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The Impact of Digital Transformation and Income Diversification on Banking Stability in Asean-5 Emerging Countries

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Abstract: This research aims to analyse the impact of digital transformation and income diversification on banking stability in the ASEAN-5 emerging countries for the period 2014-2023. In recent years, banks are dealing with digital transformation to enhance operational efficiency and offer more innovative financial services, while diversifying revenue through non-interest income sources to reduce their reliance on interest income, which is vulnerable to fluctuations in interest rates. The research employed a purposive sampling method for a sample of 80 institutions in the ASEAN-5 emerging countries (Indonesia, Malaysia, Philippines, Thailand, and Vietnam) that fulfilled certain criteria. The estimation method employed is panel data regression utilizing the Dynamic System Generalized Method of Moments (GMM) — which allows researchers to address endogeneity issues in the relationships between variables— to examine the constructed model. The research results indicate that digital transformation has a negative impact on bank stability and takes time to show its positive impact. This result shows that the adoption of technology requires a significant investment at the beginning of implementation, but over time it will enhance bank's financial stability. Second, low-income diversification tends to decrease bank stability due to reliance on a single source of income, and when banks reach a certain level of income diversification, their stability will increase due to risk spreading. Finally, the moderating effect of income diversification on the relationship between digital transformation and bank stability, indicates that stability significantly increases when banks reach certain levels of income diversification and digital adoption.

Keywords: Digital Transformation, Income diversification, Bank Stability, ASEAN-5.

INTRODUCTION

Digital transformation enhances operational efficiency and customer experience, but it also introduces new risks that may impact banking stability (Chen et al., 2023). As financial institutions integrate advanced technologies such as artificial intelligence, big data analytics, and blockchain, their business models are evolving and enabling them to gain a competitive advantage in the industry (Khattak et al., 2023). However, banking will face various risks, such as cyber security threats, data privacy issues, and other operational vulnerabilities while

executing digital innovation (Chen et al., 2023). Digitalization in banking has emerged as one of strategic initiative to assist banks in broadening their services and generating chances not only for their traditional income from interest but also for non-interest income expansion to keep up with FinTechs. Similar with digital transformation, income diversification strategies can either enhance resilience or introduce volatility for banking such as possibility to lose fee-based customer and substantial investment needed in non-interest activities (Deyoung & Roland, 2001; Le, 2021; Lu & Van Nguyen, 2024; Nguyen et al., 2023). Therefore, it is crucial to analyse the interplay between digital transformation, income diversification, and banking stability.

Previous research has predominantly focused on the effects of digital transformation and diversification on bank profitability and performance rather than stability (Do et al., 2022; Nguyen-Thi-Huong et al., 2023; Wu & Cheng, 2024). Furthermore, studies in this domain have largely been conducted in developed markets like Europe and North America as well as in the forefront countries among economies worldwide, such as China and United States (Chhaidar et al., 2023; Do et al., 2022; Wu & Cheng, 2024; Xiang & Jiang, 2023). As many banks are enhancing adoption of technology in their operational process, there is a need to examine how this initiative will impact the bank stability. The paradigm change in FinTech in the banking sector means that banks have few options but to increase technology spending to survive in the fast-changing FinTech era (Uddin et al., 2020). Lack of regulations governing the digital transformation adoption in banking sector may also have serious implications for systemic financial stability (Gao, 2023). Thus, this paper will focus on the stability of inside-bank digitalization.

While existing literature provides insights into the individual effects of digital transformation and income diversification on banking outcomes, findings remain inconclusive. Some studies suggest that digital transformation enhances stability through operational efficiencies (Lestari et al., 2023), while others indicate increased cyber risks and financial vulnerabilities (Khattak et al., 2023; Uddin et al., 2020). Similarly, income diversification has been linked to improved financial stability in some cases (Shahriar et al., 2023) but associated with greater risk exposure in others (Liang et al., 2020). Notably, prior research has not extensively examined the moderating effect of income diversification on the relationship between digital transformation and banking stability, particularly in the context of emerging markets. Addressing this gap, our study seeks to provide empirical evidence on these dynamics.

The banking industry in Southeast Asia has been undergoing significant changes in recent years due to digital transformation and income diversification. Digital banking adoption in Southeast Asia has accelerated due to regulatory reforms and shifting of consumer behaviour reflecting in the region emerging markets digital banking penetration that continue to increase amounting to more than 50% of penetration globally, as well as the increasing services in digital payments, digital lending, and digital wealth (Temasek; Bain, 2023). This study aims to bridge this gap by exploring how digital transformation and income diversification impact banking stability in the ASEAN-5 region.

The ASEAN-5 emerging countries — comprising Indonesia, Malaysia, Thailand, the Philippines, and Vietnam — were selected for this study due to their rapidly evolving financial landscapes and their increasing role in global trade and investment (ASEAN, 2023; Temasek; Bain, 2023). These nations exhibit diverse regulatory frameworks and varying levels of technological adoption, making them ideal for studying the heterogeneous impacts of digital transformation and income diversification on banking stability. Furthermore, the region's digital economy has expanded significantly, accelerated by the COVID-19 pandemic, highlights the urgency of ensuring financial system resilience (Temasek; Bain, 2023). Given the economic significance of the banking sector in the ASEAN-5 emerging markets, it is crucial

to understand the interaction between digital transformation, income diversification, and banking stability in these countries.

To analyse the impact of digital transformation and income diversification on banking stability, this study employs a panel data regression approach using a balanced panel dataset of conventional banks in the ASEAN-5 countries spanning the period 2014 to 2023. This period is selected as it encompasses significant regional and global events, including the COVID-19 pandemic, rapid financial technology (FinTech) development, shifts in macroprudential and monetary policies, fluctuations in exchange rates and inflation, and ongoing global economic uncertainty, all of which have considerably impacted banking stability in ASEAN-5 countries. The Dynamic System Generalized Method of Moments (GMM) is applied in this study to address potential endogeneity issues and ensure robust estimations (Khattak et al., 2023; Uddin et al., 2020). Banking stability is measured using the Z-score indicator, with digital transformation is proxied by natural logarithm of capitalized software expenditures, while income diversification is assessed using the Herfindahl-Hirschman Index (HHI) derived from interest and non-interest income ratios.

The remainder of this paper is structured as follows. Section 2 outlines the research methodology, including data sources, sample selection, and econometric models. Section 3 presents the empirical results and discusses their implications. Finally, Section 4 concludes the study with key findings, policy recommendations, and suggestions for future research.

METHOD

This study adopts a quantitative approach to examine the impact of digital transformation and income diversification on banking stability across conventional banks in ASEAN-5 emerging countries over the period 2014 to 2023. This study employs a panel data regression approach using the Generalized Method of Moments (GMM) to estimate the impact of digital transformation and revenue diversification on banking stability across multiple banks. The use of the GMM method addresses potential endogeneity issues within the model, ensuring more robust and accurate estimations. Additionally, this approach provides a comprehensive understanding of the relationships between the key variables over time. The estimation model applied in this study aligns with methodologies used in prior research by (Khattak et al., 2023; Shahriar et al., 2023; Uddin et al., 2020), ensuring consistency with established empirical frameworks.

Sample Data

The study uses secondary bank-level data from the S&P Global Market Intelligence database and annual financial statements collected from the respective commercial banks' websites. The sample consists of banks listed on the stock exchanges of the ASEAN-5 emerging countries—comprising Indonesia, Malaysia, Thailand, the Philippines, and Vietnam—covering a ten-year period from 2014 to 2023. In addition, country-level control variables are retrieved from the World Bank Development Indicators. The selection of banks for the sample was conducted based on specific criteria to ensure data consistency and comparability, and representativeness across countries and over time. The criteria applied in selecting the sample are as follows:

1. The banks included in the study must report information regarding digital transformation, specifically capitalized software expenditures, in their annual financial statements; banks that do not disclose this information are excluded from the research sample.
2. Only conventional banks, both state-owned and private, are included in the sample. Additionally, Islamic banks are excluded due to their distinct operational principles that differ from conventional banking models.

3. The banks included in the sample must have annual financial statements with clear and complete reporting details of non-interest income.

These selection criteria used to ensure that the banks included in the sample accurately represent the commercial banking sector in the ASEAN-5 emerging countries and provide sufficient data for analyzing the relationships between digital transformation, income diversification, and banking stability. Below is the summary of the dataset used in this research.

Table 1. Sample Distribution

Country	Number of Banks Listed in the S&P Capital IQ Database	Number of Banks After Selection
Indonesia	212	24
Malaysia	2922	15
Filipina	216	16
Thailand	126	15
Vietnam	126	10
Total	**3602**	**80**

Source: Data Processed (2025)

The research sample consists of 80 conventional commercial banks from the five ASEAN emerging countries over the ten-year period from 2014 to 2023. Initially, 3,602 banks were recorded in the S&P Capital IQ database and following the application of sample selection criteria, the final sample comprises 24 banks from Indonesia, 15 from Malaysia, 16 from the Philippines, 15 from Thailand, and 10 from Vietnam. These banks are listed on their respective national stock exchanges and provide comprehensive financial statement disclosures required for this study. The resulting balanced panel data consists of 800 observations, offering a robust dataset to analyze the impact of digital transformation and income diversification on banking stability across diverse regulatory, technological, and economic environments in the ASEAN-5 emerging countries.

Variables Descriptions

The explanatory parameters included in the analysis are listed in table 1 along with the corresponding estimates.

Table 2. Variable Descriptions

Variables		Measures	Symbol	Sources
Bank Stability	Dependent	Measure of bank stability; $\frac{ROA + CAR}{\sigma_{ROA}}$	Zscore	Khattak et al. (2023); Uddin et al. (2020); Shahriar et al. (2023)
Digital Transformation	Independent	Measure the bank digital adoption level $Ln\ capitalized\ purchased\ software$	DT	Khattak et al. (2023); Uddin et al. (2020);
Income Diversification	Independent	The Herfindahl-Hirschman Index (HHI) construction to measure the diversification of bank's income sources $1 - \left[\left(\frac{INT_i}{TOP_i}\right)^2 + \left(\frac{NON_i}{TOP_i}\right)^2\right]$	Inc_Div	Shahriar et al. (2023)
Bank Size	Control	Ln $Total\ Assets$	Size	Khattak, et.al. (2023); Uddin, et.al. (2020)

NPL Ratio	Control	$\frac{Non-performing\ Loan}{Total\ Loan}$	NPL	Uddin, et.al. (2020)
Liquidity Ratio	Control	$\frac{Total\ Loan}{Total\ Deposits}$	Liq	Shahriar et al. (2023)
Leverage Ratio	Control	$\frac{Total\ Deposits}{Total\ Assets}$	Lev	Shahriar et al. (2023)
GDP Growth	Control	GDP growth rate in related countries	GDP	Khattak, et.al. (2023); Uddin, et.al. (2020)
Inflation Rate	Control	Inflation rate in related countries	Inflation	Khattak, et.al. (2023); Uddin, et.al. (2020)

Source: Data Processed (2025)

The dependent variable in this study is bank stability. Financial stability refers to the ability of the financial system to function effectively, manage risks, and dynamically absorb external shocks (Schinasi, 2004). Stability measured using the Z-score—a widely recognized indicator of bank stability, as it combines profitability, capital adequacy, and the volatility of return on assets—higher Z-score indicates greater stability, as it signifies a lower risk of bankruptcy (Casu, et.al., 2021). This measure is appropriate for evaluating the stability of banks in the ASEAN-5 region, given its ability to represent both operational performance and capital buffer against financial distress, as well as it indicates a reduced risk of bankruptcy.

There are the two primary independent variables in the model. Digital transformation measured using the natural logarithm of capitalized software of each bank (Khattak et al., 2023) and this metric proxied the direct digital adoption of banks, with banks that have higher software capitalization values considered more digitally transformed (Papadimitri et al., 2021). Digitalization has vital role in shaping the operational framework of banks, supported by resource-based theory by Penrose & Penrose—competitive advantage is derived from internal resources and capabilities, allowing firms to grow and achieve higher profitability—and also Schumpeter's innovation theory—technological progress creates opportunities for new sources of profit through investment in innovative products (Shanmugam & Nigam, 2020). Income diversification, based on portfolio theory, is seen as a key strategy to reduce risk by combining various sources of income, including interest from loans and investments, as well as non-interest income such as fees and commissions (Le, 2021; Casu et al., 2021). It is measured by constructing the Herfindahl-Hirschman Index (HHI) to determines the concentration of income sources within a bank. A lower HHI value indicates greater diversification, whereas a higher HHI implies that the bank is more dependent on its interest income sources (Liang et al., 2020).

Several control variables are included into the analysis to account for factors that may influence bank stability in addition to the primary variables. These variables are chosen for their relevance to the banking sector and stability measures, and they are also in accordance with the existing literature (Khattak et al., 2023; Shahriar et al., 2023; Uddin et al., 2020). The bank size is measured as the natural logarithm of total assets, controls for the effect of bank scale on stability. Bank liquidity is measured by the ratio of total loans to total deposits, which reflects the bank's ability to meet short-term obligations. The loan-to-asset ratio is representing the proportion of the bank's assets allocated to loans, which is an important determinant of financial risk. Lastly, as our sample includes global data, we also identify a set of country-level controls that are relevant to this study due to differences in each country's economic conditions. This research will include GDP growth rate and inflation by Consumer Price Index to control the model using national-level data from the World Bank.

Research Models

The study employs panel data regression to analyze the relationships between digital transformation, income diversification, and bank stability, and specifically uses Generalized Method of Moments (GMM) approach to address potential endogeneity issues in the model (Khattak et al., 2023; Shahriar et al., 2023). This method is chosen due to its ability to provide consistent estimates in the presence of simultaneity and omitted variable bias, which is common in banking sector research. Below are the models specified for the empirical test.

$$ZScore_{i,t} = \beta_{0_{i,t}} + \beta_1 DT_{i,t} + \beta_2 Size_{i,t} + \beta_3 NPL_{i,t} + \beta_4 Liq_{i,t} + \beta_5 Lev_{i,t} + \beta_6 MCR_{i,t} + \varepsilon_{i,t} \quad (1)$$

$$ZScore_{i,t} = \beta_{0_{i,t}} + \beta_1 Inc_Div_{i,t} + \beta_2 Size_{i,t} + \beta_3 NPL_{i,t} + \beta_4 Liq_{i,t} + \beta_5 Lev_{i,t} + \beta_6 MCR_{i,t} + \varepsilon_{i,t} \quad (2)$$

$$ZScore_{i,t} = \beta_{0_{i,t}} + \beta_1 DT_{i,t} + \beta_2 Inc_Div_{i,t} + \beta_3 DT_{i,t} * Inc_Div_{i,t} + \beta_4 Size_{i,t} + \beta_5 NPL_{i,t} + \beta_6 Liq_{i,t} + \beta_7 Lev_{i,t} + \beta_8 MCR_{i,t} + \varepsilon_{i,t} \quad (3)$$

Where, *i* and *t* denote the bank and year respectively. *DT* denotes the bank's digital transformation and *Inc_Div* denotes the bank's income diversification. *Size, NPL, Liq, Lev* denotes the bank-specific characteristics that might impact the bank's stability. *MCR* represents the industry concentration in the country where the bank operates and used to control country-specific heterogenity, while $\varepsilon_{(i,t)}$ indicates the residual value of the model.

RESULTS AND DISCUSSION

This section presents the descriptive statistics, correlation matrix and the discussion on main findings of the study.

Table 1. Descriptive Statistics

Variables	Obs	Mean	Std. Dev.	Min	Max	Skew.	Kurt.
stability	800	3.629	.915	.316	5.284	-.781	3.534
digital transformation	800	8.916	2.171	2.299	13.416	-.344	2.552
income diversification	800	.365	.111	.025	.500	-.810	2.828
bank size	800	16.044	1.758	11.195	19.227	-.450	2.532
NPL ratio	800	.029	.018	.005	.074	.939	3.318
liquidity ratio	800	.863	.203	.428	1.314	.128	3.432
leverage ratio	800	.707	.107	.445	.855	-.883	3.240
GDP growth	800	.001	.970	-1.899	1.949	.011	2.481
inflation rate	800	.028	.019	-.011	.064	.130	2.688

The descriptive statistical analysis in table 3 highlights key characteristics of the 800 observations from 80 conventional banks in the ASEAN-5 countries over the period 2014 to 2023. The average bank stability, represented by Zscore, is 3,629 with a standard deviation of 0,915, indicating overall good stability with moderate variation across banks. The digital transformation variable has a mean of 8,916 and a standard deviation of 2,171, with values ranging from 2,299 to 13,416, reflecting significant heterogeneity in digital technology adoption. Income diversification, has an average value of 0,365 and a standard deviation of 0,111, suggesting a relatively balanced mix between interest and non-interest income sources.

In terms of bank-specific characteristics, bank size shows a mean of 16,044 (SD = 1,758) with values ranging from 11,195 to 19,227, showing the presence of both large and small banks in the dataset. While the non-performing loan ratio averages 0,029 with (SD = 0,018), highlighting differences in credit risk exposure among banks. Liquidity and leverage ratios show mean values of 0,863 (SD = 0,203) and 0,707 (SD = 0,107), respectively, indicating varied financial management strategies. At the macroeconomic level, GDP growth rates average 0,001 (SD = 0,970), while inflation rates average 0,028 (SD = 0,019), suggesting

diverse economic conditions across the ASEAN-5 countries. All classical assumption tests, including tests for normality, multicollinearity, and heteroskedasticity were conducted to ensure the validity of the estimation model. The dataset and test results are available upon request.

Table 4 reports correlation analysis of the variables used in the study. The highest correlation (0.679) is seen between Bank size and Z-digital transformation which is expected as bank with higher asset amount have more ability to adapt to newest technology. The inexistence of higher correlations between the variables implies our estimations would not suffer from possible issue of multicollinearity. The correlation analysis presented in table 4 reveals several significant relationships among the variables used in this study. Banking stability (Z-score) has a positive correlation with digital transformation (0,226), indicating that higher digital investments tend to enhance stability. Income diversification also shows a positive correlation with Z-score (0,224), suggesting that a higher level of income diversification tends to improve bank stability. Furthermore, income diversification has a strong positive correlation with digital transformation (0,376), indicating that banks with higher technological adoption are also likely to have more diversified income streams.

Table 2. Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) stability	1.000								
(2) digital transformation	0.226	1.000							
(3) income diversification	0.224	0.376	1.000						
(4) bank size	0.552	0.679	0.432	1.000					
(5) NPL ratio	-0.288	-0.147	-0.086	-0.327	1.000				
(6) liquidity ratio	-0.015	0.213	-0.016	0.163	-0.103	1.000			
(7) leverage ratio	0.110	-0.012	-0.106	0.169	0.073	-0.422	1.000		
(8) GDP growth	-0.115	-0.108	-0.080	-0.115	-0.114	-0.295	0.095	1.000	
(9) inflation rate	-0.244	-0.194	-0.253	-0.254	0.078	-0.188	0.170	0.417	1.000

Source: Researcher Processed Results (2025)

Bank size exhibits a relatively positive correlation with the Z-score (0,552), as well as income diversification (0,432), indicating that larger banks tend to have higher stability, higher technology adoption, and more diversified. The non-performing loan (NPL) ratio is negatively correlated with bank stability (-0,288), confirming that higher credit risk is associated with lower bank stability. Inflation also shows a negative correlation with the Z-score (-0.244), highlighting that rising inflationary pressures can erode banking stability. Overall, these results reinforce the notion that banking stability is positively influenced by larger bank size and lower credit risk, while macroeconomic instability, such as inflation, poses challenges to maintaining financial resilience.

This section presents the results upon estimation of equation (1), (2), and (3) explained in section 3. We estimate different model specifications to add credence to our findings. Table 5 reports the results in the impact of digital transformation on banks stability. Table 6 shows the findings on the impact of income diversification on banks stability and finally table 7 reports the results the moderating role of diversification in impacting the relationship between digital transformation and stability.

The number of practical observations in this research decreases to 720 due to the use of lag variable. After testing the classical assumptions, we conduct a comparation of lag bank stability coefficients for each model between the common effect, fixed effect, and the GMM models. For model 1, the GMM result showed highest lag coefficient (0,975), indicating strong stability dynamics although it exceeded GMM rule of thumb. The Sargan-Hansen test produced

p-values of 0,5780 and 0,5205, indicating that the instrument was valid and there was no overidentifying restriction. Although it did not meet the rule of thumb, the GMM of model 1 was still considered statistically valid and robust to capture the dynamic relationships between variables in this study.

The results of the Two-Step GMM regression for model 1, as presented in Table 5, indicate that several variables significantly influence banking stability in the ASEAN-5 context. The lagged stability variable (coefficient = 0,975; p 0,000 < 0.01) demonstrates a strong positive and significant relationship, indicating stability inertia (Casu, et.al., 2021; World Bank, 2016) and is in line with the Financial Stability theory (Schinasi, 2004). The result showed that financial stability is persistent, where banks with good and stable financial conditions in the past tend to maintain their stability in the future.

Table 3. Impact of Digital Transformation on Bank Stability

WC-Robust

stability	Coef.	std. err.	z	P>z	[95% conf.	interval]	Sig
lag stability	0.975	0.011	89.720	0.000	0.953	0.996	***
digital transformation	-0.116	0.056	-2.080	0.038	-0.225	-0.007	**
lag digital transformation	0.108	0.055	1.980	0.048	0.001	0.215	**
banksize	0.007	0.006	1.150	0.250	-0.005	0.019	
NPL ratio	-0.612	0.459	-1.330	0.182	-1.512	0.287	
liquidity ratio	-0.052	0.038	-1.360	0.172	-0.128	0.023	
leverage ratio	-0.210	0.094	-2.240	0.025	-0.393	-0.026	**
GDP growth rate	-0.027	0.006	-4.630	0.000	-0.039	-0.016	***
inflation rate	0.453	0.299	1.520	0.130	-0.133	1.040	
_cons	0.289	0.109	2.660	0.008	0.076	0.501	***

Fitting full model:			
Step 1	f(b) = .01212153	Num of obs	= 720
Step 2	f(b) = .4213823	Num of groups	= 80
Moment conditions:		Linear	= 46
		Nonlinear	= 0
		Total	= 46
Wald chi2 (8)	= 27.57	Arellano–Bond test for zero autocorrelation	
Prob > chi2	= 0.0006	H0: No autocorrelation	
		Order z	Prob > z
		2 1.2351	0.2168
Sargan-Hansen test of the overidentifying restrictions			
H0: overidentifying restrictions are valid			
2-step moment functions, 2-step weighting matrix		chi2(36)	= 33.7106
		Prob > chi2	= 0.5780
2-step moment functions, 3-step weighting matrix		chi2(36)	= 34.9064
		Prob > chi2	= 0.5205

**** p<.01, ** p<.05, * p<.1*

Source: Researcher Processed Results (2025)

Digital transformation has a negative and significant effect (coefficient = -0,116; p-value 0,038 < 0,05), while its lagged variable has a positive significant effect (coefficient = 0,108; p-value 0,048) to bank stability. This reflects the potential for initial disruption due to technology investment and operational risk caused by high transition costs or initial risks in implementing digitization. These results support the theory of Resource-Based and Schumpeter's innovation theory, which emphasizes that internal capabilities, including digital capabilities, can create competitive advantage and financial stability in the long term (Lestari et al., 2023; Shanmugam & Nigam, 2020). Digital transformation takes time to show its positive effects, such as

increasing the efficiency and resilience of bank operations, which will support increased bank stability after the initial adjustment phase has passed, as shown by previous studies conducted by (Khattak et al., 2023; Uddin et al., 2020).

Meanwhile, for the bank's internal control variables, only leverage ratio shows a marginally significant adverse effect on bank's financial stability, with coefficient value -0,210 and p-value of 0,025. This can be interpreted that the larger the leverage ratio, the greater its negative influence on bank stability. Dependence on third-party funds can increase financial risk and reduce stability. This finding is consistent with the Financial Instability Hypothesis, which states that high levels of dependence on third-party funds make banks more vulnerable to liquidity crises and the sudden withdrawals of funds by customers, can increase financial risk and financial volatility of banks (Minsky et al., 1992). While the other three control variables, namely bank size, NPL, and liquidity ratio, do not significantly affect financial stability, indicating that the three factors have not consistently affected bank resilience in the ASEAN-5 context during the observation period.

For the macroeconomic control variables, only GDP growth significantly influences bank financial stability. It has an adverse effect with a coefficient value of -0,027 and significant at the 1% level (p-value 0,000). This result can be interpreted that the slowdown in regional economic growth in aggregate creates pressure on the banking system's stability. This result is in line with previous research conducted by (Shahriar et al., 2023), that less stable macroeconomic environment can suppress the financial sector's resilience. Meanwhile, inflation, with a coefficient of 0,453 and p-value of 0,130, is insignificant for bank stability. Although not significant, the p-value is near the 10% significance level indicates that the increase in inflation is slightly related to the increase in bank stability due to adjustments in interest rates and adaptive risk management strategies.

The Wald chi-square test is used to simultaneously test the significance of all independent variables on banking stability. The results show a chi-square value of 27,57 and a prob>chi2 of 0,0006 < 0,05. Thus, we can say the independent variables in model 1 simultaneously have significant effect on banking stability variations. In addition, the results of the Arellano-Bond test also show no autocorrelation in this model with p-value of second order higher than 5%. To ensure the consistency and validity of the estimation results, a robustness check was also carried out using the One-Step GMM method which is available upon request. The results are consistent with the Two-Step GMM where the stability lag variables, digital transformation, and lagged digital transformation are each significant at the 1% and 10% levels, and GDP is significant at the 5% level. Even in the results robustness test, the significance of the leverage ratio variable becomes p-value 0.060 (p < 10%) from the previous significance at the 5% level. However, the change in the significance of the results has a moderate effect and it is sensitive to estimation method, where One-Step GMM tends to be more affected by the homoscedasticity assumption while Two-Step GMM is more robust against heteroscedasticity, thus producing a smaller and asymptotically efficient standard error.

In short, digital transformation both current and past adoption, leverages ratio management, and macroeconomics factor of a country may influence bank financial stability. While other factors, such as bank size, NPL, and liquidity ratio, do not have a significant effect. This finding implies that the digital transformation strategy must be managed carefully to avoid adverse effects from its implementation, and there is a need to manage bank leverage and sensitivity of macroeconomic conditions to maintain sustainable banking and financial stability.

Table 4. Impact of Income Diversification on Bank Stability

WC-Robust

stability	Coef.	std. err.	z	P>z	[95% conf.	interval]	Sig
lag stability	0.994	0.011	94.660	0.000	0.974	1.015	***

income diversification	-0.721	0.295	-2.440	0.015	-1.298	-0.143	**
Income diversification_sq	1.073	0.435	2.470	0.014	0.220	1.926	**
bank size	-0.005	0.005	-0.870	0.385	-0.015	0.006	
NPL ratio	-0.274	0.535	-0.510	0.609	-1.323	0.775	
liquidity ratio	-0.043	0.047	-0.910	0.362	-0.136	0.050	
leverage ratio	-0.145	0.079	-1.840	0.066	-0.301	0.010	*
GDP growth rate	-0.018	0.007	-2.670	0.008	-0.032	-0.005	***
inflation rate	0.438	0.312	1.400	0.160	-0.173	1.049	
_cons	0.366	0.113	3.250	0.001	0.145	0.587	***

Fitting full model:			
Step 1	f(b) = .0045551	Num of obs	= 720
Step 2	f(b) = .19097364	Num of groups	= 80
Moment conditions:		Linear	= 24
		Nonlinear	= 0
		Total	= 24
Wald chi2 (8)	= 19.81	Arellano–Bond test for zero autocorrelation	
Prob > chi2	= 0.0111	H0: No autocorrelation	
		Order z	Prob > z
		2 1.5332	0.1252
Sargan-Hansen test of the overidentifying restrictions			
H0: overidentifying restrictions are valid			
2-step moment functions, 2-step weighting matrix		chi2(14)	= 15.2779
		Prob > chi2	= 0.3594
2-step moment functions, 3-step weighting matrix		chi2(14)	= 15.3829
		Prob > chi2	= 0.3525

**** p<.01, ** p<.05, * p<.1*

Source: Researcher Processed Results (2025)

The results for model 2, as presented above in table 6, demonstrate that income diversification has a significant impact on banking stability in ASEAN-5 countries. The lagged stability variable in fixed-effect model has coefficient amounting to 0,5857, common-effect model coefficient is 0.9723, and GMM coefficient is 0,9942, indicating that GMM captures the stability dynamics more strongly. However, as it also exceeds the rule of thumb, which is at risk of overestimation. However, the Sargan-Hansen test shows p-values of 0,3594 and 0,3525, both weighting matrixes are above 5% significance, indicating that the model is valid and does not experience overidentifying restrictions.

The regression results show that income diversification affects bank stability, and the lagged stability has a significant positive effect (coefficient 0,994; p-value 0,000), indicating the presence of stability inertia consistent with the result of model 1. The financial stability of ASEAN-5 banks is formed from fundamental conditions and strategic decisions that are consistent over time (Casu, 2021; Shahriar et al., 2023). Based on table 6 above, the primary focus of this model is that income diversification has negative effect with a coefficient of -0,721 and is significant (p-value 0.015) on bank stability at a significance level of 5%. These results indicate that bank stability decreases when the HHI index increases (diversification decreases). This is in line with Portfolio theory, that stated the dependence on one source of income can increase risk due to the lack of risk distribution from various financial activities. Thus, less diversified banks are more vulnerable to economic shocks that affect particular income.

On the other hand, income diversification and bank stability also have a nonlinear relationship that forms a U-shaped curve based on the square value of income diversification, which has positive coefficient of 1,073 and a p-value of 0,014. This indicates that at a very low level of diversification (high HHI index), initial diversification efforts can increase risk because banks face managerial complexity and a lack of experience in multi-income management. However, after reaching a certain level of diversification (decreasing HHI index), bank stability

increases because risks are spread more evenly and dependence on one type of income decreases. This finding is consistent with previous studies conducted by (Liang et al., 2020) and (Shahriar et al., 2023), which emphasize that the impact of diversification depends on the scale, technological readiness, and organizational structure of the bank. These results also support the Financial Stability theory, where banks with optimal income from various sources will be more resistant to economic fluctuations and changes in market conditions (Schinasi, 2004).

For control variables based on bank characteristics, this model is consistent with the previous model, where only the leverage ratio has a marginally negative effect on bank financial stability, as indicated by the coefficient value of -0,145 and p-value of 0,066, which is significant at the 10% level. The results of the study indicate that the greater the proportion of bank funding originating from third-party funds compared to its total assets, the greater the tendency for increased financial risk and market volatility, which can ultimately suppress bank stability. The financial system in ASEAN-5 countries, which is relatively dominated by banks, has high leverage levels that can worsen systemic risk if not accompanied by a substantial capital buffer. This aligns with the Financial Instability Hypothesis (Minsky, H.P., 1992). While the other three bank characteristic control variables, namely bank size, NPL ratio, and liquidity ratio, do not significantly influence financial stability and have not become the main factors determining the financial stability of banks in ASEAN-5 countries.

In this model, only the GDP growth significantly influence bank financial stability. GDP growth has an adverse effect by creating pressure on the banking system's stability as reflected in the coefficient value of -0,018 and a p-value of 0,008, which is significant at the 1% level ($p < 0.01$). These results indicate that the slowdown in economic growth consistently reduces bank stability. This also indicates that the banking sector in ASEAN-5 is still susceptible to the macroeconomic cycle. Meanwhile, inflation does not have a significant effect on bank stability, with a coefficient of 0,438 and a p-value of 0,160, so the relationship between inflation and bank stability is more complex and depends on the success of the monetary policy mix in maintaining price stability.

The results of the Wald chi-square test show a value of 19,81 and are significant at the 1% level (prob>chi2 = 0,0111 <0,05). Although some variables are not significant individually, simultaneously, the independent variables in this model significantly contribute to the variation in bank stability. In addition, the results of the Arellano-Bond test also show no autocorrelation in this model as the p-value on second order is higher than 5%. A robustness check using the One-Step GMM approach is also conducted to ensure the consistency and validity of the estimation results in Model 2 which is available upon request. The estimation results in appendix shows a significance of 5%. Validity of the instrument robustness check was also done by looking at the probability value of the Sargan-Hansen test and the autocorrelation using the Arellano-Bond test both had a significance above 5%, so that the model did not experience any problems: over-identification, autocorrelation, and results robustness check.

Overall, these findings highlight the important role of balanced diversification strategies, and it has a more complex non-linear relationship pattern on bank stability depending on the optimal level of diversification achieved by banking institutions. Banks will feel the benefits of broad income diversification, especially in terms of financial stability, after the level of diversification passes a certain point when accompanied by a mature managerial strategy and effective risk management. However they need to refrain from excessive diversification, which could inadvertently increase systemic risk.

For model 3, comparison of lagged stability variable shows the highest coefficient value in GMM (0,9904), higher than fixed-effect model (0,5901) and common-effect model (0,9692), indicating that the GMM model captures the stability dynamics powerfully. However, it exceeds the rule of thumb and has the potential for overestimation. The Sargan-Hansen test

shows p-values of 0,3960 and 0,1225, indicating no over-identification problem, and the instruments used are valid. The regression results show that lagged stability variable remains significant (coefficient 0,990; p-value 0,000), strengthening the evidence of stability inertia in the ASEAN-5 financial system. This finding supports the arguments of (Casu, 2021) and (Shahriar et al., 2023) that bank stability is persistent and influenced by risk structure and internal policies that are consistent over time.

Table 5. Moderating Role of Income Diversification between Digital Transformation and Bank Stability

WC-Robust

stability	Coefficient	std. err.	z	P>z	[95% conf.	interval]	Sig
lag stability	0.990	0.013	74.020	0.000	0.964	1.017	***
digital transformation	0.001	0.006	0.160	0.873	-0.011	0.013	
income diversification	0.069	0.072	0.960	0.337	-0.072	0.210	
moderating var (DT x Income Div)	-0.086	0.068	-1.270	0.202	-0.219	0.046	
moderating var_sq	0.210	0.107	1.970	0.049	0.001	0.420	**
banksize	-0.003	0.008	-0.390	0.694	-0.019	0.012	
nplratio	-0.201	0.456	-0.440	0.659	-1.095	0.693	
liquidity ratio	-0.042	0.040	-1.060	0.290	-0.119	0.036	
leverage ratio	-0.183	0.079	-2.320	0.020	-0.338	-0.029	**
GDP growth rate	-0.023	0.007	-3.290	0.001	-0.036	-0.009	***
inflation rate	0.317	0.401	0.790	0.430	-0.469	1.103	
_cons	0.270	0.141	1.920	0.055	-0.006	0.547	*

Fitting full model:			
Step 1	f(b) = .02576943	Num of obs	= 720
Step 2	f(b) = .5986208	Num of groups	= 80
Moment conditions:		Linear	= 58
		Nonlinear	= 0
		Total	= 58
Wald chi2 (10)	= 24.07	Arellano–Bond test for zero autocorrelation	
Prob > chi2	= 0.0074	H0: No autocorrelation	
		Order z Prob > z	
		2 1.5471 0.1219	
Sargan-Hansen test of the overidentifying restrictions			
H0: overidentifying restrictions are valid			
2-step moment functions, 2-step weighting matrix		chi2(46)	= 47.8897
		Prob > chi2	= 0.3960
2-step moment functions, 3-step weighting matrix		chi2(46)	= 57.3104
		Prob > chi2	= 0.1225

**** p<.01, ** p<.05, * p<.1*

Source: Researcher Processed Results (2025)

The primary focus of this model is the moderating effect of income diversification on the relationship between digital transformation and bank stability, which is represented by the quadratic interaction variable (moderating var_sq). The moderating variable has a positive and significant influence on Two-Step GMM with a moderation coefficient value of 0,210 and a p-value of 0,049. This indicates a non-linear U-shaped relationship between the moderation of income diversification and the effect of digital transformation on bank financial stability after reaching a certain level of diversification and digitalization. In this case, banks that have effectively diversified their sources of income can drive their financial stability better by optimizing the benefits of digitalization, such as speed of service, automation of risk processes, and increased market access. This result is in line with the Resource-based theory, which supports the idea that combining digital capabilities and adequate business diversification can create a competitive advantage in maintaining financial stability. If managed optimally, integrating digital technology into a diverse revenue structure will support bank resilience to

market changes. In addition, the test results also support the Financial Stability theory, that income diversification moderates the relationship between digital transformation and bank stability, where structured and planned diversification can reduce the negative impacts of digitalization and maintain bank stability (Schinasi, 2004).

These results also support previous studies conducted by (Liang et al., 2020) and (Shahriar et al., 2023), which emphasize that adequate diversification provides income buffers and increases the effectiveness of digital strategies in dealing with financial volatility. In the context of ASEAN-5 facing accelerated digital transformation after the COVID-19 pandemic, integrating digital strategies with diversified income structures is important for bank resilience in the long term. However, this model's main independent variables (digital transformation and income diversification), are not significant individually (p = 0,873 and p = 0,337). This indicates that in model 3, the influence of the two variables depends on the interaction effect. In the interaction regression model, the significance of the primary variable can disappear because its effect depends on the moderator variable's value, so the focus of interpretation shifts to the interaction coefficient.

The control variables again show consistent results with the two previous models, where only the leverage ratio and GDP affect bank stability in ASEAN-5. The leverage ratio has a significant result at the 5% level (p-value 0.020). It has an adverse effect (-0.183), and GDP has a coefficient value of -0.023 with significance at the 1% level (p-value 0.001). Other variables, such as bank size, NPL ratio, liquidity ratio, and inflation rate, also do not show statistical significance in this third model. This indicates that these factors have a limited or indirect effect on financial stability in the observation period. The Wald chi-square test in Appendix 9 shows a value of 24.07 and is significant at the 1% level (prob>chi2 = 0,0074 <0,05). These results indicate that simultaneously, all variables in this model contribute to the variation in bank stability in ASEAN-5. The results of the Arellano-Bond test have a value of 1,5471 and a significance value of 0,1219 (p> 0,05), so there is no autocorrelation in this model.

Finally, a robustness check using One-Step GMM was also done to ensure the consistency and validity of the model estimation results. The estimation results which is available upon request show consistent evidence that the moderation variable remains statistically significant with a coefficient of 0,214 (p = 0,052), which is significant at the 10% level. The validity of the instrument for a robustness check can be seen from the probability of the Sargan-Hansen test, which has a value above the 5% significance level, and the autocorrelation in the model shows the Arellano-Bond test value, which has a significance above 5% as well. So, the robustness check further strengthens the finding that the two variables have a significant synergistic effect on bank stability.

Thus, this result further strengthens the finding that income diversification positively moderates the effect of digital transformation on bank stability. It indicates that the effectiveness of digitalization in strengthening stability depends on the extent to which bank revenue has been optimally differentiated. Therefore, the relationship between digital transformation, income diversification, and bank financial stability forms a complex non-linear relationship pattern, and banks require a balanced strategic approach, where they can take advantage of both digital transformation and income diversification to strengthen their financial stability in an increasingly dynamic and technology-driven financial environment.

Based on the empirical findings in Equations 1, 2, and 3, digital transformation and income diversification play important and complementary roles in shaping bank stability in ASEAN-5 emerging economies. These findings give insight on how internal strategic goals interact with broader macroeconomic factors that influence financial resilience. The next section summarizes the main findings, acknowledges the study's limitations, and outlines future research directions that will improve our understanding of banking stability dynamics in an increasingly digitalized banking system.

CONCLUSION

This study explores the impact of digital transformation and income diversification on banking stability in ASEAN-5 emerging countries over the period 2014–2023 using GMM approach. The results demonstrate that digital transformation plays a crucial role in strengthening banking stability through increased operational efficiencies and better risk management, in line with principles of resource-based theory and innovation theory. However, the advantages of digital transformation are not apparent immediately, reflected by its negative impact at the beginning of implementation due to high costs and transition risks. However, it takes time for digital transformation to improve efficiency and financial stability, which aligns with the resource-based theory and Schumpeterian innovation. Income diversification shows a non-linear effect to bank stability. At the initial level, diversification reduces stability due to management complexity, but after reaching an optimal point, stability increases because risks are spread out. The moderating effect of revenue diversification strengthens the positive effect of digital transformation on bank stability, indicating that integrating digital strategies and diverse revenues creates stronger financial resilience.

Despite providing valuable insight, this study has several limitations. First, the measurement of digital transformation through capitalized software expenditures may not cover a wide variety of digital initiatives, including cybersecurity improvements or digital customer engagement. Second, although the study addresses endogeneity concerns by using system GMM, potential measurement errors in variables, particularly in cross-country financial reporting practices, could affect the findings. Third, the study excludes Islamic bank and smaller financial institutions that might have different stability dynamics.

Future research may expand the focus by including alternative measures of digital transformation, such as FinTech adoption rates or digital banking indices, and by examining how cybersecurity risks and regulatory frameworks moderating the relationship between digitalization and stability. Furthermore, studies comparing developed and emerging markets may provide wider generalization of the results. As digital transformation continues to reshape the financial sector, understanding its relationship to strategic income diversification will remain critical for sustaining banking stability in an in an increasingly complicated financial landscape. These research results can be the basis for making adaptive banking policies and strategies amidst the challenges of the digital economy in the ASEAN region.

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