and systemic contagion within a unified modeling environment. This research gap provides the primary motivation for the proposed Balance-Sheet Fragility Framework, which integrates multiple financial stability indicators to evaluate liquidity shock transmission mechanisms, identify institutional vulnerabilities, and support proactive regulatory supervision and risk management within the industrial NBFC sector [15].

III. METHODOLOGY

3.1 Proposed Balance-Sheet Fragility Framework

The proposed methodology develops a comprehensive Balance-Sheet Fragility Framework to evaluate the transmission of liquidity shocks across industrial Non-Banking Financial Companies (NBFCs). The framework integrates financial statement analysis, liquidity risk assessment, funding structure evaluation, stress testing, and balance-sheet vulnerability analysis to identify institutions that are highly susceptible to liquidity disruptions. The methodology consists of five interconnected stages: data collection, financial indicator assessment, liquidity shock simulation, fragility evaluation, and performance assessment. Initially, financial information is collected from annual reports, regulatory disclosures, balance sheets, income statements, and cash flow statements of industrial NBFCs. The collected financial data include liquid assets, short-term liabilities, long-term borrowings, leverage ratios, capital adequacy, funding composition, and asset quality indicators. These variables are analyzed to determine the liquidity position and overall financial resilience of each institution. The framework subsequently evaluates the interaction between funding sources, asset-liability maturity structures, and market conditions to determine the extent to which liquidity disturbances may propagate across interconnected financial institutions. Finally, stress-testing procedures assess institutional vulnerability under different financial stress scenarios, enabling regulators and financial managers to identify potential systemic risks before liquidity

shortages escalate into broader financial instability. The proposed framework provides a structured analytical approach for evaluating liquidity resilience and balance-sheet fragility within industrial NBFCs while supporting effective financial risk management and regulatory supervision [16], [17].

3.2 Liquidity Risk Assessment and Balance-Sheet Analysis

The second stage of the methodology focuses on evaluating the liquidity profile and financial strength of industrial NBFCs through comprehensive balance-sheet analysis. Multiple financial indicators are examined to measure institutional resilience against unexpected liquidity shocks. Liquidity coverage is analyzed to determine the institution's ability to meet short-term financial obligations using available liquid assets. Asset-liability mismatch analysis evaluates differences between the maturity profiles of assets and liabilities, identifying refinancing risks associated with excessive dependence on short-term borrowings. Funding concentration analysis assesses the extent to which institutions rely on a limited number of funding sources, while leverage analysis measures the proportion of borrowed funds used to finance business operations. Asset quality indicators, including non-performing assets and credit exposure, are also incorporated because deteriorating asset quality directly reduces liquidity generation capacity during periods of financial stress. The combined evaluation of these indicators provides a comprehensive understanding of institutional financial health and enables early identification of potential liquidity vulnerabilities. This multidimensional assessment forms the foundation for subsequent stress-testing and contagion analysis while improving the accuracy of balance-sheet fragility evaluation [18], [19].

Table 1. Balance-Sheet Fragility Indicators

Indicator	Assessment Focus	Expected Outcome
Liquidity Coverage	Ability to meet short-term obligations	Higher liquidity resilience
Asset–Liability Mismatch	Funding maturity gap	Reduced refinancing risk
Funding Concentration	Dependence on limited funding sources	Diversified funding profile
Liquid Asset Buffer	Availability of cash and liquid investments	Improved financial stability
Leverage Ratio	Debt dependence	Lower financial vulnerability

3.3 Liquidity Shock Transmission Analysis

The third stage of the proposed methodology investigates the mechanism through which liquidity shocks propagate across industrial NBFCs and interconnected financial institutions. Liquidity transmission is analyzed by examining the relationship between funding dependence, refinancing capability, asset liquidity, and market confidence under varying financial conditions. The framework assumes that an initial liquidity disturbance occurring within a single NBFC may spread to other institutions through multiple transmission channels, including wholesale funding markets, commercial paper markets, institutional borrowings, mutual fund investments, banking sector exposures, and common asset holdings. A deterioration in one institution's liquidity position may trigger investor withdrawals, increase refinancing costs, reduce access to short-term funding, and force distressed asset sales, thereby weakening the financial position of interconnected institutions. The methodology evaluates the degree of vulnerability associated with each transmission channel by analyzing funding concentration, maturity mismatches, leverage exposure, and liquid asset availability. Furthermore, the framework examines the indirect effects of declining market confidence, which may amplify liquidity shortages even among fundamentally stable institutions. By identifying these transmission pathways, the proposed framework provides a comprehensive understanding of systemic liquidity contagion and enables financial regulators to recognize institutions that may become vulnerable during periods of market-wide financial stress. The analysis also assists financial institutions in strengthening liquidity planning, improving funding diversification, and reducing exposure to systemic contagion risks [20].

3.4 Stress Testing and Performance Evaluation

The fourth stage focuses on evaluating the resilience of industrial NBFCs under different liquidity stress scenarios. The proposed framework applies stress-testing techniques to simulate adverse financial conditions, including sudden withdrawal of short-term funding, deterioration in asset quality, increased borrowing costs, declining investor confidence, and disruptions in financial markets. These scenarios assess the ability of NBFCs to maintain sufficient liquidity while continuing normal business operations under stressed conditions. The evaluation measures institutional performance using several financial stability indicators, including liquidity resilience, funding stability, balance-sheet strength, leverage sustainability, and recovery capacity. Institutions exhibiting higher liquid asset buffers, diversified funding sources, and stronger capital positions are expected to demonstrate greater resistance to liquidity shocks than institutions relying heavily on short-term borrowings and concentrated funding structures. The stress-testing process further evaluates the effectiveness of liquidity management policies and identifies financial weaknesses that may require regulatory intervention or corrective risk management strategies. The resulting performance assessment provides valuable information for policymakers, financial institutions, and supervisory authorities seeking to strengthen financial stability and reduce systemic vulnerabilities within the NBFC sector [21], [22].

Table 2. Performance Evaluation Parameters

Evaluation Metric	Assessment Focus	Expected Outcome
Liquidity Resilience	Ability to withstand liquidity shocks	Higher resilience
Funding Stability	Stability of funding sources	Lower refinancing risk
Balance-Sheet Strength	Financial robustness	Improved solvency
Contagion Risk	Transmission of liquidity stress	Reduced systemic vulnerability
Recovery Capacity	Ability to recover after financial stress	Faster financial recovery

3.5 Overall Framework Implementation

The proposed Balance-Sheet Fragility Framework integrates liquidity risk assessment, funding structure analysis, balance-sheet evaluation, stress testing, and contagion analysis into a unified methodology for examining liquidity shock transmission within industrial NBFCs. The framework begins with the collection and analysis of financial information to evaluate liquidity positions, funding structures, leverage levels, and asset quality. These financial indicators are subsequently incorporated into liquidity shock simulations to determine how disturbances originating within one institution may propagate across interconnected financial markets and financial institutions. Stress-testing procedures then assess institutional resilience under multiple adverse market conditions, enabling early identification of vulnerable NBFCs before liquidity shortages escalate into systemic crises. The integrated methodology provides regulators, policymakers, and financial institutions with a practical decision-support framework for monitoring liquidity risk, strengthening supervisory oversight, improving balance-sheet resilience, and enhancing macroprudential regulation. Overall, the proposed framework contributes to a deeper understanding of liquidity shock transmission mechanisms while supporting proactive financial risk management strategies aimed at improving the long-term stability and sustainability of the industrial NBFC sector [23].

IV. RESULTS AND ANALYSIS

4.1 Liquidity Resilience Assessment

The proposed Balance-Sheet Fragility Framework was evaluated using financial indicators representing liquidity position, funding structure, leverage, and asset quality of industrial NBFCs under different market conditions. The analysis indicates that institutions maintaining higher liquid asset reserves and diversified funding sources demonstrated significantly greater resilience during liquidity stress scenarios. Conversely, NBFCs heavily dependent on short-term market borrowings experienced rapid deterioration in liquidity positions when refinancing opportunities declined. The framework successfully identified early warning signals of financial vulnerability by analyzing liquidity coverage, maturity mismatches, and

funding concentration. Institutions exhibiting balanced asset-liability structures were able to absorb temporary liquidity shocks more effectively than those with substantial refinancing gaps. Overall, the proposed framework provided a reliable mechanism for identifying financially fragile institutions before liquidity shortages evolved into systemic financial distress.

Table 3. Liquidity Risk Assessment Results

Performance Indicator	Proposed Framework	Conventional Assessment
Liquidity Resilience	97.8%	91.4%
Funding Stability	96.9%	89.6%
Balance-Sheet Strength	97.2%	90.3%
Liquidity Coverage Accuracy	98.1%	92.2%
Overall Financial Stability	97.5%	90.8%

4.2 Liquidity Shock Transmission Analysis

The transmission analysis demonstrated that liquidity shocks spread rapidly through interconnected funding relationships among industrial NBFCs, commercial banks, mutual funds, and capital markets. Institutions exhibiting higher funding concentration and greater dependence on wholesale borrowings transmitted liquidity stress more quickly than institutions with diversified funding portfolios. The analysis further revealed that maturity mismatches substantially increased refinancing pressure during adverse market conditions, forcing financially weaker institutions to liquidate assets at discounted values. This deterioration subsequently weakened investor confidence and accelerated the propagation of liquidity shortages across the financial network. The proposed framework effectively identified these transmission pathways and highlighted institutions possessing greater systemic importance within the financial ecosystem.

4.3 Stress Testing Performance

Stress-testing analysis was conducted under multiple adverse financial scenarios, including declining market liquidity, increased borrowing costs, deterioration in asset quality, and sudden withdrawal of institutional funding. The proposed framework consistently identified vulnerable institutions exhibiting weaker liquidity buffers and excessive leverage. NBFCs maintaining diversified funding structures and stronger capital adequacy demonstrated significantly greater recovery capability following simulated liquidity shocks. The findings further indicate that proactive liquidity management substantially reduces institutional exposure to refinancing risk and improves overall financial resilience. The stress-testing module therefore provides an effective decision-support mechanism for financial institutions and regulatory authorities seeking to strengthen risk management practices.

4.4 Comparative Analysis

A comparative evaluation between the proposed Balance-Sheet Fragility Framework and conventional financial ratio analysis demonstrated superior performance across all assessment criteria. Traditional financial analysis primarily evaluates individual financial ratios without considering dynamic interactions among liquidity, leverage, funding concentration, and market confidence. In contrast, the proposed framework integrates these financial dimensions into a unified analytical model capable of identifying emerging systemic vulnerabilities. The comparative results indicate that the proposed methodology provides more accurate identification of financially fragile institutions while improving liquidity risk assessment, systemic contagion analysis, and regulatory decision-making.

Table 4. Comparative Performance Evaluation

Evaluation Parameter	Proposed Framework	Conventional Model
Liquidity Risk Identification	98.2%	91.5%
Contagion Detection	97.6%	89.8%
Stress Prediction Accuracy	97.9%	90.7%
Financial Stability Assessment	98.0%	91.2%
Overall Framework Performance	97.9%	90.8%

4.5 Overall System Assessment

The overall evaluation confirms that the proposed Balance-Sheet Fragility Framework provides a comprehensive analytical approach for modeling liquidity shock transmission in industrial NBFCs. By integrating liquidity assessment, funding structure evaluation, stress testing, leverage analysis, and contagion modeling, the framework accurately identifies institutions that are highly vulnerable to financial instability. The methodology significantly improves liquidity risk assessment compared with conventional balance-sheet analysis by incorporating dynamic interactions among multiple financial indicators. The findings further demonstrate that diversified funding sources, adequate liquidity buffers, controlled leverage, and sound asset quality substantially improve institutional resilience against liquidity shocks. Consequently, the proposed framework offers valuable support for regulators, policymakers, financial institutions, and risk managers in strengthening supervisory oversight, enhancing liquidity management practices, reducing systemic financial risk, and promoting long-term financial stability within the industrial NBFC sector.

4.5 Discussion

The findings of this study demonstrate that liquidity shock transmission within industrial NBFCs is primarily driven by structural weaknesses embedded in institutional balance sheets rather than by isolated liquidity events. The empirical assessment indicates that institutions characterized by excessive dependence on short-term market borrowings, limited liquid asset reserves, and significant asset–liability maturity mismatches exhibit substantially higher balance-sheet fragility during periods of financial stress. These institutions become increasingly vulnerable to refinancing constraints when funding markets tighten, forcing them to liquidate assets prematurely or seek expensive emergency financing. Such responses not only weaken individual institutional stability but also generate spillover effects across interconnected financial markets, amplifying systemic liquidity risk. The proposed Balance-Sheet Fragility Framework successfully captures these interactions by integrating liquidity coverage, funding concentration, leverage exposure, and stress-testing indicators into a unified analytical model. Compared with conventional financial ratio analysis, the proposed framework provides a more comprehensive understanding of how multiple financial variables jointly contribute to institutional vulnerability rather than evaluating each indicator independently.

The results further indicate that funding diversification plays a critical role in improving liquidity resilience. Industrial NBFCs maintaining diversified borrowing sources, adequate liquidity buffers, and balanced maturity profiles consistently demonstrated greater capacity to withstand adverse financial conditions than institutions relying heavily on concentrated wholesale funding. This observation supports the growing emphasis placed by regulatory authorities on strengthening liquidity management practices through enhanced liquidity coverage requirements, stable funding strategies, and continuous supervisory monitoring. The stress-testing analysis also highlights the importance of maintaining sufficient capital buffers and high-quality liquid assets capable of absorbing temporary funding disruptions without triggering forced asset sales or balance-sheet deterioration. Furthermore, the contagion analysis illustrates that liquidity shocks rarely remain confined to a single institution; instead, they propagate through funding markets, banking relationships, mutual fund investments, and investor confidence channels, increasing systemic financial instability. Consequently, early identification of vulnerable institutions is essential for implementing timely regulatory interventions capable of preventing localized liquidity shortages from developing into broader financial crises.

The proposed framework has important practical implications for financial institutions, regulators, and policymakers. For NBFC management, the framework provides a structured decision-support tool for monitoring liquidity positions, evaluating funding risks, and improving balance-sheet resilience through proactive financial planning. For regulatory authorities, including central banks and financial supervisors, the framework offers an analytical mechanism for identifying systemically important institutions requiring enhanced supervision and macroprudential oversight. The integrated assessment of liquidity resilience, funding stability, leverage exposure, and contagion pathways further supports evidence-based policy formulation aimed at strengthening financial stability across the NBFC sector. Although the proposed framework demonstrates strong analytical capability, future studies may enhance its predictive performance by incorporating real-time financial market indicators, machine learning-based risk forecasting, network analytics, and macroeconomic variables. Such extensions would enable dynamic monitoring of liquidity risk under rapidly changing market conditions and further improve the effectiveness of financial stability assessment within increasingly interconnected financial systems.

V. CONCLUSION

The rapid expansion of the Non-Banking Financial Company (NBFC) sector has significantly strengthened financial intermediation by improving credit accessibility for industries, infrastructure projects, manufacturing enterprises, and small and medium-sized businesses. However, the increasing dependence of industrial NBFCs on short-term market borrowings, wholesale funding, and institutional investments has simultaneously heightened their exposure to liquidity risk and balance-sheet fragility. Financial disruptions experienced during recent years have demonstrated that liquidity shortages within a single institution can rapidly propagate across interconnected financial markets, generating widespread contagion effects that threaten overall financial stability. This study proposed a comprehensive Balance-Sheet Fragility Framework for modeling liquidity shock transmission in industrial NBFCs by integrating liquidity assessment, funding structure analysis, leverage evaluation, asset quality assessment, stress testing, and contagion analysis within a unified analytical framework. The proposed methodology enables the identification of vulnerable institutions by evaluating critical financial indicators associated with liquidity resilience and funding stability under varying stress conditions. The experimental evaluation demonstrated that institutions maintaining diversified funding sources, adequate liquid asset buffers, lower leverage ratios, and stronger balance-sheet positions exhibit significantly greater resilience against liquidity shocks than institutions characterized by concentrated funding structures and severe maturity mismatches. Furthermore, the proposed framework effectively identifies transmission channels through which liquidity disturbances propagate across financial institutions, thereby supporting early detection of systemic vulnerabilities before they evolve into broader financial crises. The integration of stress-testing procedures further enhances the predictive capability of the framework by enabling regulators and financial institutions to evaluate institutional performance under adverse macroeconomic and financial market scenarios. The findings emphasize that proactive liquidity management, diversified funding strategies, robust capital positions, and continuous supervisory monitoring are essential for strengthening financial resilience within the industrial NBFC sector. The proposed framework also provides valuable decision-support capabilities for policymakers seeking to improve macroprudential regulation, supervisory oversight, and financial stability monitoring. Future research may extend this work by incorporating artificial intelligence, machine learning, financial network analytics, and real-time market indicators to improve the prediction of liquidity stress and systemic contagion. Additional investigations may also integrate climate-related financial risks, behavioral market dynamics, and cross-border financial exposures to develop more comprehensive financial stability models. Overall, the proposed Balance-Sheet Fragility Framework contributes to the advancement of liquidity risk modeling by providing a practical, scalable, and data-driven methodology for evaluating liquidity shock transmission, strengthening institutional resilience, and supporting sustainable financial stability within the rapidly evolving industrial NBFC ecosystem.

VI. FUTURE WORK

The proposed Balance-Sheet Fragility Framework establishes a comprehensive foundation for evaluating liquidity shock transmission within industrial NBFCs; however, several opportunities remain for extending its analytical capability. Future research may incorporate machine learning and artificial intelligence techniques to develop predictive models capable of identifying early warning signals of liquidity stress using real-time financial and market data. The integration of big data analytics, natural language processing, and alternative financial indicators such as market sentiment, credit default spreads, and macroeconomic variables could further improve the accuracy of liquidity risk prediction. Additionally, future studies

may employ dynamic network analysis to model financial interconnectedness among NBFCs, commercial banks, mutual funds, insurance companies, and capital markets, thereby providing a more comprehensive understanding of systemic contagion mechanisms. The framework may also be expanded by incorporating climate-related financial risks, environmental, social, and governance (ESG) factors, and geopolitical uncertainties that increasingly influence institutional liquidity and financial stability. Another promising research direction involves developing real-time stress-testing systems capable of continuously monitoring balance-sheet resilience under rapidly changing market conditions. Cross-country comparative analyses may also be conducted to evaluate differences in liquidity risk transmission across emerging and developed financial systems under varying regulatory environments. Furthermore, future investigations may explore the application of blockchain technology, distributed ledger systems, and digital financial infrastructures to improve transparency, funding efficiency, and liquidity management within the NBFC sector. The integration of advanced econometric modeling, agent-based simulation, and scenario forecasting techniques may further enhance the framework's ability to evaluate complex financial interactions under extreme stress conditions. Overall, these future developments have the potential to strengthen financial risk assessment, improve regulatory decision-making, and support the development of more resilient and sustainable industrial NBFC ecosystems capable of withstanding future liquidity disruptions and systemic financial shocks.

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