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Digital transformation, income diversification, and bank stability: Evidence from an emerging economy

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ABSTRACT

This study examines the impact of digital transformation on the financial stability of commercial banks, with a particular focus on the moderating role of income diversification in this relationship. Using a panel dataset of 22 Vietnamese commercial banks over the period 2010–2023, this study applies the System Generalized Method of Moments estimator to account for endogeneity, dynamic effects, and unobserved heterogeneity. Digital transformation is measured through a text-mining approach based on data extracted from annual reports, while financial stability is assessed using the Z-score. Income diversification is proxied by the share of non-interest income in total revenue. The results indicate that digital transformation and income diversification independently and significantly enhance financial stability. Furthermore, the interaction between the two is statistically significant, suggesting that the stability gains from digital initiatives are amplified when banks maintain a more diversified income structure. Component-level analysis further reveals that investments in data analytics and payment infrastructure are key contributors to resilience, while fintech adoption and cybersecurity disclosures do not show significant effects. These findings highlight the importance of aligning digital transformation with income diversification to strengthen bank stability. The study offers practical insights for bank managers and policymakers, emphasizing the need for targeted digital investments and supportive regulatory frameworks to ensure sustainable innovation in the banking sector.

Contribution/Originality: This study introduces a novel text-mining method to measure digital transformation and empirically explores the moderating role of income diversification in its effect on bank stability. Using panel data from Vietnam, it offers new evidence on how technology–strategy alignment enhances financial resilience in emerging markets.

1. INTRODUCTION

The banking sector in emerging economies is experiencing a significant shift due to the rapid integration of digital technologies. Innovations such as blockchain, big data analytics, artificial intelligence (AI), and cloud computing are reshaping traditional banking models, improving service delivery, reducing operational costs, and expanding financial inclusion. These advancements have enabled banks to enhance customer service and strengthen internal control mechanisms. However, they also introduce new challenges, particularly in the form of cybersecurity threats, data privacy issues, and the potential for operational disruptions, which may adversely affect financial stability.

The interaction between digital transformation and financial stability has garnered increasing attention in both academic and policy circles. Digitalization enables real-time risk monitoring, automates compliance processes, and creates new opportunities for non-interest income, potentially enhancing the resilience of financial institutions. However, heavy reliance on digital infrastructure may also increase vulnerabilities, especially in countries with limited regulatory oversight or uneven technological readiness. The shift toward non-traditional income sources and greater investment in fintech partnerships can introduce new risks, such as technology dependence, reputational risks, and market volatility.

This duality presents a significant challenge for commercial banks, especially in emerging markets like Vietnam, where the pace of digital adoption has accelerated in recent years. Vietnamese banks have made substantial investments in digital banking infrastructure, mobile applications, and electronic payment systems, supported by government initiatives aimed at promoting financial innovation. While these developments are promising, they have also coincided with rising concerns about systemic risk and financial fragility, particularly in the wake of global economic uncertainties and technological disruptions. Although the issue is becoming increasingly important, there is still limited empirical research examining the link between digital transformation and financial stability in the context of Vietnamese banks.

This study contributes to the literature by empirically examining the effects of digital transformation on the financial stability of Vietnamese commercial banks over the 2010–2023 period, with a particular focus on the moderating role of income diversification a dimension that remains underexplored in digital finance research. By combining a novel text-mining technique that quantifies digital transformation from narrative disclosures in annual reports with the System Generalized Method of Moments (System GMM) estimator, the study provides robust evidence on how the interaction between technology adoption and income structure shapes bank resilience. The results offer practical implications for strategy alignment, risk management, and regulatory design in emerging financial systems, where both digitalization and diversification are central to sustainable stability.

2. LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

The banking industry has experienced substantial changes driven by advancements in digital technology, particularly in emerging markets where financial institutions seek to expand access, optimize operational efficiency, and enhance risk management. Digital transformation has emerged as a key strategic focus, enabling banks to streamline processes, reduce transaction costs, and deliver more advanced financial services. However, its implications for financial stability remain uncertain, as rapid technological adoption introduces new risks such as cybersecurity threats, regulatory challenges, and earnings volatility. Understanding whether digital transformation strengthens or undermines financial stability is essential, especially in economies where traditional banking models still dominate and regulatory frameworks struggle to keep pace with innovation.

Digital transformation in the banking sector involves a wide array of technological innovations, including automation, blockchain, big data analytics, AI, and cloud computing. These technologies enhance operational efficiency by reducing transaction costs, improving risk management, and enabling real-time decision-making (Begenau, Farboodi, & Veldkamp, 2018). The use of AI and machine learning in credit scoring and fraud detection allows banks to make faster and more accurate lending decisions, thereby improving credit portfolio quality and reducing default risks (Fuster, Plosser, Schnabl, & Vickery, 2019). The integration of blockchain technology further enhances security and transparency in transactions, minimizing fraud and operational inefficiencies (Chiu & Koeppl, 2019). However, the increased reliance on digital infrastructure and fintech partnerships also exposes banks to operational and systemic risks, including cybersecurity threats, data privacy concerns, and technological disruptions. The rapid expansion of digital banking also raises regulatory challenges, as many emerging markets lack comprehensive legal frameworks to govern fintech activities, potentially leading to financial instability (Uddin, Ali, & Hassan, 2020).

The link between digital transformation and financial stability can be interpreted through contrasting theoretical perspectives. Financial Intermediation Theory (Diamond, 1984) suggests that banks play a key role in mitigating information asymmetry and efficiently allocating capital. Digital transformation enhances this function by improving credit risk assessment, automating lending decisions, and enabling real-time financial monitoring. Incorporating AI and big data analytics improves fraud detection and increases operational efficiency, thereby reducing banks' vulnerability to systemic risks (Fuster et al., 2019).

Additionally, digital banking services lower transaction costs and expand financial inclusion, stabilizing cash flows and improving liquidity management (Begenau et al., 2018). However, Disruptive Innovation Theory (Christensen, 1997) presents a contrasting view, arguing that technological innovation introduces instability by fundamentally altering traditional business models.

The rapid expansion of fintech firms and digital financial services has increased competition, reducing banks' market power and potentially eroding profit margins (Chiu & Koeppl, 2019). Moreover, excessive reliance on algorithmic credit scoring and automated lending can lead to procyclicality, amplifying financial instability during economic downturns (Brunnermeier, 2009).

Empirical studies present mixed findings regarding the impact of digital transformation on bank stability. On the one hand, technological advancements allow banks to improve credit risk assessment, operational efficiency, and fraud detection, contributing to overall financial resilience. The integration of machine learning in credit modeling reduces default risks and enhances asset quality, reinforcing financial stability (Fuster et al., 2019). Fintech-driven competition has also pressured traditional banks to enhance customer service and adopt more cost-efficient models, indirectly strengthening the sector's stability (Chiu & Koeppl, 2019).

On the other hand, excessive reliance on digitalization can introduce new vulnerabilities. The increasing dependence on third-party cloud computing, external fintech providers, and interconnected digital infrastructures exposes banks to greater cybersecurity risks and potential system-wide disruptions (Uddin et al., 2020). Additionally, the rapid expansion of non-bank digital financial services has contributed to regulatory fragmentation, increasing systemic risk due to unclear oversight and financial interdependencies study by Beccalli (2007) found that while IT investment improves operational efficiency, its impact on profitability and stability is not guaranteed, as high implementation costs and shifting regulatory landscapes may erode expected gains. Similarly, Ho and Mallick (2010) argue that while digitalization reduces transactional costs, it also intensifies competitive pressure, potentially undermining profit margins. This duality raises the first research hypothesis.

H_1: Digital transformation enhances the financial stability of commercial banks.

The impact of digital transformation on financial stability is not uniform across all banking institutions, as various moderating factors influence the magnitude and direction of this relationship. One critical factor is the regulatory environment; well-developed prudential regulations, cybersecurity policies, and fintech oversight can help mitigate systemic risks, whereas regulatory gaps may expose banks to financial vulnerabilities and compliance uncertainties (Arner, Barberis, & Buckley, 2017). Similarly, technological readiness determines whether digital transformation enhances resilience or introduces new risks; banks with advanced IT infrastructure and robust cybersecurity measures can better integrate digital technologies, while those with underdeveloped digital capabilities may face heightened cyber threats, operational inefficiencies, and disruptions to core banking activities (Chiu & Koeppl, 2019; Uddin et al., 2020).

The competitive landscape also plays a significant role while increased competition from fintech firms can drive traditional banks toward operational efficiency and innovation, excessive market pressure can reduce profitability, increase cost burdens, and encourage risk-taking behaviors that may undermine financial stability (Boot, Hoffmann, Laeven, & Ratnovski, 2021; Ho & Mallick, 2010). Additionally, risk management capabilities influence the extent to which digital transformation stabilizes or destabilizes banks; institutions that leverage AI-driven risk assessment, big data analytics, and fraud detection technologies are more likely to strengthen their financial position, whereas those

lacking adequate internal controls may be more vulnerable to cyber fraud and systemic shocks (Fuster et al., 2019; Laeven, Levine, & Michalopoulos, 2015).

An important factor in understanding the relationship between digital transformation and bank stability is income diversification. Traditional banking models in many emerging markets rely heavily on interest-based income, making them vulnerable to interest rate fluctuations and economic cycles (Demirgüç-Kunt & Huizinga, 2010). Digital transformation has enabled banks to expand non-interest revenue streams, including transaction fees, wealth management services, and fintech partnerships, potentially enhancing financial resilience (Sanya & Wolfe, 2011). The Modern Portfolio Theory (Markowitz, 1952) supports this view, suggesting that diversifying income sources reduces overall financial risk, as revenue fluctuations from different activities are less correlated than those derived solely from lending operations. Studies indicate that banks with diversified revenue models exhibit lower earnings volatility and stronger financial performance (DeYoung & Roland, 2001; Köhler, 2014). Furthermore, digital transformation facilitates the expansion of fee-based banking services, allowing banks to reduce reliance on traditional net interest margins and stabilize income streams (Valverde & Fernández, 2007).

However, income diversification does not always lead to greater financial stability. The Too-Much-Diversification Hypothesis (Stiroh, 2006) suggests that over-diversifying, particularly into non-traditional banking areas such as trading and investment banking, can increase revenue volatility rather than reduce it. Banks shifting their income structures toward transaction-based services may become more vulnerable to fluctuations in financial markets, regulatory uncertainties, and competitive pressures (Lepetit, Nys, Rous, & Tarazi, 2008; Stiroh & Rumble, 2006). Empirical studies have found that non-interest income sources are often more cyclical and sensitive to financial shocks, making them less stable than traditional lending activities (DeYoung & Torna, 2013). Abuzayed, Al-Fayoumi, and Molyneux (2018) confirm that while income diversification improves profitability, it may also lead to excessive risk-taking, particularly when banks lack effective risk management strategies. These contrasting findings give rise to the second hypothesis of this study.

H_2: Income diversification strengthens financial stability by reducing earnings volatility.

The interaction between digital transformation and income diversification remains a key area of study. While digital transformation enables banks to diversify revenue sources, the stability implications depend on how well banks manage the risks associated with new business lines. Khattak, Ali, Azmi, and Rizvi (2023) provide evidence that digital transformation strengthens financial stability when banks successfully expand non-interest income while maintaining robust risk controls.

However, their study also highlights that banks failing to manage revenue volatility from new digital services may face greater financial instability. Mehmood, Shah, Azhar, and Rasheed (2014) argue that in highly digitalized financial systems, the benefits of technology-driven diversification outweigh the risks, particularly when supported by regulatory oversight and risk-adjusted capital buffers. This theoretical and empirical basis supports the third hypothesis.

H_3: Income diversification amplifies the positive effect of digital transformation on financial stability.

3. METHODOLOGY

This study employs a balanced panel dataset of 22 Vietnamese commercial banks over the period 2010–2023. The data are extracted from audited financial statements, annual reports, and macroeconomic indicators published by banks and regulatory institutions. This timeframe is selected to capture the evolution of digital transformation in the Vietnamese banking sector and the subsequent acceleration of digitalization, particularly during the COVID-19 pandemic.

To empirically assess the relationships among the variables, three econometric models are specified. The first model evaluates the direct effect of digital transformation on bank stability. The second model examines the influence

of income diversification on stability. The third model introduces an interaction term between digital transformation and income diversification to test the potential moderating effect. The baseline models are as follows:

$$STB_{i,t} = \beta_0 + \beta_2 DT_{i,t} + \beta_3 CT_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \quad (1)$$

$$STB_{i,t} = \beta_0 + \beta_2 DIV_{i,t} + \beta_3 CT_{i,t} + \mu_i + \delta_t + \varepsilon_{i,t} \quad (2)$$

$$STB_{i,t} = \beta_0 + \beta_2 DT_{i,t} * DIV_{i,t} + \beta_3 CT + \mu_i + \delta_t + \varepsilon_{i,t} \quad (3)$$

Where superscripts i denote the bank, and t denotes the year; β denotes slope; $\varepsilon_{i,t}$ is the error term; δ_t and μ_i represents time-fixed effects and firm-fixed effects, respectively.

Bank stability (STB) in this study is assessed using the Z-score, a widely recognized metric for evaluating a bank's resilience. Consistent with the approaches of Li, Tripe, and Malone (2017) and Khattak et al. (2023) the Z-score is computed using the formula.

$$Zscore_{it} = \frac{ROA_{it} + EA_{it}}{\text{sd(ROA)}}$$

Where ROA refers to the return on total assets, EA represents the equity-to-assets ratio, and sd (ROA) denotes the standard deviation of ROA. A higher Z-score reflects a lower risk of insolvency, indicating stronger financial stability.

Digital transformation (DT) is the primary explanatory variable in this study. Following the approach proposed by Kriebel and Debener (2019), this variable is constructed using a content analysis technique based on textual data extracted from banks' annual reports. A Python-based algorithm is used to identify and count occurrences of digital transformation terms across documents. These keywords are carefully selected and grouped into seven categories representing key dimensions of digital transformation: digital infrastructure, ATM and electronic payments, internet banking, mobile banking, cybersecurity, big data analytics, and fintech adoption.

To assess both the prominence and uniqueness of digital-related content, the study applies the Term Frequency–Inverse Document Frequency (TF-IDF) technique.

This method reflects a term's significance in a given document relative to its frequency across the entire collection of documents. Term frequency (TF) is measured by dividing the number of times a term appears in a document by the total word count of that document. Inverse document frequency (IDF) is determined by taking the logarithm of the total number of documents divided by the number of documents containing the term. The TF-IDF score is then calculated as:

$$TFIDF_i = TF_i * IDF_i$$

Where:

$$TF_i = \frac{\text{The times a term appears in the document}}{\text{Total number of words in the document}}$$

$$IDF_i = \log\left(\frac{Total\ number\ of\ documents}{Number\ of\ documents\ included\ this\ term}\right)$$

The total digital transformation index (DT) is calculated by summing all TFIDF scores of the relevant keywords for each bank-year.

$$DT = \sum TFIDF_i$$

Income diversification (DIV) is considered a potential mediator in the relationship between digital transformation and financial stability. DIV is measured as the ratio of non-interest income to total income, capturing the extent to which banks rely on alternative revenue sources such as fees, commissions, and trading income. This measure is widely used in the literature (Stiroh & Rumble, 2006) and reflects a bank's capacity to reduce dependence on traditional interest-based income.

CT is a set of control variables, including both bank-specific and macroeconomic factors. Loan loss provisions (LLP), calculated as loan loss reserves over total loans, serve as a proxy for credit risk (Ozili & Outa, 2017). Capital

adequacy (*ETA*) is measured as the equity-to-assets ratio, indicating a bank's ability to absorb financial shocks (Khattak et al., 2023; Xie & Wang, 2023) . Liquidity (*LTA*) is represented by the ratio of liquid assets to total assets, reflecting a bank's short-term financial flexibility. At the macroeconomic level, the study incorporates the GDP growth rate to account for economic conditions (Adusei, 2015; Ali & Puah, 2018). The impact of the COVID-19 pandemic is controlled using a dummy variable (*COVID*) that takes the value 1 for 2020–2022 and 0 otherwise.

To estimate the dynamic panel models, this study applies the System Generalized Method of Moments (GMM) estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998). This approach is particularly suitable for addressing the empirical challenges posed by the research design, which includes a relatively small number of banks (cross-sections) observed over a longer time period.

The choice of System GMM is justified by the presence of a dynamic dependent variable, where past financial stability (Z-score) may influence current stability. Moreover, it addresses endogeneity concerns that may arise due to reverse causality (e.g., more stable banks could be more inclined to adopt digital technologies or diversify income), omitted variable bias, and measurement errors. By employing internal instruments derived from the data itself, System GMM controls for unobserved heterogeneity, autocorrelation, and simultaneity, ensuring consistent and efficient parameter estimates.

To ensure the reliability of the regression estimates, a correlation matrix is employed to assess multicollinearity among the explanatory variables. According to Kennedy (2008) a correlation coefficient above 0.80 in absolute value signals potential multicollinearity. The results in Table 1 indicate that all pairwise correlations fall below this threshold, confirming that multicollinearity is not a significant issue in this study.

Table 1. Correlation matrix.

	DT	DIV	LLP	ETA	LTA	COVID	GDP
DT	1.000						
DIV	0.327	1.000					
LLP	0.098	0.239	1.000				
ETA	0.024	0.153	-0.011	1.000			
LTA	0.195	0.203	0.119	0.008	1.000		
COVID	0.203	0.237	0.038	-0.075	0.268	1.000	
GDP	-0.122	-0.114	-0.091	-0.037	-0.064	-0.581	1.000

4. RESULTS

4.1. Descriptive Statistics

Table 2 presents the descriptive statistics for the variables used in this study. The Z-score, which measures financial stability, has an average value of 2.071 with a standard deviation of 1.511, reflecting substantial variation in bank stability across institutions and over time. The digital transformation index (DT) has an average value of 4.563, with a standard deviation of 0.832, indicating that banks vary considerably in their level of digital adoption. Similarly, income diversification (DIV) has an average of 0.137, with values ranging from 0.004 to 0.455, indicating that while some banks have expanded their revenue streams beyond interest income, others remain highly reliant on traditional lending activities.

Examining the components of digital transformation, the highest average score is observed in ATM and payment services (2.630), followed by mobile banking (2.327) and internet banking (2.214), suggesting that these areas receive the most attention from banks. This indicates that banks prioritize these aspects in their digital transformation narratives. In contrast, fintech adoption (0.419) and analytics/machine learning implementation (0.449) have relatively low scores, implying that discussions on advanced financial technologies remain limited. Notably, cyber risk has a standard deviation of 0.916, reflecting significant variation in how banks address cybersecurity concerns in their disclosures.

Table 2. Descriptive statistics.

Variables	Obs.	Mean	Std. dev	Min.	Max.
Dependent variable					
Z-Score	308	2.071	1.511	0.033	6.923
Main independent variables					
DT	308	4.563	0.832	1.485	6.446
DIV	308	0.137	0.082	0.004	0.456
Sub-independent variables					
Infrastructure	308	1.690	1.092	0.000	3.968
ATM and payment	308	2.630	0.950	0.000	4.645
Internet banking	308	2.214	1.064	0.000	4.853
Mobile banking	308	2.327	1.340	0.000	5.830
Cyber risk	308	0.916	0.975	0.000	3.775
Analytics and machine learning	308	0.449	0.850	0.000	3.201
Fintech	308	0.419	0.740	0.000	3.218
Control variables					
LLP	308	0.014	0.005	0.007	0.036
ETA	308	0.110	0.062	0.007	0.455
LTA	308	0.247	0.104	0.067	0.611
GDP	308	5.824	1.505	2.560	8.120
COVID	308	0.214	0.411	0.000	1.000

4.2. Results

Table 3 presents the regression results from three baseline models using the GMM estimator. Model (1) examines the direct impact of digital transformation (DT) on bank stability. Model (2) evaluates the effect of income diversification (DIV), and Model (3) incorporates the interaction term (DT*DIV) to assess the mediating role of diversification in the DT-stability relationship.

The findings provide empirical support for the hypothesis H_1, as the coefficient of DT is 0.175 and statistically significant at the 5% level. This suggests that digital transformation enhances financial stability, potentially by improving operational efficiency, strengthening risk management, and expanding revenue opportunities.

Regarding hypothesis H_2, the coefficient of DIV is 0.059, significant at the 1% level, indicating a positive relationship between income diversification and bank stability. This suggests that banks with a more diversified income structure experience lower earnings volatility and greater financial resilience.

The interaction term DT*DIV in Model (3) has a positive coefficient of 0.009 and is statistically significant at the 5% level, supporting the hypothesis H_3. This implies that income diversification strengthens the stabilizing effect of digital transformation. Banks that effectively diversify their revenue streams benefit more from technological advancements, mitigating risks associated with over-reliance on traditional interest income.

Among the bank-specific control variables, LTA consistently exhibits a positive effect on stability across all models, with coefficients ranging from 0.016 to 0.026, significant at the 1% to 5% levels. This suggests that higher liquidity levels contribute to financial stability. In contrast, LLP does not show significant results in any model, indicating that provisioning policies do not directly impact overall stability. ETA is positively significant only in Model (2), with a coefficient of 0.060 at the 1% level, implying that well-capitalized banks may experience greater stability when diversifying income.

Regarding macroeconomic factors, GDP growth positively influences bank stability, with coefficients ranging from 0.056 to 0.089, all significant at the 5% level. This suggests that economic expansion supports financial stability by improving asset quality and reducing default risks. The COVID-19 dummy variable shows a significant positive effect in Models (1) and (2), with coefficients of 0.272 and 0.393, respectively.

Table 3. Regression results.

	(1)	(2)	(3)
	Z-Score	**Z-Score**	**Z-Score**
Z-Score (-1)	0.779***	0.353***	0.721***
	(0.057)	(0.049)	(0.055)
DT	0.175**		
	(0.084)		
DIV		0.059***	
		(0.011)	
DT*DIV			0.009***
			(0.002)
LLP	0.079	0.231	0.036
	(0.132)	(0.172)	(0.124)
ETA	-0.006	0.060***	-0.005
	(0.014)	(0.015)	(0.013)
LTA	0.026***	0.016**	0.019***
	(0.006)	(0.007)	(0.005)
COVID	0.272**	0.393***	0.123
	(0.117)	(0.151)	(0.114)
GDP	0.068**	0.089**	0.056**
	(0.027)	(0.035)	(0.026)
cons	-2.588***	-2.422***	-1.667***
	(0.380)	(0.467)	(0.339)
N	308	308	308
S-test	0.297	0.958	0.692
AR (1)	0.000	0.001	0.000
AR (2)	0.912	0.544	0.869

Note: The numbers in parentheses represent the standard errors. ***,** , * indicate statistical significance at the 1% level, 5% level, 10% level, respectively.

To further investigate the impact of digital transformation on bank stability, Table 4 presents additional regressions using the individual components of DT as explanatory variables. Analytics and Machine Learning exhibit the strongest positive effect on stability ($\beta = 0.275$, $p < 0.01$), suggesting that banks leveraging AI-driven risk management tools and big data analytics experience greater resilience. Infrastructure ($\beta = 0.156$, $p < 0.05$) and ATM & Payment services ($\beta = 0.209$, $p < 0.01$) also contribute positively to stability, implying that investments in digital infrastructure and modernized payment systems enhance financial security and operational efficiency. Internet banking, mobile banking, cyber risk, and fintech adoption do not show significant effects, indicating that these aspects of digitalization do not directly influence bank stability in isolation.

Table 4. Regression analysis of digital transformation components.

	Z-Score	**Z-Score**	**Z-Score**	**Z-Score**	**Z-Score**	**Z-Score**	**Z-Score**
Z-Score (-1)	0.751***	0.772***	0.799***	0.805***	0.794***	0.747***	0.771***
	(0.059)	(0.057)	(0.059)	(0.057)	(0.057)	(0.061)	(0.060)
Infrastructure	0.156 **						
	(0.062)						
ATM and payment		0.209***					
		(0.081)					
Internet banking			-0.016				
			(0.070)				
Mobile banking				0.063			
				(0.046)			
Cyber risk					-0.047		
					(0.064)		
Analytics and machine learning						0.275***	
						(0.090)	
Fintech							0.105
							(0.081)
LLP	0.060	0.067	0.106	0.043	0.124	0.169	0.106
	(0.132)	(0.132)	(0.145)	(0.140)	(0.133)	(0.138)	(0.132)

	Z-Score	Z-Score	Z-Score	Z-Score	Z-Score	Z-Score	Z-Score
ETA	0.003	-0.006	-0.005	-0.004	-0.005	-0.019	-0.007
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.015)	(0.014)
LTA	0.060***	0.028***	0.034***	0.032***	0.033***	0.020***	0.029***
	(0.005)	(0.005)	(0.007)	(0.005)	(0.005)	(0.007)	(0.006)
COVID	0.351***	0.300***	0.276**	0.184	0.278**	0.185	0.261**
	(0.118)	(0.116)	(0.137)	(0.142)	(0.120)	(0.127)	(0.119)
GDP	0.079***	0.089***	0.062**	0.050*	0.062**	0.056**	0.055*
	(0.028)	(0.029)	(0.031)	(0.030)	(0.028)	(0.029)	(0.029)
cons	-2.236***	-2.549***	-2.226***	-2.141***	-2.207***	-1.444***	-1.951***
	(0.339)	(0.359)	(0.350)	(0.347)	(0.348)	(0.440)	(0.406)
N	308	308	308	308	308	308	308
S-test	0.453	0.292	0.330	0.287	0.321	0.825	0.277
AR (1)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
AR (2)	0.665	0.972	0.777	0.941	0.917	0.884	0.783

Note: The numbers in parentheses represent the standard errors. ***,**, * indicate statistical significance at the 1% level, 5% level, 10% level, respectively.

5. DISCUSSION

The regression results indicate a significant and positive relationship between digital transformation and bank stability, supporting the view that technological advancements contribute to financial resilience. This finding contrasts with Khattak et al. (2023), who suggest that excessive investment in digitalization may increase financial risks due to competitive pressures and high implementation costs. While aggressive digital adoption can lead to financial strain, our results suggest that the benefits outweigh the risks, as digital transformation enhances risk management, improves operational efficiency, and diversifies revenue streams. Digital banking services, online payments, and automated monitoring systems enable banks to detect loan defaults, fraud, and operational inefficiencies more effectively, thereby stabilizing financial performance. Moreover, real-time core banking systems allow banks to optimize liquidity management and capital allocation, mitigating systemic risks and improving overall financial health. These findings align with those of Fuster et al. (2019), who argue that digital innovation enhances credit risk assessment and strengthens banking stability.

The results also confirm the positive effect of income diversification (DIV) on bank stability, reinforcing the notion that reducing reliance on interest income enhances resilience. This aligns with Stiroh (2004); Ghosh and Maji (2014) and Zheng, Islam, Hasan, and Halim (2022) who emphasizes that expanding fee-based activities, wealth management services, and other non-interest revenue sources lowers earnings volatility and strengthens financial performance. Diversification helps banks optimize fixed costs, reduce reliance on net interest margins, and mitigate exposure to credit risk fluctuations. Köhler (2014) similarly found that banks with balanced revenue models exhibit lower insolvency risk and greater stability, particularly in emerging markets. However, the findings contrast with (Stiroh & Rumble, 2006), who caution that excessive reliance on non-interest income can increase earnings volatility, particularly for banks engaged in trading and investment services.

The interaction between digital transformation and income diversification further amplifies financial stability. The significant coefficient of DT*DIV suggests that banks integrating digital technology with a well-structured diversification strategy achieve superior financial resilience. This finding is consistent with Khattak et al. (2023), who highlight that digitalization is most beneficial when accompanied by income stream expansion. Digital platforms provide new revenue opportunities through transaction fees, digital insurance, and investment advisory services, reducing banks' dependence on traditional lending activities. The combination of digital expansion and income diversification enables banks to achieve economies of scale, lower operational costs, and stabilize cash flows, ultimately enhancing their ability to withstand economic shocks. These results align with Ahamed (2017) who found that banks leveraging digital financial services alongside diversified income structures exhibit lower default probabilities and stronger profitability.

At the component level, not all aspects of digital transformation contribute equally to stability. Among the digital transformation factors examined, analytics and machine learning have the most substantial impact, reinforcing the

role of data-driven decision-making in risk management. Advanced analytics improve loan assessments, fraud detection, and customer segmentation, leading to better financial stability (Beccalli, 2007). Investment in digital infrastructure and modern payment systems also has a positive effect, as efficient transaction processing reduces operational risks and improves cost efficiency (Valverde & Fernández, 2007). These findings highlight the importance of integrating robust data analytics and payment innovations into banking operations, consistent with Eisenhardt and Martin (2000), who argue that dynamic capabilities in digital infrastructure significantly enhance financial resilience.

However, some digitalization components show limited influence on stability. Internet and mobile banking do not exhibit a statistically significant effect, suggesting that these technologies primarily function as distribution channels rather than direct drivers of risk reduction. This result aligns with (DeYoung & Torna, 2013), who found that digital banking services enhance customer experience but do not necessarily improve financial stability. Cybersecurity investments also fail to demonstrate a strong stabilizing effect, potentially due to the high costs of security measures, which may strain profitability in the short term (Uddin et al., 2020). Similarly, fintech adoption does not appear to significantly enhance stability, reflecting the mixed effects of digital lending. While fintech-driven financial services improve accessibility and streamline operations, they also introduce credit risks by loosening lending standards, which could increase non-performing loans and offset potential benefits (Brunnermeier, 2009).

6. CONCLUSION

This study investigates the impact of digital transformation on the financial stability of commercial banks, with a particular focus on the mediating role of income diversification. Using data from 22 Vietnamese commercial banks spanning 2010 to 2023, the analysis employs the System GMM estimator to address endogeneity and unobserved heterogeneity. The empirical results demonstrate that both digital transformation and income diversification have a statistically significant and positive influence on bank stability. Importantly, the interaction between the two factors reveals that income diversification strengthens the stabilizing effect of digitalization.

Not all aspects of digital transformation exert the same influence. Data analytics and payment infrastructure emerge as key contributors to financial resilience, while technologies such as mobile banking, internet banking, and cybersecurity do not exhibit significant effects. This indicates that back-end capabilities and data-driven innovations are more critical to stability than customer-facing digital channels. Moreover, fintech adoption shows limited stabilizing impact, potentially reflecting credit risks associated with digital lending platforms.

These findings yield important managerial and policy implications. For bank managers, the results highlight the need for a strategic and selective approach to digital investments, focusing on components that directly enhance operational efficiency and risk control. Integrating such efforts with income diversification strategies—particularly through non-interest income sources like fees and digital services can magnify stability gains. For policymakers, the study underscores the value of encouraging responsible digital innovation while maintaining a robust regulatory framework to safeguard financial stability during technological transitions.

A key methodological contribution of this research is the application of textual analysis to measure digital transformation, using term frequency-inverse document frequency scores based on annual report content. This approach offers a transparent, replicable method for quantifying technological orientation at the bank level and provides new insights into how digital narratives reflect actual digital activity.

Despite its contributions, the study has certain limitations. It does not distinguish between different bank types (e.g., state-owned vs. private, large vs. small), which may respond differently to digital transformation. Future research could incorporate this heterogeneity to enhance the analysis. Moreover, the sample is limited to Vietnamese banks and the 2010–2023 period. Broader, cross-country comparisons and extended timeframes could provide a more comprehensive understanding of how digital transformation and income diversification interact to affect bank stability in diverse regulatory and economic environments.

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