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Financial inclusion and bank risk-taking in Southeast Asia: A comprehensive analysis of traditional and digital dimensions

Hien Anh Nguyen[1], Duc Hoang Le[2], Thanh Tam Le[3*]

[1]*International School of Management and Economics, National Economics University, Hanoi, Vietnam.*
[2]*College of Technology, National Economics University, Hanoi, Vietnam.*
[3]*School of Banking and Finance, National Economics University, Hanoi, Vietnam.*

Corresponding author: Thanh Tam Le (*Email: tamlt@neu.edu.vn*)

Abstract

This paper aims to examine the impact of both traditional financial inclusion (FI) and digital financial inclusion (DFI) on bank risk-taking, particularly in the context of Southeast Asia, where this relationship remains ambiguous. Financial inclusion plays a crucial role in advancing the 17 UN Sustainable Development Goals by enhancing livelihoods, reducing poverty, and stimulating economic growth. However, its implications for financial stability are still under debate, especially with the rapid emergence of digital financial services. This research collected data from 76 commercial banks across Southeast Asian countries. The research team applied the methodology of Principal Component Analysis (PCA) to construct composite indices for both traditional (FI) and digital dimensions (DFI) of financial inclusion, followed by regression analysis to investigate their respective effects on bank risk-taking behavior. The key results are: (i) traditional financial inclusion tends to reduce bank risk-taking, whereas digital financial inclusion initially increases risk; (ii) however, this positive relationship is projected to reverse as digital ecosystems mature and regulatory frameworks strengthen. Based on these results, the recommendations are: first, governments and central banks should continue to promote both traditional and digital financial inclusion initiatives. Second, they must remain alert to potential risks during the digital transition. Third, commercial banks should enhance digital financial literacy and improve institutional quality to ensure that financial inclusion contributes to reduced bank risk-taking in the long term.

Keywords: Default risk, Digital financial inclusion, Financial inclusion, Leverage risk, Portfolio risk, Southeast Asia.

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1. Introduction

Financial inclusion involves providing financial services, such as bank accounts, credit, savings, and insurance, to all members of society, including vulnerable populations, to improve welfare, reduce poverty, and promote economic growth [1, 2]. As a catalyst for achieving the 17 UN Sustainable Development Goals, financial inclusion has been extensively studied regarding its economic and social impacts; but as Umar and Akhtar [3] point out that very few studies have examined how financial inclusion affects bank risk-taking.

This gap is particularly significant for emerging economies in Southeast Asia because many of them prioritize financial inclusion to combat poverty and boost economic growth, but overlook its potential trade-offs – financial market instability [4]. While existing research suggests financial inclusion may either reduce bank risks through the diversification effect [3, 5] or increase them through information asymmetry [6, 7], no study has looked at how both traditional and digital financial inclusion affects bank risk-taking, especially in the Southeast Asian region.

This study focuses on how both traditional and digital financial inclusion together affect bank risk-taking in Southeast Asian developing countries, using [8]'s comprehensive measurement framework. This is used as the foundation for this paper analysis because [8] is the first and only measurement to integrate both traditional and digital financial elements into one index, through principal component analysis (PCA) measure. This research addresses this core question: "Does financial inclusion and digital financial inclusion affect commercial banks' risk-taking in Southeast Asian countries?" by investigating three dimensions: default risk, leverage risk, and portfolio risk. This study is structured into five sections. Section 2 provides a review of the relevant literature; Sections 3 and 4 outline the research methodology and present the key findings, respectively; and Section 5 offers the conclusion along with policy implications.

2. Conceptual Framework and Hypotheses Development

2.1. Bank Risk-Taking

Bank risk-taking refers to the level of uncertainty a bank is able and willing to tolerate during its operations [9-11]. Banks take risks to generate equivalent returns and remain competitive [5]. The theory of risk-taking behavior by Le Maux [12] suggests that institutions take risks to ensure their long-term survival. However, risk tolerance varies for each bank, depending on factors such as asset quality, market competition, strategy, etc [5, 13].

Analyzing bank risk-taking is crucial for each bank's sustainability, financial stability and economic health [5]. Firstly, excessive risk-taking is a major cause of financial instability; as seen in 2008, it led to systemic failures [14, 15]. Secondly, understanding risk-taking behavior helps commercial banks manage risks effectively, ensuring an uninterrupted provision of capital and financial services, thereby fostering stable economic development [16]. Thirdly, policymakers use this knowledge to set appropriate capital buffers and supervision mechanisms to mitigate systemic risks [5]. Finally, stakeholders used bank risk-taking analysis to make informed decisions. While shareholders seek higher returns through riskier strategies, bondholders and depositors prefer stability [17].

2.1.1. Measurements of Bank Risk-Taking

According to Srivastav and Hagendorff [18] Banna et al. [19] and Zhao et al. [20], bank risk-taking levels are commonly assessed using three key proxies: default risk (DR), leverage risk (LR), and portfolio risk (PR). These indicators provide a comprehensive view of a bank's risk exposure and financial stability.

2.1.1.1. Default Risk

Default risk is measured using the Z-score, which is calculated as:

Z-score = - (ROAA + capital to assets ratio) / σ (ROAA)

Default risk is an inverse proxy that measures risks from both investment and financing activities of commercial banks. A higher Z-score indicates lower bank risk-taking, and the bank is more stable [21, 22]. To simplify empirical models, we multiplied the Z-score by (-1) to ensure a direct relationship between higher values and greater risk-taking [5, 23, 24].

2.1.1.2. Leverage Risk

Leverage risk is measured by the equity-to-asset ratio divided by ROAA volatility:

Leverage risk = - Equity over asset /σ (ROAA)

This ratio reflects the extent to which a bank relies on external borrowing rather than its own capital. A lower capital buffer increases leverage risk, making banks more vulnerable to financial distress. High-quality (Tier 1) capital and risk-adjusted capital ratios are commonly used to assess leverage risk [25].

2.1.1.3. Portfolio Risk

Portfolio risk measures the volatility of asset returns resulting from investment activities. In the context of commercial banks, it refers to the credit risk arising from lending activities and other credit exposures of a bank [26]. Portfolio risk is calculated as:

Portfolio risk = - ROAA/σ (ROAA)

A higher portfolio risk value indicates greater instability in returns. Alternative measures include the risk-weighted assets-to-assets ratio, which accounts for the composition of risky assets in a bank's portfolio [27-29].

2.2. Financial Inclusion and Digital Financial Inclusion

Financial inclusion (FI) refers to the provision of financial services, such as bank accounts, credits, and savings, especially for underserved groups, in a timely, fair, and cost-effective manner [2]. FI enhances the welfare of citizens, eradicates poverty, and facilitates economic growth [1]. Moreover, FI is found to support green growth, which is economic growth without sacrificing environmental aspects [30].

Digital financial inclusion (DFI) extends financial inclusion (FI) through cost-effective digital solutions, enabling remote and cashless transactions [5]. Since 2014, DFI has been declared a "game-changing" development in the banking sector, facilitating inclusive growth [31]. This transition was accelerated and became even more pronounced due to lockdowns and other preventative measures during the COVID-19 pandemic.

2.2.1. Impacts of Financial Inclusion and Digital Financial Inclusion on Bank Risk-Taking

FI affects bank risk-taking through two mechanisms: (1) stabilizing banks' funding bases and (2) expanding target borrowers. Firstly, FI reduces liquidity risk in commercial banks by stabilizing deposits and loan bases Almaleeh [32]. Ahamed and Mallick [33] explained that financial inclusion allows banks to obtain cheaper retail deposits, which reduces their reliance on more volatile wholesale funding sources. This stability in funding lessens the pressure on banks to engage in high-risk lending practices, thereby facilitating a more conservative risk profile for commercial banks. Banna and Alam [5] further note that DFI reduces default and leverage risks while increasing financial mobility, particularly during crises. Secondly, FI can also affect commercial bank risk-taking by broadening banks' customer base. Financial intermediation theory [34] suggests that banks, as financial intermediaries, pool deposits into one large account and lend them to many different places. This helps diversify risk and manage debt better. Diversification theory [35] suggests that diversifying investments helps to minimize unsystematic risk in a portfolio. Financial inclusion helps expand the customer base of commercial banks, thereby strengthening the financial intermediation function of commercial banks and helping them benefit from diversification theory [36-38].

However, some studies indicate a positive relationship between FI and bank risk, particularly for unlisted banks [3]. Asymmetric information theory [39] explains that information asymmetry between borrowers and lenders increases moral hazard and adverse selection, thereby raising credit risks [7]. Additionally, while access to savings accounts enhances financial stability, unchecked credit expansion may weaken it [6]. In the Southeast Asia context, broader financial inclusion may come with adverse borrower selection, which means commercial banks bear a higher probability of lending to people who cannot pay them back [40].

Hypothesis 1: Financial inclusion positively affects bank risk-taking

DFI is also argued to have an effect on commercial bank risk-taking behaviors. Sajid et al. [41] claimed that by enhancing bank risk-taking flexibility, DFI enables banks to recover from financial losses and bounce back to a stable state sooner. Zhao et al. [42] explained that DFI improves the risk-bearing capacity of commercial banks through two channels: diversifying banks' revenue sources and improving customer credit evaluation in banks. Firstly, DFI expands the utilization of financial products and creates more flows of surplus funds for commercial banks, hence discouraging them from taking excessive risks in lending activities. Secondly, digital technology is used in banks' management and operational tasks, helping them improve the efficiency in customer creditworthiness evaluation, hence correctly restricting the credit amount for each customer. According to Banna et al. [19], at initial stages, DFI may intensify competition within the banking sector due to the participation of new fintech firms entering the market. This may force commercial banks to shift to riskier sectors to retain market share. However, as DFI progresses, operational efficiency improves, and bank risk-taking is reduced. Hence, DFI and bank risk-taking have an inverted U-shaped relationship.

Hypothesis 2: Digital financial inclusion positively, then negatively affects bank risk-taking

2.2.2. Measurement of FI and DFI

This research used the financial inclusion index proposed by Khera et al. [8], which integrates both traditional and digital financial elements. This index uses principal component analysis (PCA) to consolidate various relevant indicators into two key sub-indices: (1) Supply-side (ACCESS) index, which measures the availability of financial services; and (2) Demand-side (USAGE) index, which captures the extent to which individuals and businesses utilize financial services. Subsequently, these two indices are aggregated into the comprehensive digital financial inclusion index (DFI). The use of PCA helps address issues of multicollinearity and over-parameterization in the dataset, ensuring a more accurate and reliable measurement of financial inclusion Ahamed and Mallick [33]. Nguyen [43] has proven that this PCA comprehensive FI index is multidimensional, easy to explain, and well-suited for comparison over time and across many countries.

2.3. Impacts of Other Factors on Bank Risk-Taking

This study divided the control variables that influence bank risk-taking into two groups: internal and external factors.

2.3.1. Factors from Banks

2.3.1.1. Bank Size

Bank size, measured by the log of banks' total assets, has little effect on banks' univariate risk, but notable effect on banks' systemic risk [44]. Large banks tend to have significantly higher systemic risk than small banks. This suggests that, while bank size may not directly correlate with univariate risk, it does contribute to broader systemic vulnerabilities within

the banking sector. Another study supporting this idea is by Galletta and Mazzù [45] who explained that larger banks may have more complex asset structures that could influence their risk profiles.
Hypothesis 3: Bank size positively affects bank risk-taking

2.3.1.2. Profitability

Return on average assets (ROAA) is calculated by dividing net income by average total assets. Banks with higher profitability tend to engage in riskier lending practices because they have more resources to absorb potential losses [46]. However, this relationship is not strictly linear, and banks must navigate the trade-off between maximizing profit and managing risk effectively [47].
Hypothesis 4: Profitability positively affects bank risk-taking.

2.3.2. External Factors

2.3.2.1. GDP Growth Rate

According to Kidane [48], an economy with increasing GDP typically has lower credit risk as firms and households have better financial stability, leading to lower default rates on loans. Umar and Akhtar [3] also found that economic expansion enhances borrowers' repayment capacity. On the contrary, during economic downturns, banks face heightened credit risks due to declining incomes and increased defaults [49]. Moreover, over-optimism during economic booms tempts banks to engage in riskier lending practices, which can lead them to financial distress when economic conditions deteriorate [50].

Hypothesis 5: GDP growth rate negatively affects bank risk-taking

2.3.2.2. Inflation

Inflation is measured by the annual Consumer Price Index (CPI). Higher inflation erodes the purchasing power of borrowers and increases the likelihood of loan defaults Ngoc Nguyen [16]. Babouček and Jančar [51] emphasized that high inflation often leads banks to take on more risk due to the erosion of asset values and the need for higher returns. Inflationary pressures can also trigger policy changes, such as tighter monetary policies, which may further affect the risk-taking behaviors of banks [52].
Hypothesis 6: Inflation positively affects bank risk-taking

2.3.2.3. Institutional Quality

This research used the institutional quality index as the average value of control of corruption, government effectiveness, political stability, regulatory quality, rule of law, and voice and accountability. This combined factor plays a crucial role in shaping bank risk-taking behavior. Strong institutional frameworks enhance transparency and reduce uncertainties, hence discouraging commercial banks from taking excessive risks. Porta et al. [53] stated that effective governance ensures the enforcement of contracts, thereby helping economic activities become more predictable and fostering financial stability. According to Demirgüç-Kunt et al. [54] regulatory frameworks with higher institutional quality indices have higher fines for non-compliance, which deters excessive risk-taking behaviors of banks and enhances market discipline. Conversely, environments with lower institutional quality indices, characterized by corruption, political instability, and ineffective regulation, are associated with higher risk-taking by banks due to lax oversight and the pursuit of short-term profits [55].

Hypothesis 7: Institutional quality negatively affects bank risk-taking

2.4. Conceptual Framework Figure

Based on the literature synthesis above, the conceptual framework is illustrated in Figure 1.

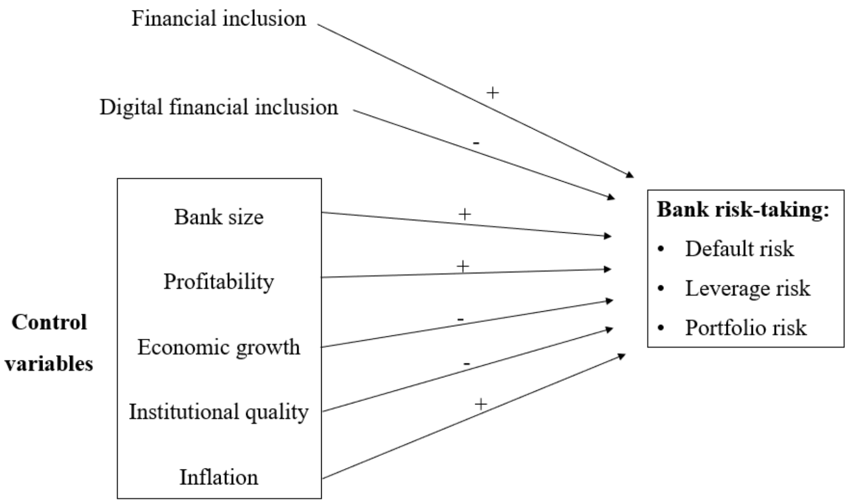

Figure 1.
Conceptual framework

3. Methodology

3.1. Data

This study employs a panel data analysis approach using data from 76 commercial joint-stock banks (Appendix 1) across nine Southeast Asian countries (Vietnam, Philippines, Singapore, Thailand, Cambodia, Laos, Malaysia, Myanmar, Indonesia) over four years: 2011, 2014, 2017, and 2021. Brunei and Timor-Leste were excluded from this research due to the unavailability of FI and DFI data in these two countries.

The data is collected from various databases and international organizations, such as the IMF database, ICT Indicators database, the Financial Access Survey, and the World Bank database. All variables are briefly mentioned in Table 1. Some FI and DFI components from the Global Findex Database of the IMF are available only once every three to four years. Consequently, this study includes only the four most recent reporting years (2011, 2014, 2017, and 2021), with observations from other years removed from the dataset.

Table 1.
Summary of hypotheses and variables in the regression model.

Variable	Notation	Measurement	Expectation Sign	Research
Dependent Variable				
Default risk (Z-score)	DR	Z-score = (ROAA + capital to assets ratio) / σ (ROAA)		
Leverage risk	LR	Leverage risk = Equity over asset /σ (ROAA)		
Portfolio risk	PR	Portfolio risk = ROAA/σ (ROAA)		
Independent Variables				
Financial inclusion	FI	PCA	+	Banna and Alam [5], Almaleeh [32], Ahamed and Mallick [33], Umar and Akhtar [3], Hadi et al. [36], Farid [37], Ghasarma et al. [38], Musau et al. [7] and Feghali et al. [6]
Digital financial inclusion	DFI	PCA	-	Banna and Alam [5] and Sajid et al. [41]
Bank size	A	Log of banks' total assets	+	Pais and Stork [44] and Galletta and Mazzù [45]
Profitability	ROAA	Return on average assets (ROAA)	+	De Leon [46] and Xue et al. [47]
Economic growth	GDP	GDP growth rate	-	Kidane [48], Umar and Akhtar [3] and Hidayat [49]
Inflation	I	Percentage change in Consumer Price Index (CPI)	+	Jancar [56] and Nguyen and Dinh [57]
Institutional quality	Ins	Average value of control of corruption, government effectiveness, political stability, regulatory quality, rule of law, and voice and accountability	+	Pais and Stork [44] and Musau et al. [7]

The FI and DFI index are calculated through principal component analysis. Table 2 shows all components included in the calculation.

Table 2.
FI and DFI index components.

		Components
Traditional financial inclusion	Supply	Number of ATMs per 100,000 adults
		Number of Branches per 100,000 adults
	Demand	% of adults with a financial institution account
		% of adults who save at a financial institution
		% of adults with debit cards
		% of adults who received wages through a financial institution account
		% of adults who use a financial institution account for utility
Digital financial inclusion	Supply	Mobile subscription per 100 people
		% of the population who have access to the internet
		Number of registered mobile money agents per 100,000 adults
	Demand	% of adults who have a mobile account
		% of adults who use internet to pay
		% of adults who use mobile phone to receive salary or wages
		% of adults who use mobile phone to make utility payments

Because of data unavailability within the selected research scope, the number of registered mobile money agents per 100,000 adults was omitted from the calculation of DFI.

3.2. Methodology

The study used multiple regression models to analyze the trend and degree of how which financial inclusion and digital financial inclusion affect commercial banks' risk-taking levels. Data was processed using Stata 14. The baseline equation is produced as follows:

$$\text{Bank risk-taking}_{it} = \alpha + \beta_1 FI_{it} + \beta_2 DFI_{it} + \beta_3 A_{it} + \beta_6 ROAA_{it} + \beta_7 GDP_{it} + \beta_8 I_{it} + \beta_9 Ins_{it} + U_{it}$$

where:

Bank risk-taking: measured by default risk (DR), leverage risk (LR), and portfolio risk (PR). This variable represents the risk-taking of commercial banks in year t.

i = 1,…,N for each cross section; t = 1,…,N for time periods of the study; α = intercept; β_s = slope; and U = error term

Firstly, we used the Ordinary Least Squares (OLS) estimation to obtain the initial assessment of the relationship between variables. Then, we used Fixed Effects (FEM) estimation to include individual-specific fixed effects in the model and eliminate the effects of time-invariant unobserved heterogeneity [58]. After that, we used the modified Wald statistic to test groupwise heteroskedasticity in the residuals of FEM [59] and Wooldridge's test to test autocorrelation in panel data [60]. The results of these two tests indicated that the panel data exhibits heteroskedasticity but no first-order autocorrelation. Therefore, Feasible Generalized Least Squares (FGLS) estimation is employed to fit the linear model to the dataset. FGLS is suitable for data with more time periods than cross-sections; it addresses serial correlation and slope heterogeneity in standard regression models [61].

This study examined two variations of the FGLS model: FGLS with panel heteroskedasticity and standard errors assuming an AR(1) error, and FGLS with panel heteroskedasticity only. We compared their prediction accuracy using mean squared error. The model with panel heteroskedasticity only demonstrated a lower mean squared error, indicating it is the better fit.

4. Findings

4.1. Descriptive Statistics

Table 3.
Descriptive statistics.

Variable	Observations	Mean	Std. Dev.	Min	Max
DR	300	-1.47	0.31	-2.53	-0.68
LR	300	-3.24	3.32	-26.51	-0.40
PR	300	-3.47	2.37	-15.90	1.23
FI	230	0.00	1.22	-2.04	2.00
DFI	215	0.00	1.31	-3.08	3.32
A	300	16.04	2.22	9.19	20.05
ROAA	300	0.01	0.01	-0.04	0.04
GDP	300	0.05	0.03	-0.12	0.10
Inflation	300	0.04	0.03	0.01	0.19
Ins	300	-10.55	36.03	-161.73	1.62

There are 300 observations overall, but only 215 observations have complete data on all variables. Traditional financial inclusion (FI) and digital financial inclusion (DFI) variables have the most missing data. The three bank risk-taking dimensions, default risk (DR), leverage risk (LR), and portfolio risk (PR) have been multiplied by (-1) to ensure a direct relationship between higher values and greater risk-taking. Consequently, all values of bank risk-taking are negative. Default risk has the highest mean (-1.47) and the lowest standard deviation (0.31), compared with the other two risks. Thus, default risk consistently has the highest probability of occurring across banks in the sample. The ranges of leverage risk and portfolio risk are quite wide; this may suggest heterogeneity error in the dataset. This suspicion will be tested econometrically in the model specification part.

Both FI and DFI means are negative and close to zero. Negative values occurred because the PCA method reflects the linear combinations of the data points relative to their new mean axes of zero. However, DFI has a greater standard deviation (1.31), indicating that the widespread use of digital banking services in countries varies significantly. This dataset includes commercial banks of various sizes, ranging from 9 thousand to 508 million. The average ROAA is 1.31%, with the smallest value of -3.58%. Thus, some commercial banks perform poorly relative to their asset size. The average GDP growth rate of nine Southeast Asian countries over four years is 4.74%, with 2017 having the highest mean GDP growth of nearly 6%. The GDP growth rate shows substantial variation, from -12.02% to 9.69%, reflecting diverse economic conditions across countries in Southeast Asia. Similarly, inflation averaged 3.92%, with values ranging from 0.58% to 18.68%. The average value of the institutional quality index (Ins) is -10.55, with a variation of 36.03, indicating that institutional quality in Southeast Asia is quite unstable, and this condition varies significantly among the nine countries. Myanmar has the lowest institutional quality index, with an average of -129.7, while all other countries' indexes hover around -0.11. Overall, among all variables, only the institutional quality variable has outliers; therefore, the dataset is acceptable for overall assessment.

4.2. Correlation Coefficient Analysis

Table 4.
Correlation matrix.

	DR	LR	PR	FI	DFI	A	ROAA	GDP	Inflation	Ins
DR	1.00									
LR	0.80	1.00								
PR	0.78	0.66	1.00							
FI	-0.45	-0.25	-0.28	1.00						
DFI	-0.31	-0.14	-0.16	0.70	1.00					
A	-0.28	-0.10	-0.25	0.41	0.32	1.00				
ROAA	-0.03	-0.10	-0.29	-0.09	-0.11	-0.06	1.00			
GDP	-0.06	-0.03	-0.06	-0.14	-0.27	-0.08	0.06	1.00		
Inflation	0.22	0.07	0.10	-0.57	-0.62	-0.29	0.09	0.22	1.00	
Ins	-0.34	-0.19	-0.24	0.50	0.44	0.10	0.15	0.32	-0.38	1.00

This table displays the Pearson correlation, which indicates the strength of the linkage between two variables. The colors represent the strength of the correlations: red signifies a strong correlation, yellow indicates a moderate correlation, and green denotes weak or no correlation. Default risk, leverage risk, and portfolio risk exhibit strong positive correlations with each other, with correlation coefficients ranging from 0.66 to 0.8. This is because the calculations of these risk measures are quite similar. However, this does not pose a problem for the estimation of the regression models, as each model includes only one of these variables as a dependent variable. FI and DFI have a strong correlation of 0.7, and both are negatively correlated with all risk measures. This suggests that countries with a high traditional financial inclusion index tend to also have high digital financial inclusion indexes. FI shows stronger negative correlations with risk measures (-0.45, -0.25, -0.28) compared to DFI (-0.31, -0.14, -0.16). Therefore, while both traditional and digital financial inclusion may be associated with lower bank risk-taking, the relationship is stronger for traditional financial inclusion. Institutional quality (Ins) has positive correlations with both financial inclusion measures (0.50 with FI and 0.44 with DFI), indicating that a more stable and transparent regulatory framework may promote greater financial inclusion. Bank size shows a negative correlation with all risk measures, particularly default risk (-0.28) and portfolio risk (-0.25). This suggests that larger banks may be less prone to taking excessive risks.

Table 5.
Result for VIF test.

Variable	VIF	1/VIF
FI	2.57	0.38946
DFI	2.56	0.390223
Ins	2.23	0.447461
Inflation	1.82	0.549994
GDP	1.68	0.594842
A	1.36	0.73274
ROAA	1.1	0.90887
Mean VIF	1.9	

The variance inflation factor test measures the strength of the correlation between regression variables. All VIF values are below 10, with the highest values being for FI (2.57) and DFI (2.56). Therefore, there are no multicollinearity issues or significant bias in the dataset.

4.3. Regression Results

This study adopted Feasible Generalized Least Squares (FGLS) estimation to address the groupwise heteroskedasticity problem in the residuals. What distinguishes this study from previous research on the relationship between digital financial inclusion (DFI) and bank risk-taking is the inclusion of the first-differenced squared term of DFI ($\Delta(DFI^2)$) in the models to test the hypothesized non-linear relationship. This modification enables examination of whether the DFI–bank risk-taking relationship follows an inverted U-shaped pattern. All FGLS model results are compared with basic OLS with robust standard errors and OLS with clustered standard errors to assess robustness. The sign of all coefficients remained consistent across models, providing strong evidence of robustness in our FGLS models and indicating that the empirical results are reliable.

Table 6.
Regression models and results.

Variable	DR1	LR1	PR1
FI	-0.12332651***	-1.1213761***	-0.35102542***
DFI	0.06374827***	0.80527638***	-0.07669886
delta_DFI2	-0.01071115	-0.10369696*	0.08139026*
A	-6.128e-10***	-1.917e-09***	-4.876e-09***
ROAA	-0.41686372	35.828633***	-65.306897***
GDP	1.2342726**	15.042611***	3.9414809*
I	-6.0161036***	-50.246516***	-15.078807*
Ins	-0.00271117***	-0.02271453***	-0.01041589***
_cons	-1.3935519***	-3.3631029***	-2.0053638***

Note: (legend: * p<0.05; ** p<0.01; *** p<0.001)).

Table 7.
Model comparison for robustness check).

Variable	DR1	DR_ols_ robust	DR_ols_ clustered	LR1	LR_ols_ robust	LR_ols_ clustered	PR1	PR_ols_ robust	PR_ols_ clustered
FI	-0.123 (0.006)	-0.507 (0.275)	-0.120 (0.040)	-1.121 (0.087)	-1.152 (0.496)	-1.152 (0.573)	-0.351 (0.087)	-0.507 (0.275)	-0.507 (0.300)
DFI	0.064 (0.016)	0.089 (0.345)	0.064 (0.057)	0.805 (0.124)	1.032 (0.593)	1.032 (0.757)	-0.077 (0.108)	-0.089 (0.345)	-0.089 (0.389)
delta_DFI2	-0.011 (0.005)	-0.014 (0.106)	-0.012 (0.012)	-0.104 (0.033)	-0.151 (0.126)	-0.151 (0.100)	0.081 (0.034)	0.019 (0.106)	0.019 (0.087)
A	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)	-0.000 (0.000)
ROAA	-0.417 (0.882)	-73.265 (26.019)	-0.975 (2.412)	35.829 (9.172)	50.324 (48.357)	50.324 (59.414)	-65.307 (12.046)	-73.265 (17.634)	-73.265 (22.428)
GDP	1.376 (1.234)	17.634 (4.814)	5.187 (1.264)	15.043 (2.576)	17.158 (10.614)	17.158 (13.321)	3.941 (2.006)	4.814 (5.127)	4.814 (5.799)
I	-6.016 (0.435)	-30.804 (5.127)	-6.430 (1.063)	-50.247 (7.316)	-52.111 (42.250)	-52.111 (27.422)	-15.079 (6.985)	-30.804 (5.127)	-30.804 (8.054)
Ins	-0.003 (0.002)	-0.011 (0.006)	-0.003 (0.001)	-0.023 (0.004)	-0.024 (0.012)	-0.024 (0.016)	-0.010 (0.002)	-0.011 (0.006)	-0.011 (0.007)
_cons	-1.394 (0.026)	-1.750 (0.736)	-1.366 (0.140)	-3.363 (0.208)	-3.720 (1.540)	-3.720 (1.670)	-2.005 (0.239)	-1.750 (0.736)	-1.750 (0.795)
N	139	139	139	139	139	139	139	139	139
r^2		0.197	0.281		0.115	0.115		0.197	0.197

The coefficient of FI is significant and negative in all three models, indicating that financial inclusion has a negative relationship with all dimensions of bank risk-taking. Specifically, FI exhibits coefficients of -0.12 for default risk (significant at $p<0.001$), -1.12 for leverage risk (significant at $p<0.001$), and -0.35 for portfolio risk (significant at $p<0.001$). This result suggests that commercial banks in countries with a higher level of traditional financial inclusion tend to take less risk. Therefore, we reject hypothesis 1 that financial inclusion positively affects bank risk-taking.

In contrast to FI, DFI coefficients are only significant in two out of three models, and their signs are positive. DFI appears to have a positive relationship with default risk in the first model (DR1), with a coefficient of 0.06, and leverage risk in the second model (LR1), with a coefficient of 0.81. No significant relationship is found between DFI and portfolio risk. These mixed results suggest that DFI may increase bank risk-taking, but only certain types, particularly default risk and leverage risk. The positive relationship between DFI and risks might also reflect the expansion of financial services to previously underserved populations through digital channels, which could initially increase risk exposure before risk management systems fully adapt. This regression result confirms Hypothesis 2: Digital financial inclusion increases bank risk-taking in its initial stage of implementation.

Bank size (A) coefficients are significant and negative in all models, indicating that larger banks are associated with less risk-taking. Consequently, we reject the third hypothesis, which states that bank size positively affects bank risk-taking. Profitability, measured by ROAA, is significant in leverage risk and portfolio risk models. While it has a positive coefficient for leverage risk (35.83), its coefficient in the portfolio risk model is negative (-65.31). This result suggests that more profitable banks tend to take more leverage risk and less portfolio risk. Therefore, this study rejects hypothesis 4 because the effect of profitability on bank risk-taking is more nuanced than a simple positive relationship.

Inflation (I) demonstrates a significant, negative impact on all dimensions of commercial banks' risk-taking, while GDP growth rate does not have any significant relationship with bank risk-taking at all. Thus, we reject both hypothesis 5 (GDP growth rate negatively affects bank risk-taking) and hypothesis 6 (Inflation positively affects bank risk-taking). Institutional quality (Ins) coefficients are significantly negative in all models, so this variable has a negative relationship with all dimensions of bank risk-taking. This result suggests that banks in more volatile regulatory environments tend to have less risk-taking behavior than banks in other areas. Hence, we reject the final hypothesis that competitiveness positively affects bank risk-taking.

Table 8.
Summary of hypotheses and actual results.

Variable	Hypothesis	Actual result	Conclusion
Financial inclusion	Financial inclusion positively affects bank risk-taking	Financial inclusion negatively affects bank risk-taking	Not support
Digital financial inclusion	Digital financial inclusion positively, then negatively affects bank risk-taking	Digital financial inclusion positively affects bank risk-taking	Support
Bank size	Bank size positively affects bank risk-taking	Bank size negatively affects bank risk-taking	Not support
Bank profitability	Profitability positively affects bank risk-taking	Profitability increases leverage risk, but decreases portfolio risk	Not support
GDP growth rate	GDP growth rate negatively affects bank risk-taking	Not statistically significant	No conclusion
Inflation	Inflation positively affects bank risk-taking	Inflation negatively affects leverage risk	Not support
Institutional quality	Institutional quality negatively affects bank risk-taking	Institutional quality negatively affects bank risk-taking	Support

5. Discussions

5.1. Key Findings

5.1.1. Traditional Financial Inclusion

The regression results indicate that traditional financial inclusion negatively impacts bank risk-taking across all risk dimensions: default, leverage, and portfolio risk. This negative relationship is explained through two mechanisms: funding base stabilization [33] and diversification benefit [34]. In the first mechanism, financial inclusion helps banks access cheaper and more stable retail deposits and reduces their dependence on volatile wholesale funding. Hence, it reduces bank risk-taking. In the second mechanism, financial inclusion expands commercial banks' customer bases, thereby diversifying their loan portfolios and reducing bank risk-taking. This finding is consistent with previous research. Almaleeh [32] and Ahamed and Mallick [33] studies, which also found a negative relationship between traditional financial inclusion and bank risk-taking.

In contrast, this negative relationship differed from Umar and Akhtar [3], which stated a positive relationship between financial inclusion and risk in unlisted banks. This divergence could be because 71 out of 76 commercial banks in this research are listed on stock exchanges; hence, they must retain a more robust risk management framework. Additionally, the concerns about adverse borrower selection [40] do not materialize in this research scope. This may be because financial literacy has increased simultaneously with financial inclusion in Southeast Asia from 2014 to 2021 [62]. As borrowers become more financially knowledgeable, they are more likely to demand more financial services, use them more wisely, and are less likely to take out loans that they cannot repay [63, 64]. This helps reduce the adverse selection problem and the risk level for banks [33]. In summary, this study's results suggest that the government, central banks, and commercial banks should continue expanding financial inclusion because this factor helps reduce bank risk-taking and ensures stability in banking systems.

5.1.2. Bank Size

The empirical results of this study reject hypothesis 3, demonstrating a negative relationship between bank size and bank risk-taking. This conclusion differs from Pais and Stork [44], who stated that larger institutions face higher systemic risk. Hoang et al. [65] explained this negative relationship because larger banks tend to have larger boards, more deliberation on risk control, hence reducing extreme risk-taking behaviors. This negative relationship could also be because bigger banks benefit from economies of scale, which allow them to diversify their investments and reduce their overall risk level [66].

5.1.3. Inflation

Inflation coefficients are only significant in leverage risk models, so the inflation rate and leverage risk have a significant, negative relationship. This result rejects hypothesis 6 that the inflation growth rate positively affects bank risk-taking. This contradicts [51] the positive relationship between inflation and bank risk-taking. They explain it because high inflation often leads banks to take on more risk due to the erosion of asset values and the need for higher returns. This unexpected result suggests the opposite direction of the argument: an inflationary environment makes commercial banks more conservative in their operations, hence reducing their risk levels.

5.1.4. Profitability

This research partially confirms hypothesis 4 regarding the positive relationship between profitability and bank risk-taking. Specifically, the empirical results show that higher ROAA is associated with higher leverage risk but lower portfolio risk. Thus, the relationship in the context of Southeast Asia is more nuanced than the straightforward positive relationship suggested by De Leon [46]. The positive relationship between profitability and leverage risk suggests that more profitable banks have a lower equity-to-asset ratio compared with their ROAA volatility. This result is consistent with previous findings. Huong et al. [67] studied nine Southeast Asian countries, which found that commercial banks with more short-term deposits and debts than short-term assets tend to be more profitable. While the negative relationship between profitability and portfolio risk is explained in Dao and Nguyen [68] research. They demonstrated that commercial banks with riskier lending practices will have higher portfolio risk and less stability, so their profitability will also decrease. These findings suggest that while raising short-term funds for long-term investments is profitable, this strategy can also increase portfolio risk and threaten bank stability. Therefore, commercial banks should balance profitability goals with risk management thresholds to maintain their sustainability.

5.2. Empirical Evidence to Support the Existing Hypotheses

5.2.1. Digital Financial Inclusion

The regression results show that digital financial inclusion increases banks' default risk and leverage risk during its initial implementation stage, and reduces banks' leverage risk in later stages, thus confirming the second hypothesis. This finding aligns with Banna et al. [19] study, which claimed that digital financial inclusion initially intensifies bank risk-taking when banks are adjusting to the new norm. When banks have adopted a new risk management framework to adapt to the new digital financial environment, their risk level will decrease, as illustrated by the negative coefficient of leverage risk in this research result. This dataset could not clearly show the negative relationship in the later stages because of the relatively new nature of digital financial services in Southeast Asia. In its introduction stage, digital financial inclusion involves the participation of new fintech firms entering the market, which drives up competition and forces commercial banks to shift to riskier sectors to retain market share [19]. Another reason for the positive relationship between digital financial inclusion and bank risk-taking is a lack of technology understanding in customers [69]. This research suggests that the surge in digital banking must be supported by customers' understanding of digital services, which helps them navigate new digital financial products and services effectively, thereby improving banking stability. These two limitations are attributable to the relatively recent implementation of digital financial services in Southeast Asia, compared with other regions studied by previous researchers [70]. In summary, this result highlights the importance of improving digital literacy alongside promoting digital financial inclusion because, without sufficient customer understanding, digital financial inclusion may cause more harm than good to the stability of each bank and the financial system as a whole.

5.2.2. Institutional Quality

Institutional quality has a significant, negative relationship with all three dimensions of bank risk-taking. Therefore, we accept hypothesis 7, which states that institutional quality negatively affects bank risk-taking. According to Demirgüç-Kunt et al. [54], this negative sign is because regulatory frameworks with a higher institutional quality index have stricter supervision and higher fines for non-compliance, which deter excessive risk-taking behaviors of banks and enhance market discipline. This finding shows that governments should improve their national institutional quality to prevent commercial banks from taking excessive risks.

5.3. Variable for Discussions

5.3.1. GDP Growth Rate

GDP growth rate variable is insignificant in all six risk models, so we reject hypothesis 5 that GDP growth rate negatively affects bank risk-taking. This result is different from Huang et al. [71], who support a negative relationship between GDP growth rate and bank risk-taking because during periods of negative GDP growth, market volatility and non-performing loan ratios rise, increasing the risk level faced by commercial banks. It is also different from Umar and Akhtar [3] and Kidane [48], who argue that economic growth enhances borrowers' repayment capacity and reduces bank risk. This study's regression results suggest that the GDP growth rate has no relation to bank risk-taking.

6. Conclusion and Policy Implications

This research examines the impact of traditional financial inclusion and digital financial inclusion on bank risk-taking across three dimensions: default risk, leverage risk, and portfolio risk. The analysis employs various econometric models, including OLS, FEM, REM, and FGLS, with FGLS identified as the most suitable for this dataset. The regression results indicate that traditional financial inclusion helps reduce bank risk-taking across all dimensions, whereas digital financial inclusion initially increases leverage risk. This trend is expected to reverse once banks adjust their risk management frameworks to address new risks associated with digitalization and improve operational efficiency. These econometric findings offer recommendations for governments, central banks, and commercial banks to manage risk levels, thereby supporting the stability of the financial system.

6.1. Recommendations

6.1.1. For Governments and Central Banks

Firstly, governments should continue promoting traditional and digital financial inclusion initiatives, while central banks should implement additional supervision during digital transitions to prevent commercial banks' excessive risk-taking during this period. This is because part 3 findings suggest that traditional financial institutions reduce the level of bank risk-taking, while digital financial inclusion initially increases risks. Secondly, governments and central banks should enhance financial literacy programs to raise public awareness. This is because the literature review in part 2 suggests that financial literacy enhances the effectiveness of traditional and digital financial inclusion in reducing risks for commercial banks. Finally, governments should strengthen institutional quality, such as regulatory frameworks, corruption prevention, and legal enforcement mechanisms, because the findings in part 3 show a consistent negative relationship between institutional quality and bank risk-taking.

6.1.2. For Commercial Banks

Firstly, commercial banks should continue to expand traditional banking services to underserved populations because the empirical results in part 3 show that by increasing traditional financial inclusion, banks can raise a more stable funding base, diversify their loan portfolio and revenue sources, and hence reduce the risk level for banks. Secondly, banks should adopt new risk management frameworks to adjust for increasing digital financial inclusion and enhance their digital operational efficiency to gradually reduce their risk level and move to the second downward-sloping curve according to Banna et al. [19]. This is because the part 3 findings show that Southeast Asian banks, in the initial stage, when digital financial inclusion increases, bank risk-taking.

6.2. Limitations and Future Research Directions

The primary limitation of this study is the short duration of observation, as data from the Global Findex Database is updated only once every three to four years. Additionally, although this research mentions the mediating effect of financial literacy, it has not included it as a variable in the regression models. Future research can improve upon this study by utilizing a longer and more comprehensive dataset for traditional and digital financial inclusion and by incorporating digital financial literacy into the regression model for deeper insights.

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