The Economics and Finance Letters
2025 Vol. 12, No. 1, pp. 16-33
ISSN(e): 2312-430X
ISSN(p): 2312-6310
DOI: 10.18488/29.v12i1.4038

The effects of technology investment on financial stability: Evidence from commercial banks in Vietnam

Nguyen Minh Nhat
Faculty of Banking, Ho Chi Minh University of Banking, Ho Chi Minh City, 84, Vietnam.
Email: nhatnm@hub.edu.vn

Article History
Received: 28 October 2024
Revised: 2 December 2024
Accepted: 17 December 2024
Published: 10 January 2025

Keywords
Commercial banks
Digital transformation
Financial stability
Technology investment.

JEL Classification:
B26; C01; G10; P34.

ABSTRACT

This study examines the effects of technology investments on financial stability at commercial banks in Vietnam. Financial services provided by banks are vital to the growth and development of the Vietnamese economy. Due to competitive constraints and the need to keep up with fast-moving FinTech startups, Vietnamese banks have made digital transformation a top strategic goal. Therefore, the study aims to investigate the impact of technology investment on the financial stability of commercial banks in Vietnam from 2012 to 2023. The research used financial data from 26 joint-stock commercial banks and panel data analysis with the ordinary least squares (OLS), fixed effect model (FEM), random effects model (REM), and generalized method of moments (GMM) to look into the link between bank stability and technology spending. The findings reveal that while technology investment significantly enhances operational efficiency and market competitiveness, it poses risks, particularly during the initial stages of digital transformation. The results show a significant negative effect of technology investment on financial stability, highlighting the need for strategic planning and robust regulatory frameworks. These insights provide valuable recommendations for bank management and policymakers to balance technological advancements with financial stability, especially in economic disruptions like the COVID-19 pandemic. Finally, the practical implications help commercial banks strive to increase asset size and expand operations to strengthen financial capacity, increase brand recognition, create solid customer trust, improve competitiveness, and bring high profits.

Contribution/Originality: This study examines the two sides of technology investment, showing how it can improve operational efficiency and threaten financial stability, especially in the beginning phases of digital transformation. This study provides critical insights into the effects of digital transformation on financial stability in the Vietnamese banking industry, particularly in the aftermath of the COVID-19 pandemic.

1. INTRODUCTION

Since the 2007-2008 financial crisis, the banking sector has undergone considerable changes in the evolution of financial markets. Banks and financial institutions have faced challenges sustaining operations, reducing losses, and maintaining stable liquidity (Pham, Dao, & Nguyen, 2021). The COVID-19 pandemic has further impacted the banking system due to declining household income and business revenue (Feyen, Gispert, Kliatskova, & Mare, 2021). Consequently, the stability of banks has become a primary concern for bank managers, deposit insurance organizations, and the public, given the risk of systemic contagion (Bai & Elyasiani, 2013). In recent years,

information technology has been a driving force behind the transformation of the banking industry, a process accelerated by the COVID-19 pandemic. FinTech services now prevalent in the banking sector include electronic money, online wallets, cryptocurrencies, electronic mortgages, wire transfers, financing, leasing, cash management, digital instruction, factoring, online insurance, crowdfunding, and digital lending (Berg, Burg, Gombović, & Puri, 2020; Gupta, Raychaudhuri, & Haldar, 2018; Thu & An, 2016). The potential for technology integration continues to grow with advancements like artificial intelligence, blockchain, and digital currencies (Koohang et al., 2023). Banks adopting technological transformation can expand their customer base, as digital platforms lower the costs for customers to find and switch banks (Dadoukis, Fiaschetti, & Fusi, 2021; Wang, Liu, & Luo, 2021).

In Vietnam, the banking sector is among the fastest-growing in digital transformation (Nguyen-Thi-Huong, Nguyen-Viet, Nguyen-Phuong, & Van Nguyen, 2023). Banks dominate the financial system as the primary provider of finance and play a crucial role as financial sources (Nga, 2022; Vo & Tran, 2015). To stay competitive amid the rise of FinTech companies, banks are diversifying their operations by enhancing solutions, product quality, and services. Consequently, despite cybersecurity risks, continuous investment in digital technology and the enhancement of e-banking systems have become strategic priorities for banks (Nguyen, Tran, & Lu, 2022).

The impact of technology investment on bank financial stability can be viewed from two perspectives. Commercial banks leverage digital products and services to meet customer needs more efficiently. Research indicates that technological investments positively affect a bank's stability. For instance, Risman, Mulyana, Silvatika, and Sulaeman (2021) suggest that technological investments enhance the financial system's efficiency and competitiveness, a view supported by Ozili (2018) and Luo, Luo, and Lv (2022). However, ineffective technology investments can pose risks and threaten financial stability. Syed, Ahmed, Kamal, and Trinidad Segovia (2021) found that increased investment in digital finance without strict regulations, particularly in developing countries, can lead to financial instability and systemic risks. Dadoukis et al. (2021) observed fluctuations in bank stability since the advent of digital financial services. During the early stages of the COVID-19 pandemic, banks with high IT adoption performed better regarding market returns, more significant deposit inflows, and heightened competition (Dadoukis et al., 2021). Similar findings have been reported in Vietnam by Nguyen-Thi-Huong et al. (2023) and Nguyen and Dang (2022). The ongoing debate about the impact of digital transformation on banking stability underscores the need for specific studies to clarify the relationship between technological factors and banking development in Vietnam, especially amid the COVID-19 context.

In addition, the research's distinctive contribution is this: (1) Recognize inconsistencies in the current literature regarding the connection between financial stability and investments in technology. One study found that investing in technology made banks more stable, whereas another found the opposite, especially in developing nations. Similarly, comparable paradoxes occur in Vietnam owing to different regulatory and operational environments; explain how these inconsistencies drive your focus on Vietnam. (2) Point out that previous research may have missed current tendencies in digital transformation, particularly after COVID-19, because it relied on out-of-date methodology or used small datasets. Using econometric models like GMM and panel data collected from 26 banks over a decade, your work improves accuracy and thoroughly examines long-term implications. (3) There is a criticism that most research overlooks developing markets, such as Vietnam, in favor of more established ones. Emphasize the significance of this setting because the financial stability outcomes of technology investments are impacted by Vietnam's distinctive regulatory environment and the country's rapid digital transition. (4) Emphasize that prior research has mainly concentrated on how technology might improve operational efficiency, but your work takes a closer look at the new dangers, such as cyber threats and higher operational expenses, that come with increasing digital adoption. (5) Studies claim technology adoption always leads to better financial stability. Still, these studies don't consider the fact that there will be short-term disruptions and the necessity to align regulations, particularly in developing markets. You should note that your study provides a balanced perspective by critically examining both the positive and negative effects. The research addresses these knowledge gaps and provides valuable information for

Vietnamese bank executives and lawmakers by articulating this critique.

This study adds to the literature by providing empirical research on the correlation between technology investment and financial stability in banks from 2012 to 2023, updating the latest evidence. Given the variations in financial products, customer consumption, and related factors, bank financial stability has fluctuated annually. Furthermore, this study offers new insights into the impact of technology investment on financial stability, particularly considering the significant influence of the COVID-19 pandemic and identifying the factors affecting financial stability. The article will be organized as follows: (2) Literature review, (3) Data and methodology, (4) Results, (5) Discussions, and (6) Conclusions and recommendations.

2. LITERATURE REVIEW AND RESEARCH HYPOTHESES

2.1. Literature Review

The definition of financial stability varies across different banks. Definitions from central banks and researchers have been compiled to illustrate these differences. The Norwegian Central Bank (2003) describes financial stability as a condition where the financial system is resilient to economic disturbances, capable of facilitating finance, making payments, and distributing risk effectively. Rasyid and Bangun (2023) view financial stability as a state where the financial system performs essential economic functions such as resource allocation, risk distribution, and payment processing, even during economic downturns or restructuring periods. Wang et al. (2021) suggest that financial stability means the banking system can fulfill all its duties or experience minimal profit shortfalls under any conditions. Other authors define financial stability by examining financial instability. Mishkin (1999) notes that financial instability arises when shocks to the financial system disrupt the flow of information and impact investment activities; this perspective is also supported by Crockett (1996). Financial stability means that the financial system works well, with financial intermediaries, markets, and infrastructure all doing their jobs well and market shocks having little effect (Ozili, 2018; Risman et al., 2021). The complexity of defining and measuring financial stability in the banking system has led to various proposed methods. Some studies suggest measuring financial stability through profit or deposit fluctuations to assess bank runs (Ngalawa, Tchana, & Viegi, 2016; Von Hagen & Ho, 2007). The ratio of negative debt to total assets is also used to represent the financial stability of the banking system (Fratzscher, König, & Lambert, 2016; Kasman & Kasman, 2015). Additionally, banking stability is expressed through the equity capital-to-total capital ratio, liquidity, and loan-to-total mobilized capital ratio (Aloulou, Grati, Al-Qudah, & Al-Okaily, 2024; Ghenimi, Chaibi, & Omri, 2017; Khan, Scheule, & Wu, 2017; Wagner, 2007).

This study uses the Z-score coefficient to represent the financial stability of Vietnam's banking system. The Z-score is considered an optimal proxy for a bank's overall risk or stability (Bai & Elyasiani, 2013; Laeven & Levine, 2009). Li, Tripe, and Malone (2017); Shabir, Jiang, Wang, and Işık (2023) and Cevik (2024) also use the Z-score index to measure bank stability before and during COVID-19, as it reflects the institution's overall stability without focusing on the risk source. The Z-score index in its natural logarithm form minimizes data volatility and enhances estimation efficiency (Houston, Lin, Lin, & Ma, 2010). The proposed formula for estimating the financial stability of the banking sector is as follows:

$$Ln\left(\frac{ROA_{it} - ETA_{it}}{SDROA_{it}}\right)$$

In there:

ROA_{it}: Average profit ratio on total assets.

ETA_{it}: Equity over total assets.

$SDROA_{it}$: Standard deviation of return on assets (ROA).

i, t: Commercial bank i, and at year t.

This index considers three critical aspects to evaluate a bank's performance: capital adequacy (measured by the

equity ratio), profitability (measured by ROA), and risk (measured by the standard deviation of ROA, indicating profit volatility). Following the methodologies of Williams (2014); Laeven and Levine (2009) and Ahamed and Mallick (2019) the standard deviation of ROA is calculated based on a rolling three-year period, making the Z-score more responsive. Investment in technology in banking is also defined and measured differently. Information technology was described by Indrajit, Van Loenen, Ploeger, and Van Oosterom (2020) as the transformation of data into information and its distribution within specific time and space limitations. Information technology (IT) investments boost financial stability and increase banks' competitive advantage, according to Apulu, Latham, and Moreton (2011). Businesses can acquire a competitive advantage and achieve long-term growth by investing more in technology, namely in new systems and equipment (Chiorazzo, Milani, & Salvini, 2008). Investment in information technology, comprising software and hardware assets shown on a company's balance sheet, was used by Brynjolfsson (1993) as a measure of digitalization levels. Financial technology investment data is also gathered through questionnaires Tippins and Sohi (2003). The logarithm of a bank's total technology investment expenses at a particular moment can also be used as a metric of technology investment (Gupta et al., 2018; Leckson-Leckey, Osei, & Harvey, 2011).

Data for this study comes from the footnotes of banks' financial statements, and it uses the ratio of software technology investment to total intangible assets to gauge the amount of money banks are putting into technology. Duong (2017) and Thu and An (2016) employ approaches that are compatible with this approach.

$$TE = \frac{The\ total\ of\ technology\ software\ investment}{The\ total\ intangible\ assets}$$

2.2. Research Hypotheses

According to several studies, firms can improve their service quality, reduce operational expenses, strengthen their corporate structure, and encourage digital transformation by investing in information technology (Martín-Oliver & Salas-Fumás, 2008). Technology helps banks expand by improving their capacity to track and evaluate loans (Berg et al., 2020) and making better lending decisions, leading to fewer bad debts and better client selection (Dadoukis et al., 2021). Based on data from 6,848 institutions in 29 European and American nations, Scott, Van Reenen, and Zachariadis (2017) concluded that the Society for Worldwide Interbank Financial Telecommunication (SWIFT) network-based technical infrastructure and communications standards benefits banking performance. Li, Spigt, and Swinkels (2017) study of the relationship between FinTech and the stock prices of US retail banks from 2010 to 2016, the stock prices of these institutions were positively impacted by the growth in FinTech funding and earnings. Acar and Çıtak (2019) concurred, suggesting that banks should enhance cooperation with FinTech companies to foster growth and stability. The rise of financial technology increases efficiency, competitiveness, and the scope of financial services (Cevik, 2024). Nga (2022) posits that technology investment increases the risk tolerance of commercial banks in Vietnam, leading to higher profits than banks with less focus on technology investment (Thu & An, 2016). During the COVID-19 period, Aloulou et al. (2024) concluded that digital transformation drove growth in the banking industry in the UAE. Dadoukis et al. (2021) also noted that technological activities contributed to bank stability during the COVID crisis, suggesting that technology could further promote banking system development. Banks with strong IT capabilities attracted substantial deposits, particularly from large enterprises, during COVID. Nguyen-Thi-Huong et al. (2023) found that while digital transformation negatively impacted return on assets and equity, bank profits increased during COVID-19 in Vietnam.

However, some studies present opposing views on the impact of technology investment on bank stability. Gupta et al. (2018) studied 13 banks in India from 2006 to 2013, finding a negative relationship between profits and technology investment. Nguyen and Dang (2022) provided evidence that FinTech development negatively affects financial stability in emerging markets, although market discipline can mitigate this negative impact. An and Rau (2021) concluded that technology-based products and services from external suppliers positively impact bank profitability, but investment in hardware and software reduces operational efficiency. Chae, Koh, and Prybutok (2014)

found no relationship between information technology and the profits or profit growth of banks in the US. Nguyen et al. (2022) showed that technology investment significantly and positively affects banks' net interest margin (NIM) but found no evidence linking technology budget spending to bank stability.

The following hypotheses are put out to examine the effect of technology investment on the financial stability of commercial banks in Vietnam, based on the study's objectives and the literature review:

Hypothesis 1 states the investments in technology positively impact the financial soundness of commercial banks in Vietnam. *Banking institutions become more efficient, competitive, and financially stable when they increase their investments in technology.*

Hypothesis 2: Commercial banks in Vietnam are less financially stable due to technology investment. While investments in technology can boost operational efficiency, this theory holds that there is a trade-off during the early phases of digital transformation; there is a higher risk of operational and cybersecurity issues, which could lead to a decline in financial stability.

Hypothesis 3: Commercial banks in Vietnam can better weather the COVID-19 pandemic thanks to increased investment in technology. According to this theory, banks could better weather the COVID-19 epidemic thanks to the intelligent use of technology that helped them adapt and stay afloat financially.

By employing state-of-the-art econometric models such as pooled OLS, FEM, REM, and GMM, we will test these hypotheses using actual data collected from 26 Vietnamese joint-stock commercial banks from 2012 to 2023.

3. DATA AND METHODOLOGY

(1) Data: This study utilizes secondary data from the financial statements of 26 Vietnamese joint stock commercial banks from 2012 to 2023. The Vietnamese banking system underwent significant restructuring from 2011 to 2015, followed by further enhancements from 2016 to 2020, particularly during the COVID-19 pandemic. We chose the time after COVID-19 because Vietnamese banks have rapidly transformed digitally. The International Monetary Fund (IMF) was also consulted for information regarding gross domestic product (GDP) and the inflation index (INF). The total number of observations in the collection is 253, including panel data from 26 banks.

Regression analysis made use of the Random Effects Model (REM), while Pooled Ordinary Least Squares (OLS) and Fixed Effects Model (FEM) were utilized for quantitative data analysis. The Feasible Generalized Least Squares (FGLS) model dealt with autocorrelation and heteroskedasticity. The two-step generalized method of moments (GMM) proposed by Arellano and Bond (1991) and Arellano and Bover (1995) was also applied if the dataset included endogenous variables.

(2) Methodology: This study uses panel data analysis to explore the impact of technology investments on banks' financial stability since the data set includes information from many banks over a specified period.

Based on the theory and analysis of Wang et al. (2021) and Banna and Alam (2021) the author builds a research model including 9 variables affecting the financial stability of joint stock commercial banks in Vietnam as follows:

$$Ln(Zscore)_{it} = \beta_0 + \beta_1 TE_{it} + \beta_2 SIZE_{it} + \beta_3 LLP_{it} + \beta_4 DIV_{it} + \beta_5 LGR_{it} + \beta_6 CIR_{it} + \beta_7 GDP_t + \beta_8 INF_t + \beta_9 COVIDTE_t + \varepsilon_{it}$$

Financial stability: Ln (Zscore)Ln ((ROA_it - ETA_it)/SDROA_it) Wang et al. (2021) and Ashraf (2017).

Technology investment: TE is (technology software investment)/(total intangible assets) Duong (2017) and Thu and An (2016).

Bank size: SIZE is Log (Total assets) Chen et al. (2019); Li et al. (2017) and found Wang et al. (2021) found that larger bank size improves financial stability.

Provision for loans to customers to total assets ratio: LLP is (Provision for loans to customers)/(Total assets); Fratzscher et al. (2016); Fu, Lin, and Molyneux (2014) and Pham et al. (2021). Loan provisions negatively affect financial stability.

Income Diversification: DIV is Herfindahl-Hirschman (HHI) index; Pambuko et Adem (2023) and Pham et al. (2021). Income diversification positively affects financial stability.

Cost-to-Income Ratio: CIR is (Total operating expenses)/(Total operating income); Shahid and Abbas (2012) and Fu et al. (2014). A higher cost-to-income ratio improves financial stability.

Loan Growth Rate: LGR is (Loan_t - Loan_(t-1))/Loan_(t-1); Ghenimi et al. (2017) and Koskei (2020). Loan growth positively impacts financial stability.

Economic Growth Rate: GDP is collected from IMF, Ahamed and Mallick (2019) and Ozili (2018). Economic growth positively impacts financial stability.

Inflation Rate: INF is collected from IMF, Wang et al. (2021) and Apulu et al. (2011). Inflation negatively affects financial stability.

Technology investment during COVID-TE; Covid * Technology investment (Covid value = 1 for years > 2020, Covid value = 0 for years < 2020); Dadoukis et al. (2021). Technology investment during COVID-19 positively impacts financial stability. Control variables include: Based on previous studies conducted by Wang et al. (2021); Banna and Alam (2021); Dadoukis et al. (2021) and Duong (2017) and other studies. The researcher incorporated several control variables into this study. Detailed formulas for these control variables are given above. The goal is to evaluate the impact of investment in the technological improvement of the Vietnamese banking system on financial stability. The variables of this study are pertinent to determining how technological investment affects the soundness of Vietnamese banks. Technology investment (TE) serves as the primary measures of banks' financial resource dedicated to digitization. According to previous research, investment in technology has the potential to influence banks' operational efficiency and competitiveness. This study uses the ratio of software investment in technology to total intangible assets as a useful way to find out how technology affects the stability of banks (Duong, 2017; Koskei, 2020; Thu & An, 2016).

4. RESEARCH RESULTS AND DISCUSSIONS

4.1. Descriptive Statistics

Examining the control variables, the size of Vietnamese commercial banks (SIZE) exhibits minor variations. The highest value is 21.5566, and the lowest is 16.5873, with an average of 19.1515 and a standard deviation of 1.1615, indicating relatively uniform bank sizes. The loan loss provision (LLP), income diversification (DIV), cost-to-income ratio (CIR), and lending growth rate (LGR) are some other control variables. Their average values are 0.0876, 0.6148, 0.1713, and 0.1965, respectively. The economic growth rate averages 5.76%, with a minimum of 2.58% and a maximum of 8.02%. The inflation rate (INF) averages 3.49%, with the highest value at 9.09% and the lowest at 0.63%. COVIDTE, which measures the rate of information technology adoption during the COVID-19 period, has the highest value of 36.05% and a standard deviation of 10.31%, reflecting a significant acceleration in technology adoption by banks during this time.

Table 1. Descriptive statistical results for the determinants of financial stability.

Variables	Observation	Mean	Std. dev.	Min	Max
Lnzscore	253	4.0254	0.8013	1.0026	6.6085
TE	253	0.1438	0.0871	0.0086	0.4199
SIZE	253	19.1515	1.1615	16.5873	21.5566
LLP	253	0.0876	0.0293	0.0382	0.191
DIV	253	0.6148	0.0980	0.0307	0.7902
CIR	253	0.1713	0.1020	0.004	0.6336
LGR	253	0.1965	0.0987	0.0251	0.5342
GDP	253	0.0576	0.1627	0.0258	0.0802
INF	253	0.0349	0.0191	0.0063	0.0909
COVIDTE	253	0.0691	0.1031	0	0.3605

The dependent variable in this study is Lnzscore, representing the financial stability of commercial banks, with 253 observations. Table 1 shows that Lnzscore has an average value of 4.0254, a standard deviation of 0.8013, a

minimum value of 1.0026, and a maximum value of 6.6085. Regarding the primary explanatory variable, technology investment (TE), the average value among Vietnamese commercial banks is 0.1438, with the highest rate at 41.99%. This indicates a growing emphasis on technology investment within Vietnam's banking sector.

Financial stability (LnZscore), technology investment (TE), bank size (SIZE), loan loss provisions (LLP), income diversification (DIV), cost-to-income ratio (CIR), loan growth rate (LGR), economic growth rate (GDP), inflation rate (INF), and COVIDTE (COVID-19 technology investment interaction) are the main variables used in the study, and their descriptive statistics are presented in Table 1.

(1) The average LnZscore (Financial Stability) for Vietnamese banks over the research period was 4.0254, indicating moderate stability. With a range of 1.0026 to 6.6085, the standard deviation of 0.8013 reveals that stability levels are not consistently high or low. These differences are probably caused by different bank policies, operational strategies, and outside economic factors. This shows that banks have big differences in how they handle risk and keep things stable.

(2) The data demonstrate that banks' levels of technology investment vary greatly, from 0.0086 to 0.4199, with a mean value of 0.1438 and a rather significant standard deviation of 0.0871. This shows differences in digital transformation goals since some banks have invested heavily in technology while others have lagged behind. When accounting for the costs and risks connected with these investments, the diversity in TE suggests that there may be differences in how digitalization affects bank stability.

(3) SIZE (Bank Size) revealed that, on average, banks have a size of 19.1515 logs of total assets, with a standard deviation of 1.1615, indicating minimal variation. The figures show that the sampled banks are of a reasonably consistent size, ranging from 16.5873 to 21.5566. There is a positive correlation between SIZE and stability because bigger banks can better manage risks, weather market fluctuations, and take advantage of economies of scale.

(4) The average loan loss provision (LLP) of 0.0876 in the fourth LLP analysis represents banks' credit risk management strategy in Vietnam. Varying provisioning procedures, with a standard deviation of 0.0293 and a maximum value of 0.191, may represent variations in bank loan portfolios and risk tolerance. Stabilizing banks and reducing profitability through excessive provisions can be signaled by high LLP values, which indicate a proactive strategy for controlling probable loan defaults.

(5) Income Diversification (DIV) revealed that many banks keep their revenue sources modestly varied, with an average DIV value of 0.6148, as determined by the Herfindahl-Hirschman Index. The wide range of non-interest revenue, from 0.0307 to 0.7902, shows that some banks are less susceptible to interest income changes because they rely more on it. Reduce reliance on traditional interest income and increase diversification to promote stability.

(6) Cost-to-Income Ratio (CIR) data showed that banks' operating efficiency ranged from 0.004 to 0.6336, with a mean CIR of 0.1713 and a standard deviation of 0.1020. Although some banks run efficiently, others may have large operational expenditures compared to their profits, as seen by this wide range. Because CIR varies, banks' management styles and resource allocations may vary, affecting stability by influencing their capacity to pay costs and maintain profitability.

(7) The mean LGR of 0.1965 indicates a moderate increase in bank lending activity across the sample, according to LGR (Loan Growth Rate). Some banks are aggressively growing their loan portfolios, while others are taking it slow, as seen by the standard deviation of 0.0987 in LGR, which ranges from 0.0251 to 0.5342. While rapid expansion of loans could boost profits, it also poses concerns that could undermine stability if not appropriately handled.

(8) The research period had a steady economic climate in Vietnam, as seen by the mean GDP growth rate of 5.76%. The growth rate ranged from 2.58% to 8.02%, reflecting cyclical growth trends. By using GDP as a macroeconomic control variable, the research can account for the impact of external economic factors on all banks.

(9) The mean inflation rate (INF) of 3.49%, with a standard deviation of 1.91%, demonstrated the period's modest inflation. Inflationary pressure is indicated by a maximum rate of 9.09% and a stable period by a minimum rate of

0.63%. Accounting for inflation allows for more precise evaluations of technology's impact on stability since it affects lending rates and bank profitability.

(10) COVIDTE (COVID-19 Technology Investment Interaction) shows that this variable captures the rate of technology adoption during COVID-19, with a high of 36.05%. It has a mean value of 0.0691 and a considerable variability of 10.31% (standard deviation). In response to the pandemic, banks swiftly adapted their services to ensure operational resilience, as seen in the increased digital use. COVIDTE adds a new dimension to the analysis by allowing us to analyze the influence of pandemic-driven technological investment on stability.

4.2. Correlation Coefficient Matrix of the Collected Variables and Regression Results

The analysis of the correlation coefficient matrix in Table 2 reveals that all correlations are below 0.8, indicating no multicollinearity among the variables. In particular, TE, CIR, LGR, GDP, and INF exhibit negative correlations with Lnzscore, while SIZE, LLP, DIV, and COVIDTE positively correlate with the dependent variable.

Table 2 shows the correlation coefficient matrix for the variables in this study. When the correlation coefficient between two independent variables is higher than 0.8, the risk of multicollinearity goes up. This can change regression coefficients and lead to wrong results. Table 2 correlations shed light on the dynamics of the linkages between bank features, macroeconomic indicators, and financial stability by highlighting numerous essential relationships among variables, including:

(1) There is a positive correlation between size and technology investment, which means that bigger banks can handle digital transformation better. The positive correlation between SIZE and investment in technology (0.2608) indicates that bigger banks are more inclined to invest in technology. This could be because they have more resources and can better undergo digital changes. It is reasonable to assume that more significant organizations can afford to put more money into technology without jeopardizing their financial viability. Investing more money in technology during the pandemic seems to be supported by a somewhat positive correlation with COVIDTE (0.5131), which indicates a meaningful relationship between the two variables. This demonstrates how the banking industry reacted to the operational difficulties brought on by the COVID-19 outbreak by speeding up the digitization trend.

(2) The negative correlation between inflation and stability highlights the need to manage macroeconomic risks in order to stabilize banks. COVID-19 Technology Investment positively correlates with stability, which supports the idea that digital adoption might help stabilize economies experiencing shocks.

Specifically, the study establishes the foundation for future regression analysis by exploring the correlations between technological investments and stability within the context of Vietnamese banks. To interpret the data presented in the following sections, this correlation matrix is a basic understanding of the possible interactions among the variables.

Table 2. Correlation coefficient matrix of the collected variables.

Variables	Lnzscore	TE	SIZE	LLP	DIV	CIR	LGR	GDP	INF	COVIDTE
Lnzscore	1.000									
TE	-0.2482	1.0000								
SIZE	0.2992	0.2608	1.0000							
LLP	0.1199	0.0248	-0.3933	1.0000						
DIV	0.2917	0.2106	0.1361	-0.1162	1.0000					
CIR	-0.0835	0.0259	-0.0302	-0.0419	-0.1362	1.0000				
LGR	-0.2023	0.0672	-0.1240	-0.0046	-0.2454	0.4493	1.0000			
GDP	-0.1026	-0.1083	-0.0619	-0.0703	-0.0320	-0.0234	0.1029	1.0000		
INF	-0.3162	-0.1043	-0.1436	0.0329	-0.0859	0.0119	0.0568	-0.0227	1.0000	
COVIDTE	0.2006	0.5131	0.3373	0.1591	0.1324	-0.0390	-0.1795	-0.4919	-0.2379	1.000

Table 3. Regression results.

Variables	Pooled-OLS	FEM	REM	FGLS	GMM
Lnzscore					
TE	-5.2020***	-5.6404***	-5.3121***	-5.2020***	-4.6905***
SIZE	0.2964***	0.3806***	0.3003***	0.2964***	0.2096***
LLP	8.7825***	9.9871***	8.8525***	8.7825***	5.6697***
DIV	2.8574***	2.0702***	2.7734***	2.8574***	4.3156***
CIR	0.0328	-0.1063	0.0238	0.0328	1.4325**
LGR	0.1918	0.6065	0.2420	0.1918	0.5063
GDP	-1.0887	-1.4177	-1.0713	-1.0887	-2.4187
INF	-10.6151***	-11.6029***	-10.8893***	-10.6151***	-5.6541**
COVIDTE	1.4118***	1.2990*	1.4292***	1.4118***	0.3073***
Constant	-3.1369***	-4.4304*	-3.1532***	-3.1369***	-36566***
Observations	253				
R-squared	0.5052	0.5028	0.5226		
F-value/Wald chi2	0.0000	0.0000	0.0000	0.0000	0.000
No of groups	23				
No of instruments	20				
Mean VIF	1.47				
F-test	F(22.221) = 1.67				
	Prob > F = 0.0344				
Hausman test	Chi2(9) = 13.33				
	Prob>chi2 = 0.1482				
Breusch - Pagan test	Chibar2(01) = 2.19				
	Prob > chibar2 = 0.0694				
Wooldridge test	F(1.22) = 12.720				
	Prob > F = 0.0017				
AR(2)	Pr > z = 0.442				
Hansen test	Prob > Chi2 = 0.893				
Sargen test	Prob > Chi2 = 0.543				

Note: *, **, *** represent statistical significance level at 10%, 5%, and 1%, respectively.

Table 3 indicates that the mean variance inflation factor (VIF) value is 1.47, well below the threshold of 10, suggesting that multicollinearity is not an issue for the remaining variables. Additionally, Table 3 presents the analysis results for the Pooled-OLS, FEM, REM, and FGLS models.

The R-squared values for the Pooled-OLS, FEM, and REM models are 50.52%, 50.28%, and 52.26%, respectively. These values suggest that the models explain over 50% of the variation in Lnzscore. The analysis results are consistent across the Pooled-OLS, FEM, and REM models. The variables CIR, LGR, and GDP are not statistically significant, whereas the other variables (TE, SIZE, LLP, DIV, INF, and COVIDTE) significantly impact the financial stability of banks. Specifically, TE and INF significantly negatively impact commercial banks' stability at the 10% level, while SIZE, LLP, DIV, and COVIDTE positively affect the dependent variable.

After comparing the regression results of the Pooled OLS, FEM, and REM models, the author was able to establish the best model. According to the F-test results, the FEM model is better than the Pooled-OLS model because Prob > F = 0.0344, which is less than 0.05. After that, to decide between the FEM and REM models, the Hausman test was run. The test results demonstrated that the REM model is the most appropriate choice, with a Prob > chi2 = 0.1482 value greater than 0.05.

4.3. Research Discussions

The Breusch-Pagan test was used to assess the REM model's heteroscedasticity. The test produced a chi-square value of 0.0694, more significant than the 0.05 significance level. Hence, heteroscedasticity is not present in the regression model. Nevertheless, the model encounters problems with autocorrelation, according to the Wooldridge test results. The Prob > F value of 0.0017 is lower than the approved threshold of 0.05. Therefore, to fix the autocorrelation problems, the Feasible Generalized Least Squares (FGLS) method will be used.

The parameter estimates of the fixed effects model can be skewed due to the endogeneity commonly found in panel data (Risman et al., 2021) and Chhaidar, Abdelhedi, and Abdelkafi (2023) all state that the generalized method of moments (GMM) with instrumental variables is the way to go when dealing with endogeneity, as the FGLS technique is unable to do so.

According to Chen et al. (2019), the GMM model confirms the rule of thumb in GMM, which states that the number of groups is greater than the number of instruments ($20 < 23$). Furthermore, according to Arellano and Bond (1991) there is no autocorrelation since the autoregressive (2) test's P-value is 0.442, more significant than 0.05. Furthermore, the Sargan test yields a P-value of 0.543, suggesting that the instrumental variables are adequate and suitable for dealing with endogeneity. According to the Hansen test, the model's instruments are appropriate, which produces a P-value of 0.893. To sum up, the GMM regression model is suitable, efficient, and very accurate since it satisfies all three requirements.

Adopting a Generalized Method of Moments (GMM) strategy, this study delves into the impact of certain variables on monetary stability. The GMM approach guarantees strong regression results by including endogenous variables.

This study focuses on technology investment and how it affects bank stability. The empirical results show that, with a statistical significance of 1%, technology investment (TE) significantly negatively impacts the financial stability of Vietnamese commercial banks. Contrary to previous investigations by Risman et al. (2021) and Ozili (2018), these results are in agreement with Nguyen-Thi-Huong et al. (2023) and Nguyen and Dang (2022). A decline in bank stability is associated with higher investment in technology elements, according to the SGMM estimation results. An increase in non-performing loans, especially in digital lending, may be caused by customers' excessive usage of internet-based transactions, according to research by Syed et al. (2021).

Consequently, banking stability declines significantly due to digital risks. Strict regulations for digital financial services often lack adequate consideration from banks and governments, especially in developing countries, as noted (Dadoukis et al., 2021). Business outcomes become more apparent during the initial stages of digital transformation; however, the substantial trade-off costs affect financial resources, as Nguyen-Thi-Huong et al. (2023) discussed. Thus, despite the rapid pace of digital transformation, significant investment in financial resources, human capital, and time is required to fully develop the information technology system.

The size of a bank (SIZE) shows a positive correlation with its financial stability, with a statistical significance of 1%. This finding aligns with the studies by Chen et al. (2019); Li et al. (2017) and Wang et al. (2021). According to Nguyen (2020) larger banks have lower bankruptcy costs and more stable growth rates, contributing to higher performance. Pham et al. (2021) add that larger banks are more stable since they enjoy lower bankruptcy costs and higher growth rates. Growing assets and expanding size thereby improve financial health and reduce bankruptcy risks.

Similarly, during the COVID-19 pandemic, Shabir et al. (2023) discovered that larger banks were more financially stable. According to Pham and Nguyen (2023) larger banks typically have more capital for risk management, making them safer than smaller ones. The effects of the COVID-19 pandemic were less severe on bigger banks, according to research by Demir and Danisman (2021). Consequently, large-scale banks have robust resources, making enhancing operations and responding to fluctuations easier, thereby maintaining financial stability. Moreover, these commercial banks can invest in modern technology that improves their financial services due to their substantial size.

Loan loss provisions (LLP) positively impact banking stability, which contradicts the initial hypothesis and differs from the findings of Fernández, González, and Suárez (2016) and Fu et al. (2014). The increase in bank stability with a higher loan provisioning ratio suggests that banks with solid resources are better equipped to handle credit risks when lending to customers. During the COVID-19 pandemic, increasing loan provisions became crucial. Policies on debt restructuring, extensions, and grace periods by the State Bank to support the economy have made it necessary

to increase short-term provisions, enabling banks to proactively manage lousy debt risks. But you should be very careful with high loan provisions, because a high LLP index could mean that the bank is dealing with big loss loans and spending a lot of money on provisions (Aristei & Gallo, 2019).

Income diversification (DIV) has a positive and significant relationship with a bank's stability. This finding is consistent with the studies by Wang et al. (2021) and Adem (2023). According to Dadoukis et al. (2021) a bank becomes more stable when it can diversify its revenue streams from interest and non-interest income activities, as observed in South Asian economies. These days, it's not enough to make money from lending; you must find other ways to bring in money. Commercial banks in Vietnam can benefit from income diversification in the face of rising competition and tightening global integration by cutting operational costs, avoiding possible expenses, and increasing overall income. During the COVID-19 pandemic, Rasyid and Bangun (2023) discovered that banks' financial performance is unaffected by non-interest income from fees and commissions. Despite disruptions to lending activity revenues, income diversification enabled banks to mitigate risk and maintain financial stability throughout the pandemic. Thus, this method improves banks' competitiveness and financial stability.

According to Shahid and Abbas (2012) and Fu et al. (2014) there is a favorable association between a bank's stability and the cost-to-income ratio (CIR). At the 5% significance level, an increases in the CIR variable correlates with a decrease in bank financial instability. Banks in today's technologically advanced world are always looking for new ways to improve the stability and efficiency of their operations through technology. The positive correlation between CIR and Lnzscore, according to Wang et al. (2021) shows that banks are effective at managing their costs. Thus, commercial banks can monitor and manage operational risks, guaranteeing steady operations and financial stability despite unforeseen macroeconomic swings.

The findings indicate no correlation between the loan growth rate (LGR) and financial stability. This result is consistent with the research but contradicts the studies by Ghenimi et al. (2017) and Koskei (2020). Although the income of commercial banks is primarily derived from loans (Pham et al., 2021) there is a growing focus on generating profits from non-interest activities to sustain and enhance operational efficiency (Minh & Thanh, 2020). Thus, while loan growth may positively impact, it does not significantly affect financial stability.

Inflation (INF) negatively impacts a bank's stability, with a statistical significance of 5%. This observation aligns with the research conducted by Shahid and Abbas (2012); Wang et al. (2021); Apulu et al. (2011) and Cevik (2024). The negative relationship suggests high inflation rates affect money value and reduce economic lending demand. Since lending significantly contributes to bank profits, this reduction in lending demand leads to increased bank instability. Technological investment during the COVID-19 period (COVIDTE) significantly bolstered the financial stability of Vietnamese banks, aligning with findings from Dadoukis et al. (2021); Nguyen-Thi-Huong et al. (2023) and Aloulou et al. (2024). The pandemic in Vietnam did not disrupt banking operations, including both credit and non-credit activities. Furthermore, the Vietnamese government's policies to support post-COVID-19 loans through interest rate adjustments and debt restructuring have contributed to stabilizing the banking system's financial condition. Table 3 shows that the macroeconomic factor GDP does not have statistical significance with the dependent variable, which aligns with the findings of Cevik (2024). The Vietnamese economy relies heavily on foreign investment and trade openness (Nguyen, 2020) making it susceptible to external shocks impacting macroeconomic performance and banking stability. To mitigate systemic risks, the Vietnamese banking system has taken precautionary measures, resulting in research findings that suggest economic growth has a positive but insignificant effect on financial stability. For instance, during the COVID crisis, the Vietnamese banking system demonstrated impressive growth and breakthroughs despite the decline in GDP.

The results show many essential insights based on the value of discoveries by making these links more straightforward: While investments in technology may initially unsettle banks, they help them weather crises better. This is the first trade-off in digital transformation. Different methods need to be used for different bank sizes because digital transformation strategies need to be tailored to each bank size. This is because bigger banks have more room

to maneuver. The strategic importance of cost efficiency and income diversification is based on the fact that financial institutions that utilize technology to control expenses and diversify their revenue streams are better able to weather economic storms and the costs associated with digital transformation. Digital investments can have different effects on the stabilizing effect of macroeconomic factors based on bank stability, which depends on the state of the economy. This shows how important it is to be flexible when things are uncertain.

Digital transformation brings vital benefits in resilience and adaptation but also raises hazards, as these relationships show. Technology investment has complicated and multi-dimensional impacts on bank stability. This sophisticated knowledge in developing economies like Vietnam benefits politicians and bank managers who are crafting plans to balance immediate dangers and potential rewards.

5. CONCLUSIONS AND POLICY RECOMMENDATIONS

5.1. Conclusions

From 2012 to 2023, this study looks at how technology investment affected the financial stability of commercial banks in Vietnam. Investment in technology improves banks' operational efficiency and competitiveness, but there are dangers that it can harm financial stability, at least in the near term, according to the results. The analysis led to the following important conclusions. More significant technological investments negatively impact the financial health of Vietnamese banks, according to the research. This is especially true in the early phases of digital transformation when massive implementation costs and operational risks threaten to shake up the budget. Larger banks and those with various revenue streams tend to be more financially stable, which is a positive effect of bank size and diversity. Diversifying your income makes you less reliant on traditional loan activities, which makes funding sources more reliable. Larger institutions also benefit from lower bankruptcy risks and better risk management. Effects of Loan Loss Provisions: More financial stability is linked to more extensive loan loss provisions, which goes against what was formerly believed. One possible explanation is that banks were better able to handle credit risk after the COVID-19 epidemic because they were proactive in managing risk and had preparations for any undesirable debts. During COVID-19, inflation harmed bank stability, reducing lending demand and profitability. Banks swiftly adjusted to the changing climate and used digital tools to increase resilience, thanks to investments in technology during COVID-19, which had a favorable effect on financial stability. This study enhances our understanding of the complex relationship between technological investment and financial stability in Vietnamese banks. The research shows a complex relationship between the two variables, with smaller banks having the most trouble bearing the early stability costs associated with technology investment. Nevertheless, technology serves as an essential instrument for upholding continuity and adjusting to emergencies, as demonstrated by the long-term resilience provided by digitalization, particularly during the COVID-19 pandemic.

5.2. Policy Recommendations

A lot has been accomplished on critical pillars, like changing awareness, perfecting institutions, updating infrastructure, and applying applications, thanks to the banking industry's persistent efforts in digital transformation over the past few past years to utilize data for the creation of digital banking models while simultaneously guaranteeing safety and security. The latest digital innovations and the fruits of the Fourth Industrial Revolution are also heavily utilized to create new goods and services and cater to the ever-increasing demands of consumers and companies alike. This study explores the relationship between technology investments and the stability of Vietnamese banks. Data analysis reveals that digital transformation negatively affects the financial stability of these banks. Based on these findings, the researcher provides the following recommendations for commercial banks and regulatory authorities:

First, technology investment reduces the financial stability of Vietnamese banks. Technology investment often requires large amounts of capital, long technology conversion times, and high maintenance and equipment upgrade

costs, increasing the bank's risk level in the short term. Therefore, banks must consider and develop effective investment policies and roadmaps to use capital reasonably and enhance financial stability. Banks should approach technology investments strategically, focusing on mitigating short-term risks and costs. Planning thoroughly for technological investments is crucial, with a focus on long term and desire to minimize operational disruptions in the short term. Financial institutions should also deal with the dangers of digital transformation by allocating enough funds to risk management and cybersecurity. Banks with more significant assets can better withstand economic shocks; therefore, increasing their size and capital buffers is a good idea. If banks want to be more stable and better able to absorb risks, they should work on improving their capital adequacy and diversifying their assets. Regulatory bodies should promote bank mergers and acquisitions to strengthen the industry and establish more reliable financial institutions. Finally, investing in, upgrading, and developing electronic payment infrastructure and credit information infrastructure to guarantee continuous, smooth, and secure operations, meeting the varied and quickly growing payment needs of organizations and individuals in the economy through digital means (online banking, payment via the Internet, mobile phones, contactless payments, etc.); evolving the banking sector's digital infrastructure to align with development trends. Facilitate the seamless and continuous provision of services to individuals and businesses by integrating and connecting the National Public Service Portal, the Administrative Procedure Information System, and the Public Service Portals of ministries, branches, and municipalities. This will allow for the seamless reception, registration, use, and payment of services, among other activities, to advocate for improving credit institutions and the State Bank's information systems to boost competitiveness and, over time, international competitiveness. So, for financial institutions to run smoothly and follow global best practices, they must encourage their use of technology. A more robust technological application can benefit operations, management, risk analysis, and prevention. To meet the needs of credit institutions in terms of size, complexity, management, and operations, it is crucial to constantly improve and expand the core banking system.

Second, commercial banks strive to increase asset size and expand operations to strengthen financial capacity, increase brand recognition, create solid customer trust, improve competitiveness, and bring high profits. From there, banks can respond to shocks from the internal and external environment of the bank. Additionally, the ratio of operating costs to income measures the effectiveness of a bank's management capacity, so maintaining a human resource management policy appropriate to each bank's size and financial capacity will contribute to reducing financial instability. Financial institutions should broaden their revenue streams beyond interest by entering new markets for fee-based services, financial consulting, and collaborations with FinTech firms. More reliable and varied revenue streams will be produced, and reliance on conventional loan activities will be diminished. Banks should effectively manage sufficient loan loss provisions to prepare for potential credit risks. Over-provisioning should be avoided to avoid putting an undue burden on profitability. Financial institutions, particularly those facing economic shocks like the COVID-19 epidemic, would do well to implement advanced credit risk assessment methods to foresee and control unacceptable debts. Finally, human resource development should be emphasized to fulfill the banking industry's transformation needs. To adapt to the demands of digital transformation, the banking industry needs regulations that will help it recruit and keep top talent. To build and improve banking culture in Vietnam, it is necessary to strengthen cooperation, encourage learning and research on digital transformation experiences from international organizations and countries, and then apply these lessons reasonably, effectively, and appropriately to the practical conditions of Vietnamese banking operations. Emphasize the need for security and safety measures in the workplace. To better prevent and regulate crime and guarantee security, safety, and people's legal rights and interests when offering services in the digital environment, we must enhance coordination with relevant ministries, such as the Ministry of Public Security and the Ministry of Information and Communications.

Finally, diversifying products and services helps banks improve financial capacity. Therefore, cooperation should be promoted with companies in the FinTech sector, linked products and services developed, and cross-sell products to expand distribution channels and make it easier for customers to access banking services. In addition,

diversification also helps banks reduce their dependence on revenue from lending activities. Therefore, banks can avoid interest rate fluctuations and credit quality risks. From there, the bank can maintain stability within it. Financial institutions should devise plans to lessen the blow of falling lending demand and profitability in an inflationary climate. Regulatory agencies can bolster the strength of the banking industry by considering monetary measures that stabilize inflation. Make the most of the tools Post-COVID-19: The significance of digital transformation for future resilience is shown by the positive impact of technology investments during the COVID-19 period. To stay ahead of the dynamic industry, banks must keep pouring money into innovation, especially for online banking, digital payments, and AI-powered customer service. Due to the trend of rising high-tech crime with many new and increasingly complex tactics, it is necessary to strengthen inspection and monitoring systems, analyze data to guarantee the safety and security of the system, and prevent and combat crime and money laundering.

Limitations and Future Research: This study has some limitations, but it does provide valuable insights into how technology investment affects financial stability in Vietnamese commercial banks. The research only looked at the banking industry in Vietnam, so its results might not apply to other developing or established countries. Variations in regulatory frameworks, economic situations, and technical development among nations could impact the connection between tech investment and financial stability. The research makes use of data that is publicly available and spans the years 2012 through 2023. This timeline does capture significant trends in financial stability and technological investment, but since digital banking is constantly evolving, more frequent updates and analysis may be needed to fully understand the impact of new technologies like blockchain and AI. Future research should prioritize the following areas to circumvent these limitations and investigate the relationship between financial stability and technical investment: The impact of technology investment on monetary stability in developing and developed economies might be the subject of future studies. This would be useful for two reasons: first, to learn how different legal and economic frameworks affect digital transformation, and second, to find out whether the findings from Vietnam apply to other contexts. Future research could expand the analysis to include other areas where emerging technologies are still in their early stages, such as open banking, artificial intelligence, and blockchain, and examine the effects of these technologies' adoption on financial stability in the short and long term. Interviews with bank managers, legislators, and IT specialists are examples of qualitative research methodologies that could help shed light on the difficulties and solutions associated with balancing spending money on technology and keeping the bank solvent. Incorporating this would round out the quantitative results and provide a fuller picture of digital change.

Funding: This research is supported by Ho Chi Minh University of Banking (Grant number: 2163/QĐ-ĐHNH).
Institutional Review Board Statement: The Ethical Committee of the Ho Chi Minh University of Banking, Vietnam has granted approval for this study on 15 January 2023 (Ref. No. 2879 /QĐ-ĐHNH).
Transparency: The author states that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Data Availability Statement: Nguyen Minh Nhat can provide the supporting data of this study upon a reasonable request.
Competing Interests: The author declares that there are no conflicts of interests regarding the publication of this paper.

REFERENCES

Acar, O., & Çıtak, Y. E. (2019). Fintech integration process suggestion for banks. *Procedia Computer Science, 158*, 971-978. https://doi.org/10.1016/j.procs.2019.09.138

Adem, M. (2023). Impact of income diversification on bank stability: A cross-country analysis. *Asian Journal of Accounting Research, 8*(2), 133-144.

Ahamed, M. M., & Mallick, S. K. (2019). Is financial inclusion good for bank stability? International evidence. *Journal of Economic Behavior & Organization, 157*, 403-427. https://doi.org/10.1016/j.jebo.2017.07.027

Aloulou, M., Grati, R., Al-Qudah, A. A., & Al-Okaily, M. (2024). Does FinTech adoption increase the diffusion rate of digital financial inclusion? A study of the banking industry sector. *Journal of Financial Reporting and Accounting*, *22*(2), 289-307. http://dx.doi.org/10.1108/JFRA-05-2023-0224

An, J., & Rau, R. (2021). Finance, technology and disruption. *The European Journal of Finance*, *27*(4-5), 334-345. https://doi.org/10.1080/1351847X.2019.1703024

Apulu, I., Latham, A., & Moreton, R. (2011). Factors affecting the effective utilisation and adoption of sophisticated ICT solutions: Case studies of SMEs in Lagos, Nigeria. *Journal of Systems and Information Technology*, *13*(2), 125-143. https://doi.org/10.1108/13287261111135972

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *The Review of Economic Studies*, *58*(2), 277-297. https://doi.org/10.2307/2297968

Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of error-components models. *Journal of Econometrics*, *68*(1), 29-51. https://doi.org/10.1016/0304-4076(94)01642-D

Aristei, D., & Gallo, M. (2019). Loan loss provisioning by Italian banks: Managerial discretion, relationship banking, functional distance and bank risk. *International Review of Economics & Finance*, *60*, 238-256. https://doi.org/10.1016/j.iref.2018.10.022

Ashraf, B. N. (2017). Political institutions and bank risk-taking behavior. *Journal of Financial Stability*, *29*, 13-35. https://doi.org/10.1016/j.jfs.2017.01.004

Bai, G., & Elyasiani, E. (2013). Bank stability and managerial compensation. *Journal of Banking & Finance*, *37*(3), 799-813. https://doi.org/10.1016/j.jbankfin.2012.10.026

Banna, H., & Alam, M. R. (2021). Impact of digital financial inclusion on ASEAN banking stability: Implications for the post-Covid-19 era. *Studies in Economics and Finance*, *38*(2), 504-523. https://doi.org/10.1108/SEF-09-2020-0388

Berg, T., Burg, V., Gombović, A., & Puri, M. (2020). On the rise of fintechs: Credit scoring using digital footprints. *The Review of Financial Studies*, *33*(7), 2845-2897. https://doi.org/10.1093/rfs/hhz099

Brynjolfsson, E. (1993). The productivity paradox of information technology. *Communications of the ACM*, *36*(12), 66-77. https://doi.org/10.1145/163298.163309

Cevik, S. (2024). The dark side of the moon? Fintech and financial stability. *International Review of Economics*, *71*(2), 421-433. https://doi.org/10.1007/s12232-024-00449-8

Chae, H.-C., Koh, C. E., & Prybutok, V. R. (2014). Information technology capability and firm performance: Contradictory findings and their possible causes. *MIS Quarterly*, *38*(1), 305-326. https://doi.org/10.25300/misq/2014/38.1.14

Chen, J., Zhang, K., Zhou, Y., Liu, Y., Li, L., Chen, Z., & Yin, L. (2019). Exploring the development of research, technology and business of machine tool domain in new-generation information technology environment based on machine learning. *Sustainability*, *11*(12), 1-17. https://doi.org/10.3390/su11123316

Chhaidar, A., Abdelhedi, M., & Abdelkafi, I. (2023). The effect of financial technology investment level on European banks' profitability. *Journal of the Knowledge Economy*, *14*(3), 2959-2981. https://doi.org/10.1007/s13132-022-00992-1

Chiorazzo, V., Milani, C., & Salvini, F. (2008). Income diversification and bank performance: Evidence from Italian banks. *Journal of Financial Services Research*, *33*(3), 181-203. https://doi.org/10.1007/s10693-008-0029-4

Crockett, A. (1996). The theory and practice of financial stability. *De Economist*, *144*(4), 531-568. https://doi.org/10.1007/BF01371939

Dadoukis, A., Fiaschetti, M., & Fusi, G. (2021). IT adoption and bank performance during the Covid-19 pandemic. *Economics Letters*, *204*, 1-4. https://doi.org/10.1016/j.econlet.2021.109904

Demir, E., & Danisman, G. O. (2021). Banking sector reactions to COVID-19: The role of bank-specific factors and government policy responses. *Research in International Business and Finance*, *58*, 101508. https://doi.org/10.1016/j.ribaf.2021.101508

Duong, B. M. (2017). The impact of technology on the competitiveness of commercial banks. *Vietnam Trade and Industry Review*, *27*(1), 1-9.

Fernández, A. I., González, F., & Suárez, N. (2016). Banking stability, competition, and economic volatility. *Journal of Financial Stability*, *22*, 101-120. https://doi.org/10.1016/j.jfs.2016.01.005

Feyen, E., Gispert, T. A., Kliatskova, T., & Mare, D. S. (2021). Financial sector policy response to COVID-19 in emerging markets and developing economies. *Journal of Banking & Finance, 133*, 106184. https://doi.org/10.1016/j.jbankfin.2021.106184

Fratzscher, M., König, P. J., & Lambert, C. (2016). Credit provision and banking stability after the great financial crisis: The role of bank regulation and the quality of governance. *Journal of International Money and Finance, 66*, 113-135. https://doi.org/10.1016/j.jimonfin.2016.02.015

Fu, X. M., Lin, Y. R., & Molyneux, P. (2014). Bank competition and financial stability in Asia pacific. *Journal of Banking & Finance, 38*, 64-77. https://doi.org/10.1016/j.jbankfin.2013.09.012

Ghenimi, A., Chaibi, H., & Omri, M. A. B. (2017). The effects of liquidity risk and credit risk on bank stability: Evidence from the MENA region. *Borsa Istanbul Review, 17*(4), 238-248. https://doi.org/10.1016/j.bir.2017.05.002

Gupta, S. D., Raychaudhuri, A., & Haldar, S. K. (2018). Information technology and profitability: Evidence from Indian banking sector. *International Journal of Emerging Markets, 13*(5), 1070-1087. https://doi.org/10.1108/IJoEM-06-2017-0211

Houston, J. F., Lin, C., Lin, P., & Ma, Y. (2010). Creditor rights, information sharing, and bank risk taking. *Journal of Financial Economics, 96*(3), 485-512. https://doi.org/10.1016/j.jfineco.2010.02.008

Indrajit, A., Van Loenen, B., Ploeger, H., & Van Oosterom, P. (2020). Developing a spatial planning information package in ISO 19152 land administration domain model. *Land Use Policy, 98*, 1-15. https://doi.org/10.1016/j.landusepol.2019.104111

Kasman, S., & Kasman, A. (2015). Bank competition, concentration and financial stability in the Turkish banking industry. *Economic Systems, 39*(3), 502-517. https://doi.org/10.1016/j.ecosys.2014.12.003

Khan, M. S., Scheule, H., & Wu, E. (2017). Funding liquidity and bank risk-taking. *Journal of Banking & Finance, 82*, 203-216. https://doi.org/10.1016/j.jbankfin.2016.09.005

Koohang, A., Nord, J., Ooi, K., Tan, G., Al-Emran, M., Aw, E., . . . Dennis, C. (2023). Shaping the metaverse into reality: Multidisciplinary perspectives on opportunities, challenges, and future research. *Journal of Computer Information Systems, 63*(3), 735-765. https://doi.org/10.1080/08874417.2023.2165197

Koskei, L. (2020). Non-performing loans and banks' financial stability in Kenya; Evidence from commercial banks. *Asian Journal of Economics, Business and Accounting, 15*(3), 44-52.

Laeven, L., & Levine, R. (2009). Bank governance, regulation and risk taking. *Journal of Financial Economics, 93*(2), 259-275. https://doi.org/10.1016/j.jfineco.2008.09.003

Leckson-Leckey, G. T., Osei, K. A., & Harvey, S. K. (2011). Investments in information technology (IT) and bank business performance in Ghana. *International Journal of Economics and Finance, 3*(2), 133-142. http://doi.org/10.5539/ijef.v3n2p133

Li, X., Tripe, D. W., & Malone, C. B. (2017). Measuring bank risk: An exploration of z-score. *Available at SSRN 2823946*.

Li, Y., Spigt, R., & Swinkels, L. (2017). The impact of FinTech start-ups on incumbent retail banks' share prices. *Financial Innovation, 3*(26), 1-16. https://doi.org/10.1186/s40854-017-0076-7

Luo, D., Luo, M., & Lv, J. (2022). Can digital finance contribute to the promotion of financial sustainability? A financial efficiency perspective. *Sustainability, 14*(7), 3979. https://doi.org/10.3390/su14073979

Martín-Oliver, A., & Salas-Fumás, V. (2008). The output and profit contribution of information technology and advertising investments in banks. *Journal of Financial Intermediation, 17*(2), 229-255. https://doi.org/10.1016/j.jfi.2007.10.001

Minh, S., & Thanh, T. (2020). Analysis of the impact from non-interest income to the operational efficiency of commercial banks in Vietnam. *Management Science Letters, 10*(2), 455-462. https://doi.org/10.5267/j.msl.2019.8.025

Mishkin, F. S. (1999). Global financial instability: Framework, events, issues. *Journal of Economic Perspectives, 13*(4), 3-20. https://doi.org/10.1257/jep.13.4.3

Nga, T. T. T. (2022). Information technology investment and bank risk-taking: A case study of commercial banks in Vietnam. *HCMCOUJS - Economics and Business Administration, 18*(2), 89-103.

Ngalawa, H., Tchana, F. T., & Viegi, N. (2016). Banking instability and deposit insurance: The role of moral hazard. *Journal of Applied Economics, 19*(2), 323-350. https://doi.org/10.1016/S1514-0326(16)30013-7

Nguyen-Thi-Huong, L., Nguyen-Viet, H., Nguyen-Phuong, A., & Van Nguyen, D. (2023). How does digital transformation impact bank performance? *Cogent Economics & Finance, 11*(1), 2217582. https://doi.org/10.1080/23322039.2023.2217582

Nguyen, D. T., Tran, V. D., & Lu, H. C. (2022). The impact of technological advances on Vietnamese banking. *Financial and Monetary Market Review, 12*(2), 1-5.

Nguyen, Q. K., & Dang, V. C. (2022). The effect of FinTech development on financial stability in an emerging market: The role of market discipline. *Research in Globalization, 5*, 1-15. https://doi.org/10.1016/j.resglo.2022.100105

Nguyen, V. (2020). Human capital, capital structure choice and firm profitability in developing countries: An empirical study in Vietnam. *Accounting, 6*(2), 127-136. https://doi.org/10.5267/j.ac.2019.11.003

Norwegian Central Bank. (2003). *Financial stability report*. Retrieved from https://www.norges-bank.no

Ozili, P. K. (2018). Banking stability determinants in Africa. *International Journal of Managerial Finance, 14*(4), 462-483. https://doi.org/10.1108/IJMF-01-2018-0007

Pham, M. H., & Nguyen, N. M. (2023). Bank funding diversity, risk and profitability: Evidence from Vietnam in the context of the Covid-19 pandemic. *Cogent Business & Management, 10*(1), 2191305. https://doi.org/10.1080/23311975.2023.2191305

Pham, T. T., Dao, L. K. O., & Nguyen, V. C. (2021). The determinants of bank's stability: A system GMM panel analysis. *Cogent Business & Management, 8*(1), 1963390. https://doi.org/10.1080/23311975.2021.1963390

Rasyid, R., & Bangun, N. (2023). Liquidity risk, income diversification, and bank financial performance. *International Journal of Application on Economics and Business, 1*(4), 2660-2669. https://doi.org/10.24912/ijaeb.v1i4.2660-2669

Risman, A., Mulyana, B., Silvatika, B., & Sulaeman, A. (2021). The effect of digital finance on financial stability. *Management Science Letters, 11*(7), 1979-1984. https://dx.doi.org/10.5267/j.msl.2021.3.012

Scott, S. V., Van Reenen, J., & Zachariadis, M. (2017). The long-term effect of digital innovation on bank performance: An empirical study of SWIFT adoption in financial services. *Research Policy, 46*(5), 984-1004. https://doi.org/10.1016/j.respol.2017.03.010

Shabir, M., Jiang, P., Wang, W., & Işık, Ö. (2023). COVID-19 pandemic impact on banking sector: A cross-country analysis. *Journal of Multinational Financial Management, 67*, 100784. https://doi.org/10.1016/j.mulfin.2023.100784

Shahid, M. A., & Abbas, Z. (2012). Financial stability of Islamic banking in Pakistan: An empirical study. *African Journal of Business Management, 6*(10), 3706-3714.

Syed, A. A., Ahmed, F., Kamal, M. A., & Trinidad Segovia, J. E. (2021). Assessing the role of digital finance on shadow economy and financial instability: An empirical analysis of selected South Asian countries. *Mathematics, 9*(23), 3018. https://doi.org/10.3390/math9233018

Thu, T. T. T., & An, H. T. P. (2016). The impact of technology on the competitiveness of commercial banks. *Journal of Science Technology and Food Processing, 9*(1), 137-146.

Tippins, M. J., & Sohi, R. S. (2003). IT competency and firm performance: Is organizational learning a missing link? *Strategic Management Journal, 24*(8), 745-761. https://doi.org/10.1002/smj.337

Vo, V. X., & Tran, M. T. P. (2015). Profit and risk from income diversification of Vietnamese commercial banks. *Journal of Economic Development, 26*(8), 54-70.

Von Hagen, J., & Ho, T. k. (2007). Money market pressure and the determinants of banking crises. *Journal of Money, Credit and Banking, 39*(5), 1037-1066. https://doi.org/10.1111/j.1538-4616.2007.00057.x

Wagner, W. (2007). The liquidity of bank assets and banking stability. *Journal of Banking & Finance, 31*(1), 121-139. https://doi.org/10.1016/j.jbankfin.2005.07.019

Wang, R., Liu, J., & Luo, H. (2021). Fintech development and bank risk-taking in China. *The European Journal of Finance, 27*(4-5), 397-418. https://doi.org/10.1080/1351847X.2020.1805782

Williams, B. (2014). Bank risk and national governance in Asia. *Journal of Banking & Finance, 49*, 10-26. https://doi.org/10.1016/j.jbankfin.2014.08.014