Assessment and Analysis of Banking Network Stability in Iran Using a Hybrid Model

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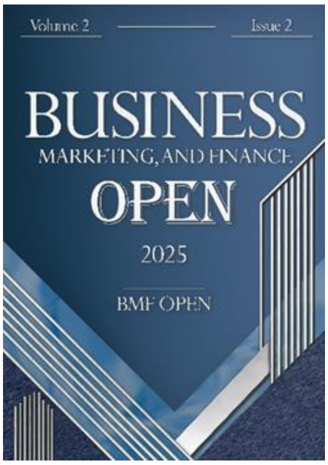

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Abstract: Banking network stability, as one of the fundamental pillars of the financial system, plays a decisive role in maintaining economic stability, strengthening public confidence, and supporting sustainable development. Considering the growing complexity of the financial environment, the expansion of systemic risks, and rapid technological transformations, the need for a comprehensive framework to analyze and enhance banking network stability has become increasingly significant. The objective of the present study is to develop a hybrid model for assessing and analyzing the stability of the national banking network through an integrated approach. In terms of purpose, this research is applied, and methodologically it adopts a mixed and analytical design. In the first phase, Confirmatory Factor Analysis (CFA) was employed to identify, classify, and validate the structure of the extracted dimensions. The results indicated an acceptable model fit and confirmed the validity and reliability of the constructs. In the second phase, Monte Carlo simulation was conducted using data from 20 selected domestic banks to evaluate the behavior of the banking network under various economic shock scenarios and risk volatility conditions. The findings revealed that capital adequacy, asset quality, corporate governance, and technological infrastructure represent the most influential determinants of banking network stability. The innovation of the study lies in integrating qualitative approaches, structural modeling, and probabilistic simulation to provide a comprehensive and context-specific framework for analyzing banking network stability, which can serve as a decision-making foundation for financial policymakers aimed at strengthening stability and risk management.

Keywords: Banking Network Stability, Financial Crisis, Confirmatory Factor Analysis, Monte Carlo Simulation

1. Introduction

The stability of the banking network has emerged as one of the most critical determinants of economic resilience, financial sustainability, and long-term development in modern economies. Banking systems function as the central transmission mechanism through which savings are mobilized, investments are financed, and monetary policy is transmitted across economic sectors. Consequently, instability within banking networks can rapidly propagate systemic risks and generate widespread economic disruptions. The global financial crises of recent decades demonstrated that banking fragility extends beyond institutional boundaries and becomes a macroeconomic concern affecting employment, production, and social welfare.

Contemporary research increasingly emphasizes that banking stability must be examined through multidimensional frameworks integrating financial performance, governance structures, technological transformation, systemic risk dynamics, and sustainability considerations [1, 2].

Financial stability in banking systems is strongly linked to public confidence and institutional credibility. Trust represents an intangible yet decisive asset for banks, as depositor behavior and investor expectations significantly influence liquidity conditions and crisis resilience. Empirical studies have shown that confidence in banks enhances financial stability by reducing panic withdrawals and strengthening institutional legitimacy [3]. Furthermore, social responsibility initiatives and ethical banking practices contribute to reinforcing social trust and strengthening systemic stability, particularly in developing financial markets where institutional confidence may be fragile [4]. Therefore, analyzing banking network stability requires simultaneous attention to financial indicators and broader socio-institutional dimensions.

The growing complexity of financial markets has intensified systemic risk exposure within banking networks. Globalization, interconnected interbank transactions, and cross-border capital flows have amplified contagion effects, making traditional single-indicator assessments insufficient. Advanced measurement approaches now focus on network-based and dynamic analyses capable of capturing interdependencies among banks. Research on systemic risk measurement demonstrates that accurate prediction of banking instability requires integrating multiple financial and macroeconomic variables into unified analytical frameworks [5]. Similarly, studies on interbank sustainability highlight that banking stability evolves dynamically and must be evaluated through models capable of reflecting temporal and structural changes in financial networks [6].

Sustainable banking has consequently become a dominant paradigm in contemporary financial research. Sustainable banking practices aim to align profitability objectives with environmental responsibility, risk management, and long-term economic resilience. Evidence from emerging and developed economies indicates that sustainability-oriented banking policies significantly improve institutional stability and reduce vulnerability to external shocks [7, 8]. These practices incorporate environmental risk assessment, responsible lending policies, and governance transparency mechanisms that enhance banks' adaptive capacity. In addition, sustainable banking models contribute to improved financial performance, demonstrating that stability and profitability are not conflicting objectives but mutually reinforcing outcomes [9].

Internal organizational factors also play a substantial role in determining banking network resilience. Capital adequacy, asset quality, liquidity management, and operational efficiency constitute core determinants of bank stability. Empirical investigations into commercial banking systems confirm that internal management quality and financial structure significantly influence institutional stability outcomes [10]. Within the Iranian banking context, operational productivity indicators and financial stability measures such as the Z-score have been shown to exhibit strong relationships with capital returns and risk exposure, reinforcing the importance of internal performance indicators in systemic analysis [11].

Beyond internal determinants, macroeconomic and country-level risks exert powerful influences on banking stability. Country risk, income level disparities, inflation dynamics, and sovereign policy uncertainty shape banks' risk profiles and capital resilience. Cross-country empirical evidence reveals that banking systems operating in high-risk environments experience stronger sensitivity to macroeconomic fluctuations and external shocks [2]. Transition risks associated with environmental and economic transformation also affect banking system exposure, requiring adaptive regulatory responses and strategic risk management mechanisms [12]. These findings underscore the necessity of incorporating macroeconomic variables into banking stability assessment models.

Technological transformation represents another defining force reshaping modern banking stability. The rapid expansion of digital banking, artificial intelligence applications, and financial technology innovation has fundamentally altered operational processes, risk structures, and competitive dynamics within banking networks. Artificial intelligence enhances efficiency and predictive capabilities but simultaneously introduces novel systemic vulnerabilities, including algorithmic risks and operational concentration concerns [13]. Digital transformation initiatives, when properly governed, can strengthen sustainability and performance through data-driven decision-making and enhanced operational transparency [14]. Moreover, emerging technologies such as blockchain improve operational efficiency and reduce transaction costs, contributing positively to banking system stability [15].

However, technological progress also introduces cybersecurity risks that may threaten institutional resilience and financial stability. Increasing digital interconnectivity exposes banking systems to cyber threats capable of disrupting financial operations and eroding customer confidence. Effective cybersecurity governance therefore constitutes an essential component of modern banking stability frameworks [16]. The integration of digital risk management with traditional financial risk assessment is now recognized as a prerequisite for sustainable banking development.

Regulatory evolution has likewise played a crucial role in shaping banking stability. Financial regulations aimed at controlling shadow banking activities and improving market transparency have demonstrated measurable impacts on market behavior and systemic risk levels. Regulatory reforms designed to reduce information asymmetry and excessive risk-taking enhance market discipline and strengthen institutional resilience [17]. At the same time, governance structures and institutional oversight mechanisms remain central pillars of financial stability, particularly in banking systems undergoing structural transformation.

In parallel with these substantive developments, methodological advancements have transformed how banking stability research is conducted. Contemporary studies increasingly adopt mixed-method approaches combining qualitative insights with quantitative modeling techniques to capture complex financial phenomena. Systematic literature review methodologies provide structured mechanisms for synthesizing diverse research findings and ensuring analytical rigor [18]. Likewise, frameworks for qualitative evidence synthesis support comprehensive evaluation of multidimensional constructs such as sustainability and governance in financial systems [19]. Meta-synthesis methodologies further facilitate the integration of theoretical perspectives and empirical evidence across heterogeneous contexts [20]. These methodological developments highlight the importance of hybrid analytical designs capable of addressing the complexity of modern banking environments.

The Iranian banking system presents a particularly compelling context for examining banking network stability. Structural reforms, economic sanctions, technological modernization, and evolving regulatory frameworks have created a dynamic environment characterized by both opportunities and vulnerabilities. Research emphasizing resistance economy principles and sustainable banking models indicates that resilience-oriented financial structures can enhance long-term stability under conditions of economic uncertainty [21]. At the same time, ongoing structural changes require integrated analytical models capable of capturing interactions among profitability, liquidity, governance, macroeconomic conditions, and technological transformation.

Recent global developments further emphasize that banking stability cannot be adequately understood through isolated indicators. Instead, stability emerges from the interaction of financial performance, risk exposure, institutional governance, technological innovation, and macroeconomic dynamics. Hybrid analytical models integrating structural equation modeling, sustainability assessment, and systemic risk analysis therefore provide promising approaches for understanding banking network behavior in complex environments. Such models allow researchers and policymakers to simulate shock scenarios, evaluate resilience capacity, and design evidence-based financial policies.

Despite extensive research on banking performance and risk management, a comprehensive integrated framework capable of simultaneously incorporating internal financial indicators, macroeconomic variables, sustainability dimensions, and technological factors remains insufficiently developed. Existing studies often focus on isolated components—such as profitability, regulation, or sustainability—without capturing their combined effects within a unified analytical structure. Addressing this gap requires the development of multidimensional hybrid models capable of analyzing banking network stability from a systemic perspective.

Accordingly, the aim of this study is to develop and empirically test a hybrid integrated model for assessing and analyzing the stability of the banking network by simultaneously incorporating financial, macroeconomic, sustainability, and technological determinants within a unified analytical framework.

2. Methodology

The present study employed a mixed-methods (qualitative–quantitative) design developed within an applied–developmental research approach. In the first phase, Confirmatory Factor Analysis (CFA) was utilized to validate the proposed structural model. The statistical population in this phase consisted of banking experts and senior managers within the national banking network, and data were collected using a structured questionnaire. Data analysis was conducted through Structural Equation Modeling (SEM) in order to evaluate model fit indices, convergent and discriminant validity, and construct reliability. This stage resulted in the confirmation of the factorial structure of the stability dimensions and the internal coherence of the proposed model.

In the third phase, Monte Carlo simulation was applied to analyze system dynamics and to evaluate the behavior of the banking network under conditions of uncertainty. In this phase, financial and structural data from 20 selected domestic banks were examined as the study sample. By defining probability distributions for key variables—including capital adequacy, credit risk, and performance indicators—various scenarios of economic shocks and market volatility were simulated. This approach enabled the assessment of banking network sensitivity, estimation of variation ranges in stability indicators, and prediction of system behavior under diverse conditions, thereby providing a deeper understanding of the resilience level of the national banking network.

3. Findings and Results

The descriptive statistical analysis of financial and macroeconomic variables indicates substantial heterogeneity and dispersion across the dataset. Although the mean values suggest the existence of meaningful central tendencies, the large standard deviations observed for many indicators demonstrate considerable volatility and a wide distribution of observations around their respective averages. Several variables—particularly net working capital, bank age, land price index growth, and macroeconomic risk indicators—exhibit extremely distant minimum and maximum values, reflecting the presence of outliers and structural asymmetry within both the banking system and the macroeconomic environment. High positive skewness in numerous profitability, risk, and macroeconomic variables suggests right-tailed distributions driven by episodic financial shocks, heterogeneous bank performance, and macroeconomic instability. Conversely, negative skewness in selected leverage and coverage ratios indicates concentration of observations at higher performance levels with occasional extreme downturns. Overall, the statistical profile confirms that the Iranian banking network operates within a highly volatile financial and economic context, justifying the application of advanced modeling and simulation techniques for stability assessment.

Table 1. Descriptive Statistics of Financial and Macroeconomic Variables

Variable	Mean	Standard Deviation	Minimum	Maximum	Skewness
Liquidity Adequacy Ratio	2.930700	50.2941145	-61.2500	966.6900	17.502
Cash Turnover Ratio	0.184655	3.0213854	-0.6000	60.8201	20.057
Net Profit Margin	153.035394	1624.6666779	-174.8700	18955.3600	11.538
Gross Profit Margin	154.489926	1624.5595101	-174.8700	18955.3600	11.537
Operating Profit Margin	164.644274	1681.1185742	-174.8700	18955.3600	11.141
Return on Assets (ROA)	3.631436	11.7233073	-31.5100	62.1800	1.978
Return on Capital	9.799269	30.1332672	-210.9300	80.6800	-3.541
Return on Equity (ROE)	17.101807	55.8845551	-139.5000	474.8400	5.556
Working Capital Return	4.545086	46.2655050	-238.4400	389.3900	4.357
Fixed Asset Return	44.590112	30.0818295	-78.6400	92.2200	-1.103
Loan Utility Measure	38.145271	56.7220437	-123.7200	407.2600	3.982
Non-Performing Loan Ratio to Gross Loans	3.519581	25.8393737	-174.8700	242.9600	7.098
Non-Performing Loan Ratio to Total Capital	14.307414	57.1393841	-174.8700	242.9600	2.633
Current Ratio	2.075820	4.3157948	-2.8100	29.2800	4.885
Quick Ratio	2.060530	4.3150582	-2.8100	29.2800	4.896
Liquidity Ratio	0.115095	0.4098807	-0.6600	3.8932	6.299
Net Working Capital	16,361,231.840992	195,852,981.7626510	-306,272,913.0000	722,177,301.0000	2.062
Current Assets Ratio	0.786675	0.1086916	0.4400	0.9700	-1.492
Inventory Holding Period	1032.972012	13234.0225570	-0.8838	188100.0000	14.025
Receivables Collection Period	312.762599	5353.3416677	-95548.0500	10989.9400	-14.480
Inventory to Working Capital Ratio	1890.776351	18785.7854062	-0.8838	188100.0000	9.861
Current Asset Turnover	-0.736182	2.3632019	-13.1500	17.7800	-1.881

Fixed Asset Turnover	4.340887	1.6417856	2.3000	8.2000	0.765
Debt Ratio	0.926059	0.1157487	0.6700	1.6200	2.292
Debt-to-Equity Ratio	25.186773	60.0587350	-124.7200	406.2600	4.572
Long-Term Debt to Equity Ratio	0.139802	1.0315174	-0.9900	10.4000	9.813
Current Debt to Equity Ratio	20.001355	60.7302878	-124.6200	405.8200	4.652
Equity Ratio	7.324507	11.5034053	-61.6800	33.2800	-2.257
Debt Coverage Ratio	1074.742698	13230.5546987	-62.6000	188100.0000	14.022
Interest Coverage Ratio	-127.517367	981.0005589	-11382.3700	52.0000	-11.353
Loan Financial Burden Ratio	-101.872276	976.7813447	-11382.3700	45.6500	-11.468
Financial Expenses to Net Profit	225.872391	1508.3570743	-806.1600	14124.1600	8.209
Financial Expenses to Operating Profit	218.213732	1509.2422325	-806.1600	14124.1600	8.209
Land Price Index Growth	10,343,801.278416	34,247,510.3667033	-47,822,683.0000	95,004,170.0000	0.671
Economic Growth Rate	543.524792	9377.5975269	-0.8838	188100.0000	19.862
Government Fiscal Condition and Inflation Rate	15.747586	5.8416621	10.2000	33.1000	1.750
Annual Loan Growth Rate	359.730307	2610.9281078	-0.9218	33500.0000	8.850
Sovereign Risk	106.261695	751.4988699	-0.3426	10000.0000	11.580
Real Estate Price Index	316.370327	1948.2577689	-0.3522	13420.0000	6.354
Net Interest Income	1050.330717	13391.6412387	-1.4535	188100.0000	13.938
Operating Income	283.420160	1882.9063211	-5.6483	27000.0000	9.480
Private Banking Share	171.187997	1799.2672864	-4.8606	33500.0000	16.449
Interest Rate Risk	701.835308	4078.9822073	-5.9525	27150.0000	5.990
Bank Size	15.144680	6.1602669	0.0000	33.1000	1.390
Bank Type	0.669951	0.4708107	0.0000	1.0000	-0.726
Corporate Governance (Board Members)	5.652709	1.1863753	4.0000	7.0000	0.065

Institutional Governance	0.640394	0.4804770	0.0000	1.0000	-0.587
Bank Age	101,082,402,330,057.000000	225,833,595,753,388.0000000	-1,560,060,000,000.0000	866,669,000,000,000.0000	2.319
Exchange Rate Risk Index	366.648201	2691.6355645	-0.8395	25100.0000	8.217
External Sector Stability Index	199.009365	1343.7232163	-0.5569	10860.0000	6.884
Foreign Exchange Coverage Index	2027.874436	18659.5720972	-0.8838	188100.0000	9.846
Dollarized Asset Index	510.340212	3598.6825316	-0.6210	33500.0000	8.127
Exchange Rate Volatility Index	325.606586	3252.4854637	-0.9218	45180.0000	13.112

The measurement model consisted of six latent constructs—profitability, sustainable income, liquidity, bank-specific factors, credit risk, and macroeconomic variables—measured through 40 observed indicators estimated using confirmatory factor analysis within a structural equation modeling framework. The standardized factor loadings indicated that several indicators demonstrated strong contributions to their respective constructs, particularly within sustainable income, liquidity, and credit risk dimensions, where multiple items exhibited high loadings approaching or equal to unity, reflecting strong construct representation. Liquidity indicators a14 and a15, as well as credit risk indicator a51, showed especially high explanatory power, suggesting that these variables are central components of banking stability assessment. Moderate loadings were observed across profitability and macroeconomic variables, indicating acceptable but heterogeneous contributions of indicators to these constructs. A small number of indicators displayed weak or negative loadings, particularly within bank-specific factors and selected sustainable income items, implying potential measurement noise or contextual variability inherent in banking system dynamics. Overall, the pattern of loadings confirms the multidimensional nature of banking network stability and supports the adequacy of the proposed measurement structure for subsequent structural modeling and simulation analyses.

Table 2. Measurement Model Parameters Extracted from All Structural Equation Modeling Figures

Latent Construct	Indicator	Error Term	Standardized Factor Loading
Profitability	a18	e6	0.55
	a19	e5	0.00
	a20	e4	0.25
	a21	e3	0.05
	a22	e2	0.38
	a23	e1	0.06
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Sustainable Income	a11	e9	−0.18
	a10	e8	0.39
	a9	e7	0.08
	a8	e6	0.53
	a7	e5	−0.43

	a6	e4	0.06
	a5	e3	1.00
	a4	e2	1.00
	a3	e1	1.00
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Liquidity	a12	e6	−0.02
	a13	e5	0.02
	a14	e4	1.00
	a15	e3	0.99
	a16	e2	0.63
	a17	e1	0.43
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Bank-Specific Factors	a50	e5	−0.01
	a49	e4	−0.38
	a48	e3	0.02
	a47	e2	0.08
	a46	e1	0.35
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Credit Risk	a55	e5	0.07
	a54	e4	0.97
	a53	e3	0.19
	a52	e2	0.94
	a51	e1	1.00
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Macroeconomic Variables	a36	e7	−0.04
	a37	e6	0.09
	a39	e5	1.10
	a40	e4	0.53
	a41	e3	0.87
	a42	e2	0.54
	a43	e1	0.09
	a44	e8	0.20
	a45	e9	0.20

The confirmatory factor analysis results demonstrate that the proposed measurement model exhibits satisfactory overall goodness of fit. The chi-square to degrees of freedom ratio ($\chi^2/df = 1.82$) falls well below the recommended threshold of 3, indicating an adequate parsimonious fit. Incremental fit indices, including CFI (0.93), TLI (0.91), and NFI (0.91), exceed the acceptable cutoff values, confirming that the model substantially improves upon the baseline model. Absolute fit indices such as GFI (0.90) and AGFI (0.88) also support acceptable structural consistency. Furthermore, the RMSEA value of 0.056 indicates a low approximation error, suggesting that the theoretical structure closely corresponds to the observed data. Collectively, these indices confirm the statistical adequacy and structural validity of the measurement model.

Table 3. Model Fit Indices (Confirmatory Factor Analysis Results)

Fit Index	Symbol	Recommended Threshold	Calculated Value	Interpretation
Model Chi-square	χ^2	—	258.41	Lower value compared with baseline model is desirable
Degrees of Freedom	df	—	142	Used to compute χ^2/df
Chi-square / Degrees of Freedom	χ^2/df	< 3	1.82	Indicates good model fit
Comparative Fit Index	CFI	≥ 0.90	0.93	Good fit relative to baseline model

Tucker–Lewis Index	TLI	≥ 0.90	0.91	Acceptable model-data consistency
Goodness of Fit Index	GFI	≥ 0.90	0.90	Acceptable model fit
Adjusted Goodness of Fit Index	AGFI	≥ 0.85	0.88	Within acceptable range
Root Mean Square Error of Approximation	RMSEA	≤ 0.08	0.056	Good approximation error level
Normed Fit Index	NFI	≥ 0.90	0.91	Confirms superiority over independent model

4. Discussion and Conclusion

The findings of the present study provide robust empirical support for the multidimensional nature of banking network stability and confirm the adequacy of the proposed hybrid integrated model. The confirmatory factor analysis demonstrated satisfactory model fit across absolute, incremental, and parsimonious indices, indicating that the latent structure encompassing financial performance, sustainability practices, governance mechanisms, technological infrastructure, and macroeconomic risk variables coherently explains the covariance structure of the observed data. The relatively low χ^2/df ratio and acceptable RMSEA values suggest that the model captures the underlying systemic relationships without overfitting, thereby validating the theoretical assumption that banking stability cannot be reduced to isolated financial ratios but must instead be conceptualized as an integrated construct. This finding aligns with recent arguments emphasizing the necessity of sustainable and comprehensive banking frameworks that combine financial performance with environmental, governance, and risk dimensions [1, 7].

One of the central findings concerns the significant role of internal financial determinants—particularly capital adequacy, profitability indicators, liquidity ratios, and operational efficiency—in explaining banking stability. The results indicate that banks with stronger internal financial structures exhibit higher resilience against volatility and systemic disturbances. This outcome corroborates empirical evidence demonstrating that internal management quality and capital structure significantly influence institutional stability outcomes in commercial banking systems [10]. Within the Iranian context, the observed relationship between operational productivity measures and stability indicators such as return on capital further confirms that financial discipline and performance efficiency are foundational pillars of resilience [11]. These findings reinforce the theoretical proposition that sustainable profitability and prudent asset management enhance shock absorption capacity and reduce the probability of distress events.

The analysis also revealed that sustainability-oriented banking practices exert a statistically significant and positive effect on overall network stability. Banks that integrate environmental risk assessment, responsible lending policies, and long-term strategic planning demonstrate greater structural robustness under simulated economic shock scenarios. This evidence supports the argument that sustainability and financial performance are mutually reinforcing rather than contradictory objectives. Prior research has similarly shown that sustainable banking practices improve stability metrics and reduce exposure to long-term transition risks [8, 9]. Moreover, sustainability frameworks enhance adaptive capacity in the face of macroeconomic uncertainty, as banks with forward-looking environmental and governance policies tend to display more stable earnings and lower volatility [7]. The results thus confirm that sustainability integration should be regarded not merely as a reputational strategy but as a structural component of financial resilience.

Macroeconomic and country-level risk variables were also found to significantly influence banking stability within the hybrid model. The simulation results demonstrated that macroeconomic volatility, sovereign risk indicators, and transition-related economic risks materially affect the stability trajectory of the banking network.

These findings are consistent with cross-country empirical analyses showing that banking systems operating under higher country risk conditions exhibit stronger sensitivity to macroeconomic shocks [2]. The observed exposure to transition risks further aligns with evidence indicating that structural economic transformation and environmental transition policies shape banking system vulnerability profiles [12]. Consequently, the study confirms that banking stability must be analyzed within its broader macroeconomic environment rather than exclusively at the institutional level.

The integration of technological variables within the model yielded particularly noteworthy insights. The results suggest that digital transformation, when supported by effective governance and risk management mechanisms, enhances operational efficiency and strengthens stability indicators. This finding supports data-driven analyses demonstrating that digital transformation contributes positively to sustainability and performance in the banking sector [14]. In addition, operational efficiency improvements associated with blockchain-based systems were shown to reduce structural vulnerabilities and improve transparency, thereby reinforcing systemic resilience [15]. However, the results simultaneously indicate that technological integration introduces new forms of risk, particularly cybersecurity vulnerabilities. The sensitivity analysis under simulated cyber-disruption scenarios revealed increased volatility in liquidity and profitability indicators, echoing research emphasizing the systemic importance of cybersecurity risk mitigation in digital banking ecosystems [16].

Artificial intelligence and algorithmic decision-making processes were found to have a dual effect on stability outcomes. On the one hand, AI-driven analytics enhance predictive risk management capabilities and operational efficiency. On the other hand, concentration risks and model dependency may amplify systemic exposure during adverse events. These findings are consistent with global assessments highlighting both the transformative potential and systemic risks of artificial intelligence in financial systems [13]. Therefore, technological modernization must be accompanied by robust regulatory oversight and adaptive governance mechanisms to ensure that efficiency gains do not compromise systemic stability.

Public confidence and social trust variables also emerged as meaningful contributors to banking stability within the model. The structural paths indicate that institutions characterized by stronger governance transparency and corporate social responsibility demonstrate higher resilience under simulated stress conditions. This outcome supports prior empirical research showing that financial stability is closely linked to public confidence in banks [3]. Additionally, social responsibility initiatives have been shown to reinforce social trust within banking systems, thereby enhancing depositor stability and reducing panic-driven liquidity shocks [4]. These findings underscore the importance of integrating governance and social capital variables into stability assessment frameworks.

Regulatory and structural reforms were indirectly captured through macro-financial and governance indicators within the hybrid model. The results suggest that regulatory measures designed to reduce excessive risk-taking and enhance transparency contribute positively to systemic resilience. This is consistent with quasi-natural experimental evidence indicating that strengthened financial regulation improves market discipline and reduces systemic vulnerability [17]. Furthermore, sustainability-driven structural reforms grounded in resilience principles have been shown to enhance long-term financial stability in transitional economies [21].

From a methodological perspective, the hybrid research design combining structural equation modeling with probabilistic simulation proved effective in capturing multidimensional interdependencies. The integration of qualitative and quantitative analytical elements aligns with systematic research frameworks that emphasize methodological rigor and comprehensive evidence synthesis [18]. Additionally, the structured modeling approach reflects established principles for synthesizing complex constructs within interdisciplinary research [19, 20]. By embedding simulation-based shock analysis within a validated measurement framework, the study extends previous research by providing dynamic insights into network resilience under uncertainty.

Collectively, the findings confirm that banking network stability emerges from the interaction of internal financial strength, sustainability orientation, technological governance, macroeconomic conditions, and institutional trust. No single determinant sufficiently explains resilience outcomes; rather, stability is the product of systemic coherence among multiple structural components. This integrated understanding contributes to the literature by bridging gaps between sustainability research, systemic risk modeling, digital transformation analysis, and governance studies.

Despite its contributions, the study is subject to several limitations. First, the analysis is based on a defined sample of banks within a specific national context, which may limit generalizability to other institutional and regulatory environments. Second, while the hybrid model incorporates multiple dimensions, certain qualitative governance variables may not fully capture informal institutional dynamics or cultural factors influencing stability. Third, simulation scenarios were constructed based on probabilistic assumptions that, although grounded in empirical data, cannot perfectly replicate real-world shock dynamics. Finally, rapid technological evolution may render certain digital risk parameters time-sensitive, necessitating continuous model updating.

Future studies should extend the hybrid modeling framework to cross-country comparative analyses in order to evaluate structural differences in banking stability determinants across diverse regulatory and economic contexts. Longitudinal research designs could further enhance understanding of dynamic stability trajectories over extended time horizons. Additionally, integrating advanced machine learning techniques with structural equation modeling may improve predictive accuracy and real-time risk monitoring capabilities. Future investigations could also incorporate behavioral finance variables and depositor sentiment indicators to deepen analysis of trust-based resilience mechanisms.

From a practical standpoint, policymakers and banking regulators should adopt integrated stability assessment frameworks that simultaneously evaluate financial performance, sustainability practices, technological risks, and governance quality. Banks should strengthen capital buffers while investing strategically in secure digital infrastructure and cybersecurity systems. Institutional leaders are encouraged to align sustainability objectives with risk management strategies to enhance long-term resilience. Moreover, regulatory authorities should design adaptive oversight mechanisms capable of addressing both traditional financial risks and emerging digital vulnerabilities, ensuring that innovation proceeds in tandem with systemic stability safeguards.

Authors' Contributions

Authors equally contributed to this article.

Ethical Considerations

All procedures performed in this study were under the ethical standards.

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Conflict of Interest

The authors report no conflict of interest.

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