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Applied Data Science for Exploring Critical Factors Affecting Systemic Risk of Commercial Banks in Vietnam

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Abstract

The banking system is essential in developing the Vietnamese economy, serving as a capital supply channel for the economy's production, business, and investment activities. In 2024, the banking industry faces many challenges, including global macroeconomic fluctuations, the Russia-Ukraina war, and policy changes. Therefore, the study aims to quantify the impact of these factors on systemic risk using a Structural Equation Modeling (SEM) approach. Furthermore, it seeks to provide empirical evidence and actionable policy recommendations to help mitigate systemic risks, enhance financial stability, and support socio-economic recovery and development. The methodology of this study applied a structural equation model consisting of five factors: (1) Macroeconomic environment, (2) internal factors of commercial banks, (3) legal framework and supervisory authorities, (4) globalization and financial integration, and (5) technology and financial innovation. Data were collected from 450 managers working in the banking sector and processed using Amos software. The study's novelty showed that five critical factors positively impact the systemic risk of commercial banks in Vietnam. In addition, the originality of this research includes introducing technology and financial innovation into the model, a new factor of the banking industry in the digital transformation period of banking. Moreover, the results highlight that robust and timely policy interventions are essential for mitigating systemic vulnerabilities and promoting financial stability. Finally, the practical implications of the article proposed policy recommendations to help managers and policymakers minimize systemic risks due to influences from external-internal factors contributing to socio-economic recovery and development. Finally, managers and policymakers should strengthen regulatory oversight, promote digital risk management, enhance governance practices, and ensure macroeconomic stability to mitigate systemic banking risk.

Keywords: Systemic Risk, Financial Innovation, Regulatory Framework, Banking, Digital Transformation

1. Introduction

A renewed focus on systemic risk has emerged in the wake of the financial crisis. Any threat to the overall economy or a specific stock market sector is a systemic risk. Companies' financial or managerial standings are impacted by this risk [1]. Depending on the investment, such risk may be associated with local and foreign variables. Interest rates, inflation, currency, and socio-political risks are all part of the systemic risk [2], [3]. The transition from a positive to a negative stable equilibrium for the financial and economic system is a crucial feature of systemic risk. Financial system risks are defined in a variety of ways around the globe, but they consistently have the following nine features: (1) Impact on financial system operations and intermediaries; (2) Scale; (3) Incident probability and possibilities; (4) Progressive phenomenon characteristics; (5) Spreading impacts; (7) Bankruptcy and collapse; (6) Interconnections among financial system components; (8) Effects on the actual economy and (9) Deterioration of trust.

Other studies have shown that the past two years of worldwide financial and economic crises have made systemic risk an incredibly pertinent issue. The systemic risk occurs when instability in the financial sector hinders a system's capacity to perform its vital duties [4]. When there is a possibility that financial services will be interrupted, reducing the value of the financial system and potentially impacting the real economy negatively, officials from the Financial Stability Board, Bank for International Settlements, and International Monetary Fund agree that systemic risk exists. In addition, systemic risk in the banking sector has become a critical concern in the post-global financial crisis era, particularly as economies face increasing interconnectivity, digital transformation, and macroeconomic volatility.

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According to the Bank for International Settlements (BIS), systemic risk refers to the risk of disruption to the financial system that can lead to severe negative consequences for the real economy due to interlinkages and contagion effects among financial institutions [5], [6]. Similarly, the European Central Bank (ECB) defines systemic risk as the possibility that an event will trigger a loss of economic value or confidence in and collapsing a significant part of the financial system. These definitions highlight that systemic risk is not merely any economic or market disturbance but involves cascading effects that threaten the financial system's stability as a whole.

Modern commercial banks aren't limited to lending money to individuals and companies; they also underwrite debt and equity securities, manage assets, process payments and settlements, and ensure the safety of deposits, among many other retail and wholesale financial services. Systemic risk indicators in the banking sector sometimes include national, regional, or global bank collapses. Systemic risk in the banking industry is the mechanism via which the model suggests that active banks might be negatively impacted by macroeconomic shocks [7].

Furthermore, systemic risk in banking is the potential for losses to cascade from the collapse of one foreign bank branch or credit institution to another, thereby affecting the entire economy and all foreign bank branches and credit institutions. Numerous studies have pointed to the prevalence of financial crises, which include multiple problems involving the banking system, currencies, and governmental debt [8]. According to numerous empirical studies examining this topic, the financial costs of managing banking crises can be substantial. According to their findings, the global economic toll of the new banking crisis of 2007–2008 was, on average, higher than that of previous crises. According to other research, the more considerable initial shock, the fact that most recent banking crises have happened in high-income nations, and the fact that the financial system has grown in size over the last decade contribute to these events' disproportionately high economic consequences.

In addition, the general shock and chain reaction induced by systemic risk propagate rapidly; therefore, there must be a connection between the parties concerned, directly or indirectly. Consider deposits, loans, and payment transactions on the system as an example of the direct link. On the other hand, the role of supplying the deposit or loan market demonstrates the indirect relationship [9], [10]. There will be a domino effect of shocks other financial institutions feel when a significant enough loss at one bank threatens illiquidity. Both theory and data point to the banking system having the highest systemic risk propagation probabilities, magnitudes, and extents of any sector. When a shock hits, the first bank to feel it usually takes the brunt of it. Depending on the original shock's magnitude and the unique features of the afflicted bank, systemic risk's dissemination and severity can differ. Therefore, this study explores the impact of macroeconomic factors, globalization, legal frameworks, internal governance, and especially technology and financial innovation on systemic risk in Vietnam's commercial banking sector.

2. Literature Empirical Review and Hypothesis Development

2.1. Systemic Risk (SR)

Systemic risk refers to the potential for a domino effect to occur whereby other treasury banks are either eliminated or prevented from locking positions due to the failure of one bank to arrange net transactions with other banks [11]. When the collapsing bank's usual liquidation and settlement operations close, even institutions that avoided doing business with it will be impacted [12]. The payment system is stuck in a deadlock in this case. System-wide payment failure can be prevented by implementing specific regulations for large payment networks [13]. Furthermore, systematic risk refers to the possibility of monetary loss due to fluctuations in market variables, including interest rates, currency rates, stock prices, and commodity prices [14], [15]. Finally, systemic risk refers to cascading financial disruptions from interconnected institutions or markets, triggered by macroeconomic shocks or internal failures.

2.2. Macroeconomic Environment (ME)

The macroeconomic environment is a part of the macroenvironment, including general economic factors that affect the economy's performance, industries, businesses, banks, and consumers. These are factors beyond the control of individuals or organizations, but they shape the general economic context, thereby affecting decisions and business strategies and significantly greatly impacting banking systemic risks [16]. Primary factors of the macroeconomic environment: (1) Economic growth based on Gross Domestic Product (GDP) growth rate indicates the development of the economy. Periods of economic growth often create many business opportunities, while recessions can reduce

demand and increase risks. (2) Inflation affects the purchasing power of consumers and the production costs of businesses [17]. High inflation reduces the value of currency, causing pressure on business activities. (3) High interest rates increase borrowing costs, affecting investment and consumer spending. Low interest rates encourage consumption and investment but can create asset bubbles. (4) Exchange rate fluctuations affect businesses involved in import and export and foreign currency loans. Stable exchange rates make it easier for businesses to make financial plans. (5) Fiscal and monetary policy by Government tax, public spending, and investment decisions impact economic resources and demand levels in the economy [18], [19], [20]. To minimize risks, banks need to have strategies to manage possible risks, such as capital reserves, diversifying investment portfolios, and enhancing solvency. Thus, the authors gave hypothesis H1 and H2 in Figure 1.

H1: ME has a significant positive impact on SR.
H2: ME positively influences TI.

2.3. Globalization and Financial Integration (GI)

Globalization and financial integration are how countries and financial markets become interconnected and interdependent by expanding international trade, investment, and capital flows [21]. This process promotes the free flow of goods, services, capital, labor, and technology, creating a tightly interconnected global financial system. Besides, the characteristics of globalization and financial integration are as follows: Enhance international trade through goods and services exchanged across borders, Facilitating Direct (FDI) and Indirect Investment (FPI) capital flows. Financial market links based on the national capital, credit, and foreign exchange markets are integrated, allowing for faster and easier transactions between countries [22], [23], [24], [25]. Globalization and financial integration bring many development opportunities and potential risks, especially in global economic fluctuations. Countries must have appropriate strategies and policies to take full advantage of the benefits while protecting the financial system against international shocks. Thus, the authors gave hypothesis H3 and H4 in Figure 1.

H3: GI significantly increase SR.
H4: GI Positively affects TI.

2.4. Legal Framework and Supervisory Authorities (LS)

The legal framework and supervisory authority are essential foundations for maintaining the stability, transparency, and safety of a country's financial and banking system. The regulatory framework defines the rules, regulations, and standards that financial institutions must comply with, while the supervisory authority is responsible for monitoring, inspecting, and addressing emerging issues to ensure compliance and reduce systemic risk [26], [27]. The regulatory structure of the banking and financial industry: (1) Laws of the formation and operation of banks, including rules for the licensing of establishments, the minimum capital required for charters, and the essential criteria for banks to operate. Verify that the bank has adequate resources and management to run smoothly. (2) Capital adequacy ratio (CAR) regulations that adhere to international standards like Basel II and Basel III; this safeguards capital. Managers should make sure that banks can handle financial shocks and hazards [28], [29], [30]. To assist banks in better handling economic swings, supervisory agencies depend on risk management legislation and adherence to international norms. Thus, the authors gave hypothesis H5 and H6 in Figure 1.

H5: LS positively influence TI.
H6: LS have a significant effect on SR.

2.5. Technology and Financial Innovation (TI)

All parts of the banking and financial system feel the effects of technological innovation, reshaping the industry and how financial services are run and offered. Financial institutions and regulators must adjust to the new realities brought about by innovation to reap its advantages while avoiding its hazards [31], [32]. Technological innovation in the financial sector relies on technology applications in financial services: Electronic payments through e-wallets, QR Codes, and mobile applications [33]. Peer-to-peer lending is based on an online platform connecting investors and borrowers without the need for traditional financial intermediaries. (3) Blockchain technology supports transparent, fast, safe transactions and reduces costs in financial activities [34], [35]. Digitizing traditional banking services, such

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as account opening, credit granting, or financial consulting through online platforms. Thus, the authors proposed the final hypothesis H7 and H8 in figure 1.

H7: TI significantly contributes to SR.
H8: TI influence internal factors (IF) of commercial banks.

2.6. Internal Factors of Commercial Banks (IF)

Internal factors of a bank are internal factors that belong to the organizational structure, management strategy, and operations. These factors determine the bank's operational efficiency, competitiveness, and risk management capacity. The key factors are: (1) The bank's vision, mission, and long-term goals affect business direction and risk management [36]. The Board of Directors has vision, management capacity, and decision-making following market fluctuations. (2) Financial resources based on the level of charter capital determine the ability to tolerate risk and comply with legal requirements on Capital Adequacy Ratio (CAR). The ratio between equity and mobilized capital affects liquidity and profitability [37]. Liquidity reserves meet short-term and long-term needs, ensuring stable business operations. (3) A risk management system is based on a mechanism to identify, evaluate, and control risks such as credit, liquidity, interest rates, exchange rates, and operational risks [38], [39]. When one or more banks do not control internal factors well, it can lead to widespread instability in the financial system. Hence, the authors gave hypothesis H9 in figure 1.

H9: IF significantly affect SR.

This study integrates three theoretical streams to construct a unified framework for analyzing systemic risk. Agency theory explains how internal governance failures due to information asymmetry or misaligned incentives can escalate operational vulnerabilities, thereby increasing systemic exposure. Macroeconomic volatility theory posits those fluctuations in interest rates, inflation, and currency values introduce external shocks that can destabilize banks' balance sheets and risk perceptions. Meanwhile, innovation theory enhances how digital transformation and financial technologies reshape risk structures, introducing efficiency gains and new systemic threats. Combining these perspectives, the five latent constructs of the macroeconomic environment, internal bank factors, legal framework, globalization, and technology/innovation are positioned as interconnected vectors through which endogenous and exogenous risk channels propagate. This synthesis provides a more comprehensive theoretical basis for the structural equation model. Based on the information provided, the authors have put forth a particular study model in figure 1.

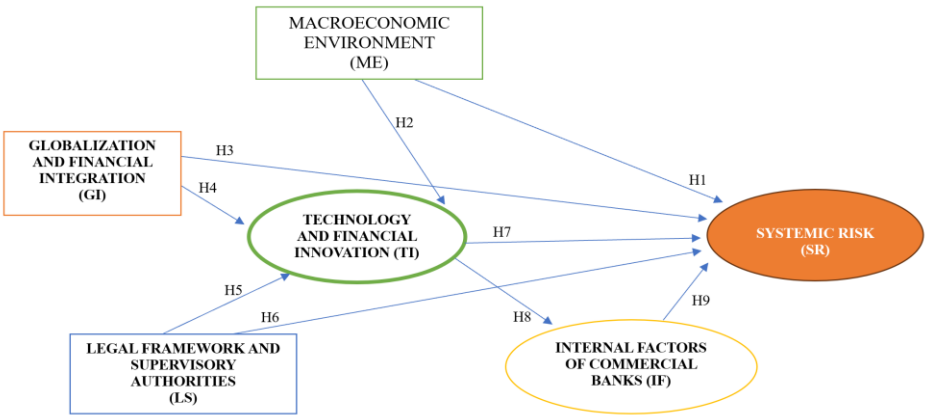

Figure 1. A research model for critical factors influencing the systemic risk of commercial banks in Vietnam

Figure 1 shows five key factors affecting the systemic risk of Vietnamese commercial banks: macroeconomic environment, globalization and financial integration, legal framework and supervisory authorities, technology and financial innovation, and internal factors. Banks can have quick solutions to increase the quality of human resources and operational efficiency. However, macroeconomic external issues require synchronous answers at many institutions, ministries, and departments over a long implementation period.

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3. Methodology and Data

To conduct the research, the authors built a process that included the following steps:

Step 1: One of the most significant difficulties facing financial systems today, particularly in light of the fast-paced changes brought about by technological advancements and more economic integration, is systemic risk in banking, which the authors used to frame their study's problem and goals. For management and mitigation techniques to be effective, it is essential to understand systemic risk factors. The study's overarching goal is to assess how many elements, such as the ME, TI, LS, and IF, SR.

Step 2: The authors conducted in-depth interviews with fifteen directors' specialists, developed a study model and theoretical framework from scratch, assessed criteria, and ultimately identified elements influencing the systemic risk faced by Vietnam's commercial banks [40]. A theoretical framework was constructed based on a review of contemporary literature on systemic risk, agency theory, macroeconomic volatility, banking innovation, and regulatory environments. The model posits five exogenous latent constructs: ME, GI, LS, TI, and IF, all hypothesized to influence SR. The conceptual framework is illustrated in figure 1 and underpins the SEM model tested in this study. The target population consists of mid to senior-level banking managers with risk management, operations, compliance, and executive leadership roles in commercial banks operating in six provinces in Southern Vietnam. A stratified convenience sampling method ensured geographical representation across areas and bank sizes. Selection criteria included: (1) Minimum five years of experience in banking, (2) Active involvement in risk-related decision-making, and (3) Consent to participate in the study. Recruitment was conducted via email invitations, institutional outreach during conferences, and direct contact facilitated by Lac Hong University's industry partners.

Step 3: 15 experts in risk management with a Ph.D. in economics, based in big cities directly under the central government of Vietnam. The authors chose to sample six big cities directly under the central government based on Hanoi, Ho Chi Minh City, Hai Phong, Da Nang, Can Tho, and Hue City to survey banking system risks, which is extremely necessary to ensure representativeness and comprehensiveness. These are considerable economic and financial centers covering key areas of the country. Hanoi and Ho Chi Minh City are two economic engines, with a concentration of large banks playing a decisive role in mobilizing capital and credit. As the largest seaport in the North, Hai Phong City is strongly affected by risks related to international trade. Da Nang City is the development center of the Central region, a place easily affected by natural disasters and climate change. Can Tho City, representing the Mekong Delta, is associated with credit risks in agriculture and fisheries. Meanwhile, Hue City has an economic focus on tourism, education, and healthcare, reflecting risks related to the service industry. The 5-point Likert-based scale was maintained because it is based on previous surveys and is convenient for data analysis. As mentioned, the scale used in the article is a 5-point Likert scale from 1 to 5, where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. The results of this preliminary study serve as a guide for questionnaire development and quantitative research.

Step 4: The authors develop research instruments, including questionnaires and interview guidelines, to build a scale and draft the questionnaire and the preliminary survey process. This step built a scale to evaluate the level of factors of systemic risk of commercial banks in Vietnam, with essential factors such as (1) Macroeconomic environment, (2) globalization and financial integration, (3) legal framework and supervisory authorities, (4) technology and financial innovation, and (5) internal factors of commercial banks. Before sample collection, preliminary research was conducted to reduce the number of unreliable observed variables. The questionnaire included 23 main content items for the research focus. 200 survey forms were sent to 15 bank branches for a preliminary survey. After eliminating invalid samples, 165 samples were used for initial research. The results showed that all scales were considered satisfactory. Based on the comments of 15 bank managers, the questionnaire was adjusted, completed, and sent to the managers. Based on the conditions mentioned above, combined with the results of the data analysis, no observed variables were eliminated during the preliminary research process because the Cronbach's alpha coefficient of all variables was more significant than 0.6. Next, the total variable correlation coefficient of the observed variables is more important than 0.4, and no observed variable has a Cronbach's alpha higher than the Cronbach's alpha coefficient if the variable is eliminated. Thus, the qualitative research results met the requirements and satisfied the evaluation criteria, and the authors have continued to move to quantitative research. After adjusting the questionnaire, we surveyed large-scale

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commercial banks in six big cities with commercial banks in Vietnam, including Hanoi, Ho Chi Minh City, Hai Phong, Da Nang, Can Tho, and Hue City. In addition, the authors directly discussed 450 survey votes from 45 branches of 15 commercial banks in Vietnam; each city was expected to collect 10 managers. Surveys were sent via email and voice directly to the respondents. The survey period was from January 2024 to May 2024, and the online form was available at the 45 branches mentioned above with an expected response rate of 94.44% and 425 valid responses.

Step 5: Exploratory Factor Analysis (EFA) was conducted prior to the SEM modeling to examine the underlying factor structure of the measurement items and validate the constructs' dimensionality. Using Principal Component Analysis with Varimax rotation, factors with eigenvalues greater than 1 were retained, and items with factor loadings below 0.5 or cross-loadings above 0.4 were excluded. The Kaiser–Meyer–Olkin (KMO) value was 0.912, and Bartlett's Test of Sphericity was significant ($p < 0.001$), confirming sampling adequacy. The EFA results support the existence of five distinct latent constructs: ME, GI, LS, TI, and IF, consistent with the proposed conceptual model, allowing progression to CFA and SEM. The authors applied the SEM analysis and validation using AMOS based on the formal quantitative research phase; the complete scale was included in the CFA confirmatory factor analysis study. The authors conducted a quantitative survey of 450 managers, but only 425 valued samples were used. The survey method used was random, convenience sampling, and mainly an email survey of managers in the bank branches listed above. After that, the sample size for the study was determined by various parameters, including the processing technique for Cronbach's alpha greater than 0.7, as specified by EFA, SEM - structural equation model, etc., and measured the model's fit with GFI ≥ 0.900, TLI ≥ 0.900, CFI ≥ 0.900, and RMSEA < 0.1 [40]. Finally, the authors drew conclusions and offered practical suggestions based on research evaluating each model component's impact on systemic risk. If required, suggest theoretical advances and compare results with international investigations. Ultimately, the authors suggest policies banks should implement by investing in technology, improving operational efficiency, and bolstering risk management. Policymakers should enhance oversight and legal frameworks to encourage safe technological innovation. In inclusion, the stratified convenience sampling method aims to ensure geographic and institutional representativeness across six centrally governing cities: Hanoi, Ho Chi Minh City, Hai Phong, Da Nang, Can Tho, and Hue. Each city was considered a stratum, with an approximately equal target of 75 respondents per city (15 bank branches × 5 managers). Furthermore, the sample included 15 commercial banks representing a mix of joint-stock, state-owned, and foreign-invested banks. Branch size was implicitly captured by selecting both large and medium branches based on staff size and asset scale, though not formally stratified. This approach ensures diversity in geography, governance structure, and operational scale, enhancing the robustness of the results.

4. Empirical Results

4.1. Current Status of Systemic Risk at Commercial Banks in Vietnam

Increasing bad debt is a prominent feature of the Vietnamese banking system in 2021 - 2023. This was predicted when the COVID-19 pandemic broke out, and especially the 4th wave with the Delta variant in 2021 caused heavy losses to the production and business activities of enterprises, livelihoods, and lives of people. According to the report of the State Bank quoted at the end of 2021, the on-balance sheet lousy debt ratio was 1.9% (an increase of 0.21 percentage points compared to the end of 2020); if the debt sold to the Asset Management Company (VAMC) is included, this figure is 3.9%. The gross bad debt ratio, including on-balance sheet lousy debt, bad debt sold to VAMC that has not been resolved, and potential bad debt from restructuring, increased sharply to 7.31% at the end of 2021 from 5.1% at the end of 2020 and is almost equivalent to the figure at the end of 2017 (7.4%). The increasing trend of bad debt in 2021 will continue in the following two years. The difficulty in customers' debt repayment ability has led to an increase in bad debt, and this reality will continue to be maintained in 2023.

Table 1 gives the mean value of all components, which is about 3.0. Moreover, overall insights for reliability based on all factors demonstrate excellent reliability (Cronbach's Alpha > 0.9), with GI having the highest value (0.950). Perceived importance is based on the most impactful through globalization and financial integration (Mean: 3.405). Least impactful based on internal factors (Mean: 2.786) and systemic risk (Mean: 2.426). Systemic risk shows the lowest variability (Std. Dev.: 0.678), indicating consensus, while other factors exhibit moderate variability.

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Table 1. Testing critical factors affecting systemic risk at commercial banks in Vietnam

Items	Cronbach's alpha	Mean	Std. Deviation
ME	0.925	3.075	1.010
GI	0.950	3.405	0.922
LS	0.930	3.085	1.002
TI	0.903	3.375	0.959
IF	0.901	2.786	0.989
SR	0.869	2.426	0.678

Table 2 displays that the SEM results highlight the relationships among critical factors SR in Vietnamese commercial banks. This section provides an academic analysis of the relationships, their strengths, and implications based on standardized estimates, Critical Ratios (CR), and statistical significance.

Table 2. Testing SEM model for factors affecting systemic risk at commercial banks in Vietnam

Relationships			Standardized Estimate	Estimate	S.E	C.R	P	Hypothesis	Result
ME	→	TI	0.117	0.085	0.030	2.789	0.005	H2	Accepted
GI	→	TI	0.124	0.145	0.047	3.071	0.002	H4	Accepted
LS	→	TI	0.463	0.367	0.041	8.960	***	H5	Accepted
TI	→	IF	0.167	0.175	0.054	3.235	0.001	H8	Accepted
TI	→	SR	0.326	0.192	0.032	5.925	***	H7	Accepted
LS	→	SR	0.250	0.117	0.024	4.851	***	H6	Accepted
GI	→	SR	0.133	0.092	0.028	3.319	***	H3	Accepted
ME	→	SR	0.121	0.052	0.022	2.349	0.019	H1	Accepted
IF	→	SR	0.235	0.133	0.026	5.044	***	H9	Accepted

Note: *** with 1%.

(1) Impact of the ME based on H2: The macroeconomic environment affects technology and financial innovation through a standardized estimate of 0.117, statistically significant at p = 0.005. The result showed that the relationship suggests that macroeconomic stability, characterized by GDP growth, inflation control, interest rate consistency, and exchange rate stability, promotes investment in technological advancements and innovation. Stable macroeconomic conditions reduce uncertainty, encouraging banks to allocate resources for digital transformation. Policymakers should prioritize maintaining stable macroeconomic conditions to create an environment conducive to technological innovation. Moreover, the authors accepted H1: macroeconomic environment affecting systemic risk based on standardized estimate is 0.121, statistically significant at p = 0.019).

(2) Impact of GI based on H4: Globalization and financial integration affecting technology and financial innovation through standardized estimate is 0.124 with statistically significant at p = 0.002). This showed that globalization encourages technological advancement by increasing competition and exposing banks to international best practices. Financial integration, characterized by cross-border capital flows and participation in global markets, necessitates the adoption of innovative technologies to maintain competitiveness and manage risks. The authors accepted H3: Globalization and financial integration affecting systemic risk through a standardized estimate of 0.133, statistically significant at 0.001.

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(3) The impact of the legal framework and supervisory authorities (LS) based on H5: The legal framework and supervisory authorities affect technology and financial innovation through a standardized estimate of 0.463, statistically significant at 0.001. A robust legal framework significantly facilitates the adoption of technological innovations. Regulatory clarity, effective oversight, and adherence to global standards encourage banks to invest in digital transformation. Besides, strengthening the legal framework is critical to fostering technological advancements while ensuring systemic stability. The authors accepted H6: Legal framework and supervisory authorities affecting systemic risk through standardized estimate is 0.250 with statistically significant at 0.001.

(4) The impact of technology and financial innovation (TI) based on H7: technology and financial innovation affect systemic risk through a standardized estimate of 0.326, statistically significant at 0.001. While technological innovation enhances efficiency, it also introduces new systemic risks. Banks increased reliance on digital banking and Fintech solutions can expose banks to cyberattacks, data breaches, and operational risks. Besides, banks must balance technological innovation with comprehensive risk management strategies, such as investing in cybersecurity infrastructure and adopting robust data protection measures. Moreover, the authors accepted H8: Technology and financial innovation affecting internal factors of commercial banks through standardized estimate is 0.167, statistically significant at p = 0.001.

(5) Impact of internal factors of commercial banks (IF) based on H9: Internal factors affecting systemic risk through standardized estimate is 0.235 statistically significant at 0.001. Internal factors, such as governance quality, Return on Equity (ROE), and Return on Assets (ROA), significantly influence systemic risk. Poor governance or low profitability increases a bank's vulnerability to external shocks, potentially exacerbating systemic risk. Therefore, strengthening internal management and financial performance is crucial for mitigating systemic risk. Figure 2 Testing SEM for factors affecting systemic risk at commercial banks in Vietnam and having the significance threshold of 0.05 for assessing five essential components of systemic risk at commercial banks in Vietnam.

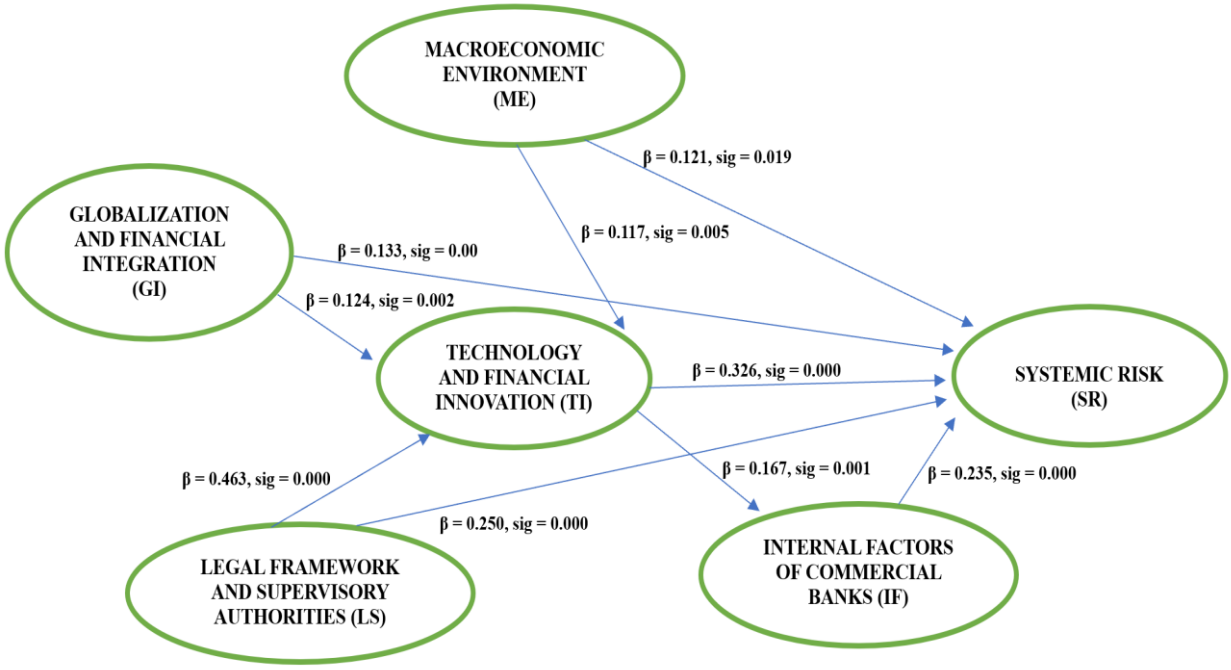

Figure 2. Testing SEM for factors affecting systemic risk at commercial banks in Vietnam

The following statistical metrics measured the model's fit: GFI = 0.872 (>0.850), TLI = 0.911 (>0.900), CFI = 0.926 (> 0.900), and RMSEA = 0.078 (< 0.1) in figure 2. According to the data presented above, research model testing showed that five critical factors of systemic risk at commercial banks in Vietnam, with essential elements such as (1) Macroeconomic environment, (2) globalization and financial integration, (3) legal framework and supervisory authorities, (4) technology and financial innovation, and (5) internal factors of commercial banks. Although the structural model demonstrated an overall good fit (CFI = 0.926, TLI = 0.911, RMSEA = 0.078), the Goodness-of-Fit Index (GFI = 0.872) was only marginally acceptable, falling slightly below the conventional 0.90 threshold. This

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indicates room for improvement in model parsimony or item specification. To address this, we tested an alternative, more parsimonious model by eliminating cross-loading indicators with lower factor loadings and assessment modification indices (MIs). However, the alternative model did not produce a significantly better fit ($\Delta CFI < 0.01$), and theoretical justification for item removal was limited. Thus, the original model was retained for theoretical coherence and interpretability.

4.2. Result Discussion

Commercial banks in Vietnam confront systemic risk, and the results of SEM and Confirmatory Factor Analysis (CFA) shed light on the many factors that contribute to this risk. Five factors, including (1) the macroeconomic environment, (2) financial integration and globalization, (3) the legal framework and supervisory authorities, (4) technological advancements and financial innovation, and (5) internal factors of commercial banks form the basis of the relationships that are examined across dimensions using standardized estimates [24], [27], [31]. By examining the normalized estimates from table 2, we can prioritize the five elements that impact SR in Vietnamese commercial banks. TI and SR were found to have a substantial and positive link in the structural model (standardized estimate = 0.326, $p < 0.001$). Although it improves operational efficiency and service delivery, this study implies that the financial sector may face new dangers due to increased investment in technological innovation [32], [33]. When banks become more dependent on digital platforms, they put themselves at risk of cyber threats, system failures, and operational failure factors. If these problems are widespread, they can affect other institutions and cause systemic disruptions. Emerging areas like peer-to-peer lending, algorithmic trading, and blockchain integration might experience governance gaps due to fast innovation outpacing regulatory monitoring. Therefore, the structural vulnerability incorporated inside digitally evolving banking institutions is reflected in the positive association reported in the model rather than just a risk-benefit tradeoff. The growing financial ecosystem in Vietnam is being shaped by technology, which has the dual purpose of driving innovation while also increasing systemic risk due to its magnified interconnection and fragility. The ranking is based on the variables' direct and indirect effects on TI and SR. Below is a prioritized list of these elements:

(1) The findings indicate that the LS have a direct effect on TI, with a Strong effect of 0.463 and a moderate effect of 0.250 (in table 2). By providing regulatory clarity and bolstering supervisorial tools, the legal framework significantly affects TI, allowing banks to embrace cutting-edge innovations [15], [34]. Furthermore, promoting openness, avoiding financial irregularities, and guaranteeing compliance moderately impact SR. As a result, legislators need to strengthen regulatory frameworks to efficiently control systemic risks and spur innovation. Keep up with the ever-changing rules by making compliance and governance a top priority for the bank.

(2) Both the direct effect of TI on SR and the indirect impact of LS, GI, and ME on SR is 0.326, making TI the most influential factor on SR. This finding is consistent with previous research (in table 2). This demonstrates how technology is pivotal in determining systemic risk [19], [36]. There are benefits, including improved efficiency and new financial innovations, but drawbacks, such as cybersecurity concerns and operational dependencies. TI makes other parameters, especially LS and GI, much more significant thanks to its mediating function. Therefore, to reduce vulnerabilities, banks should combine the advantages of innovation with solid risk management measures. On top of that, lawmakers need to enact tech-specific rules, such as data privacy and cybersecurity. TI exhibits the most substantial direct effect on systemic risk ($\beta = 0.326$, $p < 0.001$), exceeding the standardized direct effects of other constructs. While this suggests TI is a key driver of systemic risk, a formal dominance analysis or total effects decomposition was not conducted. Therefore, this conclusion is limited to direct pathways. Future research should examine all constructs combined direct and indirect effects using total effects comparison or bootstrapped mediation analysis to confirm the relative influence of TI versus other factors like legal structures or internal governance.

(3) Results from studies on the IF and their impacts on SR and TI were found to be similar (in table 2). Systemic risk is substantially influenced by internal characteristics like financial transparency, operational efficiency, and the quality of governance [21], [37]. When internal controls are weak, vulnerabilities are magnified, and when governance and performance are solid, external shocks are mitigated. For this reason, financial transparency and changes to internal governance should be top priorities for banks in their efforts to reduce risk. In addition, incentives, audits, and reporting criteria can be used by lawmakers to promote internal reforms.

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(4) The conclusions drawn from the studies on the effects of GI on TI and SR are consistent: TI experiences a moderate effect, and SR has a weak to moderate impact (in table 2). This demonstrates that technological adoption and systemic risk are both moderately affected by globalization [35], [38]. Banks are more vulnerable to financial crises due to increased exposure to global market volatility and interdependencies brought about by increased financial integration. However, by encouraging competition and forcing modernity, globalization also propels innovation. Hence, governments should monitor money moving across borders and do their best to reduce dependence on foreign funding. Additionally, financial institutions should manage risks related to global interdependencies and diversify their funding sources.

(5) Results found that the ME had a weak direct effect on TI (0.17) and the lowest direct effect among the five components (0.12) on SR (in table 2). This demonstrates that a stable macroeconomic environment fosters innovation and mitigates systemic risk by making financial activity more feasible [29], [39]. Although it does affect TI and SR, it is less significant compared to other components, suggesting that it is more of a facilitator than a primary driver. Inflation management, GDP growth, and currency stability are imperative for policymakers to guarantee economic stability. Stable macroeconomic conditions also help banks develop while lowering their risk exposure. In addition, some standardized path coefficients fall below 0.2, such as the relationship between the macroeconomic environment and systemic risk ($\beta = 0.121$, $p < 0.05$), these are considered substantively meaningful given the theoretical context and the highly interconnected nature of banking systems. In SEM, small but intensely significant effects can be practically important, primarily when represented by distally influenced or mediated relationships within complex models. The standardized estimate above 0.10 can be interpreted as a small but non-trivial effect, particularly in macro-level studies where multiple interacting factors contribute incrementally to systemic outcomes. Moreover, in emerging markets across Vietnam, even modest changes in macroeconomic stability (e.g., interest rates, inflation) can trigger significant cascading effects on financial institutions.

In conclusion, the results reveal that technology and financial innovation strongly influence systemic risk, highlighting a dual role: enhancing efficiency while introducing digital vulnerabilities such as cyber threats and operational dependencies. The legal framework significantly supports innovation and mitigates risks, underscoring the importance of adaptive regulation. Internal bank factors also affect systemic stability, affirming agency theory's relevance in risk governance. Global integration fosters modernization but increases contagion exposure. Similarly, macroeconomic conditions play a relatively modest role, suggesting that in Vietnam, institutional and regulatory structures are more critical in shaping systemic risk than macro-level volatility alone.

5. Conclusions and Policy Recommendations

5.1. Conclusions

This study investigates the determinants of systemic risk in Vietnam's commercial banking sector, emphasizing the role of technology and financial innovation amid an evolving digital and global financial landscape. Employing a SEM approach with a large sample of banking professionals, the research provides empirical evidence on the complex interactions between macroeconomic conditions, globalization, regulatory frameworks, internal bank governance, and digital transformation. The findings highlight that technology and financial innovation strongly influence systemic risk, both directly and indirectly. While these innovations improve efficiency and service delivery, they also introduce new vulnerabilities, including cyber threats and operational risks. Moreover, legal frameworks and supervisory authorities are critical in mitigating systemic vulnerabilities by ensuring compliance, enhancing transparency, and enabling safe technological adoption. The study also confirms that globalization and financial integration contribute to systemic risk through cross-border interdependencies and exposure to external shocks. Although less dominant, internal factors, such as governance quality and financial performance, remain essential in determining a bank's resilience. Macroeconomic conditions, while foundational, exert a relatively moderate direct impact on systemic risk, reinforcing the need for stable economic policies. Finally, the research offers a comprehensive framework for understanding systemic risk in emerging markets and provides actionable insights for regulating regulators and banking institutions. Strengthening regulatory oversight, enhancing internal governance, and implementing robust digital risk management strategies are essential to safeguarding financial stability in rapid technological and economic change.

5.2. Policy Recommendations

Based on the empirical findings, especially the significant impact of TI, LS, GI, IF, and ME on SR, the following targeted policy proposed:

(1) Improve TI by exhibiting the most substantial direct impact on SR (0.326) among all factors (in table 2). While it enhances banking efficiency and fosters financial inclusion, it simultaneously introduces systemic vulnerabilities such as cybersecurity threats, operational dependencies, and risks associated with rapid digitalization. Therefore, by requiring commercial banks to adhere to baseline cybersecurity requirements, such as conducting frequent vulnerability assessments, establishing protocols for incident reporting, and establishing disaster recovery methods, we may encourage them to invest in cybersecurity and infrastructure. Encourage financial institutions to put money into safe technology infrastructure, such as blockchain and risk management systems powered by artificial intelligence. Furthermore, commercial banks can improve their digital transformation initiatives by creating a "Regulatory Sandbox" to test new technologies in a safe setting. Advocate for digital banking technologies that provide data security and operational reliability while improving financial inclusion. Lastly, commercial banks should promote cooperation amongst themselves, Fintech startups, and regulatory agencies for better innovation and systemic risk solutions. Banks can benefit from implementing best practices in technology management worldwide if managers help them share their knowledge. Moreover, to enhance supervisory oversight of financial innovation by giving the dual effect of innovation - boosting efficiency while increasing exposure to cyber and operational risks - regulators such as the State Bank of Vietnam (SBV) should establish a centralized regulatory sandbox, allowing controlled experimentation of digital financial products. Rather than assigning this function to banks, the sandbox should be regulator-led, ensuring accountability, data protection, and consumer safety.

(2) Improved LS based on the most critical role in influencing both TI and SR. Its direct impact on TI (0.463) and SR (0.250) underscores its ability to promote innovation while ensuring financial stability (in table 2). Therefore, the Vietnamese government should propose policy actions based on dynamic regulatory frameworks through regularly updated regulations to address emerging risks, particularly those associated with digital banking, Fintech adoption, and cybersecurity. Strengthen frameworks for systemic risk assessment, such as stress testing and capital adequacy requirements. Moreover, risk-based supervision shifts from compliance-focused supervision to risk-based approaches prioritizing high-risk institutions and activities. Encourage system-wide risk analysis to preemptively address potential vulnerabilities. In addition, standardized reporting formats can be mandated to increase the transparency of financial operations and systemic risk assessments, leading to greater transparency and openness. Compliance with regulatory standards should be ensured by strengthening enforcement mechanisms. Lastly, digital banking systems must prioritize cybersecurity by creating legislative measures to deal with data breaches, cyberattacks, and operational disruptions. Financial institutions must have stringent cybersecurity policies and procedures as part of their regulatory duties. Moreover, codifying cybersecurity standards into prudential regulation since technological innovation contributes significantly to systemic risk, cybersecurity frameworks should be embedded into capital adequacy and risk-weighted asset calculations, aligning with emerging Basel III recommendations on operational resilience.

(3) Improve GI exerts a moderate influence on TI (0.124) and a weak to moderate effect on SR (0.133) (in table 2). Financial integration drives innovation by fostering competition and necessitating modernization. However, it also amplifies systemic vulnerabilities due to cross-border dependencies and exposure to global market shocks. Therefore, commercial banks should improve safeguarding against global risks by implementing capital flow monitoring mechanisms to manage exposure to foreign capital and international market fluctuations. Establish contingency plans to address risks stemming from global economic crises. Finally, encourages diversification by promoting domestic funding sources to reduce reliance on foreign capital. Encourage banks to diversify their revenue streams by expanding into less volatile markets or offering innovative products; commercial banks should comply with international standards by Encouraging alignment with global standards in digital banking, risk management, and compliance to mitigate globalization risks. Moreover, improving data sharing and interagency coordination. Fragmented oversight weakens systemic risk detection. The government should facilitate data-sharing protocols among the SBV, Ministry of Finance, and Credit Information Center, using real-time risk dashboards to detect contagion paths and liquidity mismatches.

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(4) Improved IF have a moderate impact on SR (0.235) through governance quality, financial transparency, and operational efficiency. Internal solid controls reduce vulnerabilities, while weak governance exacerbates systemic risks (in table 2). Therefore, Governance reforms and transparency in financial reporting are essential to align internal practices with systemic risk mitigation efforts. Commercial banks must enforce governance frameworks emphasizing accountability, risk management, and strategic decision-making. Moreover, Commercial banks conduct regular training programs for bank managers on governance best practices and systemic risk awareness. Improved financial transparency by mandating comprehensive financial disclosures to ensure alignment with regulatory standards and stakeholder expectations. Adopt international accounting standards to improve consistency and comparability. Finally, operational efficiency can be enhanced by encouraging technology to automate operational processes, reducing human errors and inefficiencies. Provide incentives for banks to invest in employee training programs that improve operational performance. Moreover, streamlining governance requirements for systemically important banks by suggesting that stronger governance, transparency, and liquidity buffers are necessary. The SBV should issue specialized governance guidelines for large banks with high interconnectivity, including board accountability mechanisms and enhanced stress testing.

(5) Improved ME has the weakest direct impact on SR (0.121) and TI (0.117) among the five factors (in table 2). While macroeconomic stability enables innovation and systemic stability, its indirect role is primarily supportive. Therefore, Vietnam continues to ensure macroeconomic stability by adopting inflation-targeting measures and ensuring predictable interest rates to reduce economic uncertainty. Align monetary policies with long-term economic growth objectives. Moreover, Vietnam fosters resilience to economic shocks by creating fiscal buffers to mitigate the impact of external shocks, such as global financial crises or geopolitical tensions. Encourage structural reforms to improve economic adaptability and resilience. Finally, inflation control, GDP growth, and stable interest rates provide a favorable environment for innovation but do not directly drive systemic risk mitigation. Moreover, macroprudential policy tools should be aligned with risk channels. The macroprudential instruments such as counter-cyclical capital buffers and Loan-to-Value ratios should be adjusted in response to credit booms and inflation shocks, especially those triggered by external volatility.

While the proposed legal and technological interventions, such as regulatory sandboxes, enhanced cybersecurity frameworks, and governance reforms, offer strong theoretical justification, their feasibility and implementation costs remain underexplored. For instance, setting up centralized sandboxes or deploying AI-based risk systems may require significant investments in digital infrastructure, technical expertise, and cross-agency coordination. Similarly, compliance with global regulatory standards could disproportionately burden small or rural banks. Considering short-term setup costs versus long-term gains in systemic stability and public trust, a cost-benefit analysis is essential. Future studies should evaluate these interventions' financial, operational, and political feasibility to enhance the applied value of policy recommendations.

Limitations and future research: Despite its solid methodology and empirical findings, this study has some drawbacks. First, the research uses cross-sectional data from the one-time point, which makes it challenging to track systemic risk over time. A longitudinal approach could reveal how technology and regulation affect risk. Second, the study only covers Vietnam, limiting its applicability to other emerging economies with different institutional, technological, and macroeconomic circumstances. Comparative studies across Southeast Asia or other developing regions might improve external validity. Third, the SEM technique captures complicated variable interactions but may not account for financial system heterogeneity or feedback loops. Further research should examine ESG risks and climate-related financial disclosures as emerging contributors to systemic vulnerability. Adding real-time risk indicators like cybersecurity breach data or digital transaction volumes may increase digital finance systemic risk models' prediction power. Adding regulatory and FinTech viewpoints to the dataset could improve systemic risk assessment. One limitation of the current analysis is the absence of a multi-group SEM to test whether the structural relationships differ across key subpopulations, such as regions (e.g., Northern vs. Southern Vietnam) or types of banks (e.g., state-owned vs. private vs. foreign-invested). Conducting measurement invariance testing followed by path coefficient comparisons would allow the model to reveal whether systemic risk drivers vary meaningfully by institutional or geographic context. Such analysis could enhance the policy relevance of the findings by enabling targeted recommendations. Future research should incorporate multi-group analysis to assess heterogeneity in systemic risk dynamics across Vietnam’s banking

landscape. While this study emphasizes Vietnam's macroeconomic and institutional context, it does not compare findings with other ASEAN banking systems (e.g., Indonesia, Thailand, or Malaysia). This limits the ability to generalize results or assess whether the drivers of systemic risk are regionally specific or part of broader Southeast Asian trends. Future research should incorporate cross-country comparisons to enhance external validity and contextualize Vietnam's systemic vulnerabilities within the regional financial landscape. Future studies should consider longitudinal designs, non-linear modeling, or panel SEM to improve robustness and temporal validity.

6. Declarations

6.1. Author Contributions

Conceptualization: L.P.N. and P.T.T.; Methodology: P.T.T.; Software: L.P.N.; Validation: L.P.N. and P.T.T.; Formal Analysis: L.P.N. and P.T.T.; Investigation: L.P.N.; Resources: P.T.T.; Data Curation: P.T.T.; Writing Original Draft Preparation: L.P.N. and P.T.T.; Writing Review and Editing: P.T.T. and L.P.N.; Visualization: L.P.N. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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The authors received no financial support for the research, authorship, and/or publication of this article.

6.4. Institutional Review Board Statement

Not applicable.

6.5. Informed Consent Statement

Not applicable.

6.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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