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Digital Financial Inclusion and Economic Growth: Nonlinear Evidence from Economies with High and Low Levels of Financial Development

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Abstract

Research Originality: This study contributes to the literature by showing that digital financial inclusion is not always a linear and uniform driver of economic growth. Its effect depends on the level of financial development and may generate diminishing returns after a certain threshold.

Research Objectives: This study examines the nonlinear effect of digital financial inclusion on economic growth, identifies its optimal threshold, and compares its effects across low- and high-financial-development economies.

Research Method: Using balanced panel data from 117 countries from 2007 to 2022, this study constructs a digital financial inclusion index through principal component analysis and applies Bayesian regression.

Empirical Results: The results show clear heterogeneity. In low-income economies, digital financial inclusion has a strong, almost linear positive effect on growth, with a posterior probability close to 100%. In highly developed financial economies, the relationship follows an inverted U-shaped pattern. The estimated threshold is approximately 27.7, after which the marginal growth effect declines.

Implications: Low-financial-development economies should expand digital financial services, while high-financial-development economies need stronger fintech regulation and consumer protection.

Keywords:

fintech access; growth threshold; Bayesian estimation; financial maturity; digital finance regulation; cross-country heterogeneity.

How to Cite:

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INTRODUCTION

Over the past two decades, financial technology has shifted financial inclusion from traditional access to digital financial inclusion (DFI). Through e-wallets, digital banking, mobile payments, and non-bank financial platforms, DFI enables households and firms, especially in developing countries, to access financial services at lower cost and with wider coverage than traditional channels (Le Quoc, 2024; Dinh, 2025a; Le Quoc et al., 2025). The World Bank (2025) reports that the share of adults owning a digital transaction account rose from 51% in 2011 to more than 76% in 2021, with Asia and Africa recording the fastest growth. However, digital readiness remains uneven. More than 90% of people in high-income Asia-Pacific countries use the internet, compared with only about 20% in lower-income countries (UNCTAD, 2023). This gap raises an important question: Does DFI affect economic growth equally across countries, or does its effect depend on the level of financial development?

The main argument of this study is that DFI supports economic growth, but not everywhere and not without limits. In economies with low levels of financial development, DFI has a strong and almost linear positive effect because it helps fill gaps left by weak traditional financial systems. In contrast, in economies with high levels of financial development, the effect is nonlinear. DFI supports growth at lower levels, but its benefits decline and become negative above a threshold of about 27.7. This suggests that digital finance can be a growth driver in one context but a source of inefficiency in another, depending on the financial system's maturity and absorptive capacity.

The relationship between DFI and economic growth can be explained through two perspectives. The first emphasizes the growth-enhancing role of finance. Finance promotes growth by mobilizing savings, allocating resources, financing innovation, and supporting productive investment. In the digital economy, DFI extends this role by reducing transaction costs, overcoming geographical barriers, and expanding access to financial services for households, small businesses, and informal workers (Demirgüç-Kunt et al., 2018). DFI can affect growth through three main channels. First, it improves capital mobilization and allocation by helping households and firms access credit, savings, payment, and investment services more easily (Lenka & Sharma, 2022). Second, it supports innovation and productivity by reducing operating costs, improving service delivery, and easing financing constraints for small and medium-sized enterprises (Wang et al., 2025). Third, it promotes social inclusion by helping unbanked and underbanked groups participate more fully in economic activity and by strengthening the resilience of low-income households during macroeconomic shocks (Le Quoc, 2024; Le Quoc, 2025a; IMF, 2022).

The second perspective is more cautious. It argues that finance does not promote growth without limits. The “too much finance” view suggests that excessive financial development may increase systemic risk, encourage overborrowing, create asset bubbles, and reduce economic efficiency (Cecchetti & Kharroubi, 2012). This argument is also relevant to DFI. At low levels, DFI can support growth by easing credit constraints and expanding financial access. However, at high levels, excessive digital financial expansion

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may lead to overindebtedness, speculative digital lending, inflationary pressure, consumer protection problems, and financial instability (Dinh, 2025b). This concern is especially important in economies with mature financial systems, where financial services are already widespread. Therefore, the effect of DFI on growth should be examined as a nonlinear relationship and compared across different levels of financial development.

Existing studies provide useful evidence but have not fully settled this debate. Many studies show that financial inclusion supports economic growth by expanding access to bank branches, accounts, credit, deposits, and other formal financial services (Inoue & Hamori, 2016, 2019; Kim et al., 2018; Sethi & Acharya, 2018). However, more recent studies question the assumption that this relationship is always linear. Nizam et al. (2020) and Karim et al. (2022) show that financial inclusion may have a threshold effect, promoting growth at low and moderate levels but weakening or reversing at higher levels.

Evidence on DFI is growing but remains more limited than evidence on traditional financial inclusion. Li et al. (2022) find that DFI increases farmers' income in China, though its effect weakens beyond certain thresholds. Daud (2023) shows that DFI is positively associated with economic growth across countries. Basnayake et al. (2024) find that DFI supports GDP growth, digital trade, and innovation in Asia-Pacific countries. Abdallah et al. (2024) also confirm a nonlinear effect in China, where DFI enhances growth below the threshold but shows diminishing effects after digital penetration exceeds the optimal level. Similarly, Becha et al. (2025) show that DFI supports regional economic development but may create trade-offs with environmental sustainability. Overall, these studies suggest that DFI can support growth, but its benefits are not unlimited.

Although this literature is useful, three gaps remain. First, many studies still focus on traditional financial inclusion rather than DFI, even though DFI operates through technology-based channels. Second, many studies treat the finance-growth relationship as linear, whereas recent evidence suggests diminishing or negative returns beyond a threshold. Third, existing studies often rely on pooled samples and provide limited comparative evidence on whether the DFI-growth relationship differs between economies with low and high levels of financial development. These gaps matter because DFI may strongly support growth where formal finance is underdeveloped, but it may become less effective or riskier as financial systems mature.

Against this backdrop, this study aims to examine whether digital financial inclusion affects economic growth nonlinearly, identify the optimal threshold at which its marginal growth effect begins to decline, and compare whether this relationship differs across economies with low and high levels of financial development. To answer these questions, this study uses data from 117 countries, including 55 with low levels of financial development and 62 with high levels, over the period 2007 to 2022. It applies Bayesian regression to estimate both the linear and nonlinear effects of DFI on economic growth. This approach allows the study to assess posterior probabilities and identify the optimal DFI threshold across different country groups.

This study contributes to the literature in three ways. First, it extends financial inclusion research by focusing on digital financial inclusion, which remains less explored than traditional financial inclusion. By testing nonlinearity and identifying the DFI threshold, the study shows that digital finance is not always linear or uniformly growth-enhancing. Second, it contributes methodologically by using Bayesian regression to estimate both the direction and probability of the effect, especially across economies with different levels of financial development. Third, it provides practical implications by showing that low-financial-development economies may benefit from further DFI expansion, while high-financial-development economies need stronger risk management to prevent overexpansion and protect growth efficiency.

METHODS

This study uses a balanced panel dataset covering 117 countries from 2007 to 2022, including 55 economies with low financial development and 62 with high financial development (Appendix 1). The study period ends in 2022 due to data availability, as several indicators used to construct the digital financial inclusion index were not consistently available for all countries after 2022. The country classification is based on the Financial Development Index. This index captures the development of financial institutions and financial markets across three dimensions: depth, access, and efficiency. Countries with index values above the global mean are classified as having high levels of financial development, while those below the global mean are classified as having low levels of financial development.

This study applies a Bayesian threshold regression framework to examine the nonlinear effect of DFI on economic growth across economies with different levels of financial development. This approach captures both threshold effects and heterogeneity between low and high-financial-development economies. It also provides posterior distributions for the estimated coefficients and threshold values, allowing a more direct probabilistic interpretation of the DFI growth relationship. The baseline model is specified as follows:

$$GDP_{i,t} = \beta_o + \beta_1 DFI_{i,t} + \beta_1 DFI^2{}_{i,t} + \beta_x X_{i,t} + \varepsilon_{i,t} \quad (1)$$

where GDP(i,t) denotes the annual real GDP per capita growth rate for country i in year t; DFI_(i,t) is the digital financial inclusion index; $DFI^2_{i,t}$ captures possible nonlinear effects; $X_{i,t}$ is a vector of control variables; $\varepsilon_{i,t}$ is the error term.

Traditionally, studies on the finance-growth nexus use GDP per capita growth as the main dependent variable. This indicator captures changes in the average standard of living, controls for inflation, and is widely used in previous studies (Karim et al., 2022; Dinh, 2024).

Unlike traditional financial inclusion, which is often measured by bank branches or ATMs, the DFI index captures broader access, usage, and efficiency in technology-based financial services. Following Karim et al. (2022) and Dinh (2025a, 2025b), this study constructs the DFI index using principal component analysis based on nine indicators: commercial bank loans, commercial bank deposits, commercial banks per 1,000 km²,

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commercial bank branches per 100,000 adults, ATMs per 1,000 km², ATMs per 100,000 adults, mobile cellular subscriptions, internet users, and fixed broadband subscriptions.

This study includes the squared term of DFI (DFI^2) to test for nonlinear effects. The "too much finance" hypothesis suggests that when financial development exceeds a certain threshold, its benefits for growth may decline or even reverse (Cecchetti & Kharroubi, 2012). Nizam et al. (2020) and Karim et al. (2022) also confirm the existence of threshold effects in the financial inclusion literature. Therefore, including DFI^2 allows this study to identify the optimal level of DFI and test whether the DFI growth relationship follows an inverted U-shaped pattern.

H1: In economies with high levels of financial development, the nonlinear effect of DFI is expected to be more pronounced. Beyond the optimal threshold, DFI may weaken economic growth due to credit saturation, excessive digital financial expansion, and systemic risks.

H2: In economies with low levels of financial development, DFI is expected to have a stronger positive effect on economic growth by improving access to finance and supporting productive activity. The optimal threshold is expected to be higher, meaning that DFI is likely to remain growth-enhancing across most of the observed range.

In addition to DFI, the model includes several control variables to reduce omitted variable bias and improve the robustness of the estimated results. The inflation rate (INF) is included to capture macroeconomic stability, as high inflation can erode purchasing power and discourage investment. Urbanization rate (UR) reflects structural transformation, as higher urbanization is often associated with better infrastructure, higher productivity, and greater access to services. Population growth rate (POP) captures demographic dynamics that may support growth by expanding the labor force or, when population growth exceeds available resources, weakening it. Trade openness (OPEN) measures international economic integration and is expected to support growth through comparative advantage and technology diffusion. Finally, the unemployment rate (UNE) reflects labor market conditions, with high unemployment indicating underused resources and lower growth potential (Appendix 2).

As specified in Equation (1), this study examines the effect of digital financial inclusion (DFI) on economic growth by modeling GDP per capita growth as a function of DFI, the squared term of DFI (DFI^2), and a set of control variables. The inclusion of DFI^2 allows the study to test whether the relationship between DFI and economic growth follows a nonlinear pattern, specifically an inverted U shape. This specification is consistent with the "too much finance" hypothesis, which argues that financial expansion may support growth up to a certain point, but excessive financial deepening may generate diminishing or negative returns.

The empirical framework of this study is built around three main components. First, economic growth is treated as the dependent variable, measured by GDP per capita growth. Second, DFI is the main explanatory variable. It is constructed as a composite index based on principal component analysis of indicators related to digital access, traditional financial access, internet use, mobile subscriptions, broadband subscriptions, deposits, loans, bank branches, and ATMs. Third, the model includes several control variables that may affect economic growth, including inflation, urbanization, population growth, trade openness, and unemployment. These variables are included to reduce omitted-variable bias and ensure that the estimated effect of DFI on growth is not driven by other macroeconomic conditions.

The data used in this study comprises a balanced panel of 117 countries spanning 2007 to 2022. The sample is divided into two groups based on the level of financial development: low- and high-financial development countries. This classification allows the study to compare whether the effect of DFI differs across economies with different financial structures. The analysis, therefore, follows a comparative research framework, in which the same model is estimated separately for each country group. This framework helps determine whether DFI produces stronger growth effects in less financially developed economies and whether excessive DFI creates diminishing returns in more financially developed economies.

To estimate the model, the study adopts a Bayesian regression approach. Unlike conventional regression methods, which rely mainly on point estimates and asymptotic significance tests, the Bayesian approach yields the full posterior distribution for each parameter. This allows evaluation not only of the magnitude and direction of the coefficients, but also of the probability that each coefficient is positive or negative. This is particularly useful for this study because the research objective is not only to test whether DFI affects growth, but also to assess the probability and stability of this effect across different financial development groups.

In the Bayesian estimation, the regression coefficients are assumed to follow diffuse normal priors, while the error variance is assigned an Inverse-Gamma prior. These weakly informative priors are used to minimize excessive subjectivity and allow the posterior estimates to be mainly driven by the data. The likelihood function is derived from the standard linear regression structure specified in Eq. (1). Posterior distributions are obtained using Markov Chain Monte Carlo techniques, combining Gibbs sampling and Metropolis-Hastings steps. The convergence of the Markov chains is assessed using the Gelman-Rubin statistic; values below 1.1 indicate acceptable convergence. Trace plots and sampling efficiency are also examined to ensure the stability and reliability of the posterior estimates.

The final results are reported using posterior means, Monte Carlo standard errors, posterior probabilities, and 95 percent credible intervals. These indicators provide a richer interpretation than conventional p-values because they allow the study to state, for example, the probability that DFI has a positive effect on economic growth or the probability that DFI^2 is negative. A negative coefficient of DFI^2, combined with a positive coefficient of DFI, indicates an inverted U-shaped relationship. The optimal threshold of DFI is calculated from the turning point formula $-\beta_1/2\beta_2$, where β_1 is the coefficient of DFI and β_2 is the coefficient of DFI^2. This threshold identifies the level of DFI at which its marginal contribution to economic growth begins to decline.

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The Bayesian framework is suitable for this study for three reasons. First, it is effective when the sample is divided into smaller country groups, such as high- and low-financial-development economies. Second, it provides more flexible inference in the presence of heterogeneity, endogeneity concerns, and non-normal data structures. Third, it allows the study to estimate nonlinear effects and threshold values probabilistically. Recent contributions, such as Huy and Dinh (2025), Quoc et al. (2025a, 2025b), and Dinh (2025c), have also applied Bayesian econometric methods in macroeconomic and financial research, supporting the relevance of this approach for studies involving complex economic relationships and cross-country heterogeneity.

RESULTS AND DISCUSSION

Before estimating the growth model, this study constructs the DFI index using principal component analysis. PCA is appropriate because DFI is multidimensional, combining traditional financial access indicators, such as bank branches, ATMs, deposits, and loans, with digital infrastructure indicators, such as internet use, mobile subscriptions, and fixed broadband subscriptions. Table 1 reports the factor loadings, where higher values indicate stronger contributions to the index.

Table 1. Results of PCA

DFI	ATM	ATMKM	DCB	LCB	CBP	CBBP	INT	MCS	FBS
	0.2111	0.1334	0.3415	0.2253	0.3460	0.4364	0.5231	0.4318	0.2111

Source: Authors' calculations

The traditional financial access indicators, including ATM, ATMKM, DCB, and LCB, have moderate factor loadings, ranging from 0.1334 to 0.3460. This shows that traditional infrastructure still contributes to the DFI index, although its role is limited. In contrast, modern financial service indicators, including CBP, CBBP, INT, MCS, and FBS, have higher loadings, ranging from 0.4318 to 0.5231. This suggests that the DFI index is mainly driven by internet access, mobile connectivity, and technology-based financial services.

Table 2. Descriptive statistics

	LFDCs				HFDCs			
Variables	**Mean**	**Std.**	**Min**	**Max**	**Mean**	**Std.**	**Min**	**Max**
GDP	3.2550	5.1537	-15.4970	34.6820	2.9109	3.8474	-12.8476	14.3176
DFI	22.8105	14.0091	0.2085	48.1429	38.2234	31.3426	0.8110	140.5565
INF	6.2389	7.4794	-1.6633	62.1807	4.1654	3.4108	-1.4891	17.1491
UR	64.9566	13.9792	37.0482	100.2908	73.7853	14.8909	37.9775	98.5929
POP	0.4932	1.0882	-1.9470	2.6138	0.7005	0.8249	-1.2606	2.5097
OPEN	88.5991	26.1388	40.4474	165.8730	78.1048	43.7823	23.2113	176.8143
UNE	10.4534	8.1144	0.5250	39.1860	7.2780	3.6689	0.2625	18.1545

Source: Authors' calculations

Table 2 shows clear differences between the two groups of economies. Low financial development economies record a higher average GDP per capita growth rate than high financial development economies, at 3.26% compared with 2.91%. However, their growth is also more volatile, as shown by the higher standard deviation and the wider range of GDP growth rates. This suggests that financially less developed economies have higher growth potential but are more exposed to macroeconomic instability. The DFI index also differs sharply between the two groups. Highly developed economies have a higher average DFI value of 38.22, compared with 22.81 in lowly developed economies. This indicates stronger digital financial infrastructure and broader service coverage in more developed financial systems. However, the higher standard deviation and wider DFI range in this group also show greater variation in digital financial penetration across financially developed economies.

The results in Table 3 show that DFI positively affects economic growth in economies with low levels of financial development. The DFI coefficient is positive in both models, increasing from 0.0244 in Model 1 to 0.1549 in Model 2. The squared term is very small at 0.0008, suggesting no clear turning point within the observed range. Thus, DFI expansion continues to support growth in these economies. These findings support Hypothesis H2. In low-income economies, traditional financial infrastructure is often limited, and many households and firms still face barriers to formal finance. DFI can therefore improve access to credit, savings, payments, and investment services, making digital finance a more direct and stable driver of growth.

This result is consistent with previous studies showing that financial inclusion supports growth, especially where access to formal finance is limited. Karim et al. (2022) found stronger growth effects in less developed financial systems, while Li et al. (2022) showed that DFI improves income in less developed regions. Basnayake et al. (2024) also reported that DFI significantly supports GDP growth at early stages of digital financial development. This study extends these findings by showing that the positive effect of DFI is highly stable across low-financial-development economies. This result also reflects the lower average DFI level in these economies, at 22.81, compared with 38.22 in high-financial-development economies. This gap suggests substantial room for DFI expansion. Further expansion can support informal workers, small firms, and households that remain outside traditional financial systems, consistent with Demirgüç-Kunt et al. (2018), who emphasize the role of digital financial inclusion in growth and poverty reduction.

The results for high-financial-development economies show a different pattern. In Model 1, the DFI coefficient is positive at 0.0646. In Model 2, DFI remains positive at 0.1551, while DFI^2 is negative at -0.0028. This indicates an inverted U-shaped relationship. DFI supports growth at low and moderate levels, but its marginal effect declines after a certain threshold. These findings support Hypothesis H1. This result is partly consistent with studies showing that financial inclusion and DFI promote growth by improving savings mobilization, credit allocation, investment, and transaction

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efficiency (Inoue & Hamori, 2016; Kim et al., 2018; Sethi & Acharya, 2018; Daud, 2023; Basnayake et al., 2024). However, this study adds a more cautious view. In mature financial systems, the positive effect of DFI is not unlimited. The finding is closer to the threshold view of Nizam et al. (2020) and Karim et al. (2022), who show that financial inclusion may support growth only up to a certain point. It also aligns with Abdallah et al. (2024) and Becha et al. (2025), who report nonlinear DFI effects. This study extends these findings by showing that diminishing returns are more visible in economies with high levels of financial development, where financial services are already widespread. This result is also consistent with the "too much finance" hypothesis of Cecchetti and Kharroubi (2012) and Arcand et al. (2012). When financial systems become too large or complex, further financial expansion may reduce growth efficiency by leading to credit misallocation, overborrowing, speculative lending, and systemic risk. In digital finance, these risks may appear through excessive digital lending, weak consumer protection, data misuse, unfair competition, and fintech expansion without adequate regulation. Therefore, this study shows that DFI can become less effective when it exceeds the absorptive capacity of financially developed economies. Overall, the growth effect of DFI depends on financial system maturity and regulatory capacity.

Table 3. Bayesian regression results

Dependent Variable: GDP	LFDCs		HFDCs	
	(1)	(2)	(1)	(2)
	Mean (MCSE)	Mean (MCSE	Mean (MCSE)	Mean (MCSE
Cons	0.2114 (0.0001)	0.1260 (0.0011)	1.3445 (0.0173)	1.1359 (0.0141)
INF	-0.0411 (0.0003)	-0.0405 (0.0005)	-0.1651 (0.0005)	-0.1903 (0.0007)
UR	-0.0045 (0.0004)	-0.0027 (0.0003)	-0.0478 (0.0001)	-0.0557 (0.0001)
POP	-1.2637 (0.0005)	-1.1374 (0.0040)	-0.4163 (0.0011)	-0.3615 (0.0065)
OPEN	0.0427 (0.0001)	0.0432 (0.0001)	0.0063 (0.0001)	0.0304 (0.0001)
UNE	-0.0732 (0.0002)	-0.0284 (0.0003)	-0.1422 (0.0003)	-0.2658 (0.0014)
DFI	0.0244 (0.0003)	0.1549 (0.0009)	0.0646 (0.0001)	0.1551 (0.0009)
DFI^2		0.0008 (0.0003)		-0.0028 (0.0003)
Avg acceptance rate	0.9136	0.9342	0.9134	0.9345
Avg efficiency min	0.2254	0.2506	0.2207	0.2707
Max Gelman-Rubin Rc	1.0000	1.0000	1.0000	1.0000

Source: Authors' calculations

Figure 1 and Table 4 further confirm the threshold effect of DFI in high-financial-development economies. Based on the Bayesian results, the estimated DFI threshold is approximately 27.69, calculated as 0.1551/(2 × 0.0028). This threshold divides the HFDC group into economies below and above the optimal DFI level. For HFDCs below the threshold, DFI remains growth-enhancing. Table 4 shows an 87.46% probability that DFI positively affects GDP growth below 27.69, with a very small simulation error (MCSE = 0.0001). This indicates that digital financial expansion can still support growth when it remains within the optimal range. For HFDCs above the threshold, the marginal benefit of DFI begins to decline. This supports the inverted U-shaped relationship found in Table 3. Beyond the threshold, risks such as credit misallocation, overborrowing, speculative digital lending, and systemic vulnerability may weaken the growth enhancing effect of DFI.

Figure 1. Correlation Between Economic Growth and Digital Financial Inclusion in Low Financial Development Economies

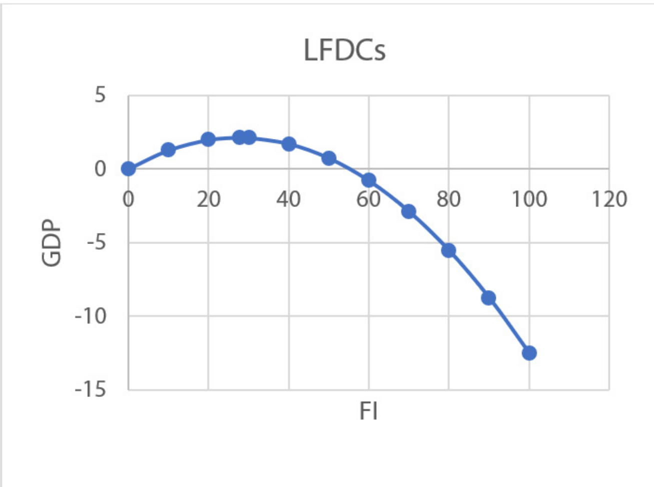

Table 4. Table of Countries Above and Below the Financial Inclusion Threshold

HFDCs			
Countries below the DFI threshold of 27.69 (30 countries)		**Countries above the DFI threshold of 27.69 (32 countries)**	
Botswana, Brazil, Brunei Darussalam, Chile, Colombia, Cyprus, Egypt (Arab Rep.), Greece, India, Jamaica, Jordan, Kazakhstan, Malaysia, Malta, Mauritius, Mexico, Mongolia, Morocco, Namibia, Panama, Peru, Philippines, Russian Federation, Saudi Arabia, South Africa, Thailand, Trinidad and Tobago, Bulgaria, Indonesia, Vietnam.		Austria, Bahamas (The), Barbados, Belgium, Croatia, Czechia, Denmark, Estonia, Finland, Hungary, Iceland, Ireland, Israel, Kuwait, Luxembourg, New Zealand, Netherlands, Portugal, Poland, Qatar, Slovenia, Spain, Sweden, Switzerland, United Arab Emirates, Australia, Canada, France, Germany, Italy, Japan, Korea (Rep.)	
Probability	**Mean**	**Std. Dev**	**MCSE**
0<Prob(GDP: FI)< 27.69	87.46	0.1368	0.0001

Source: Authors' calculations

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This finding is also consistent with recent threshold-based studies. Nizam et al. (2020) and Karim et al. (2022) show that the positive effect of financial inclusion may weaken as it reaches higher levels. Similarly, Abdallah et al. (2024) and Becha et al. (2025) find that digital financial inclusion can generate nonlinear effects, especially when digital penetration becomes too high. However, the present study extends these studies by showing that this nonlinear effect is more visible in economies with high levels of financial development. In these economies, the financial system is already mature, so further DFI expansion may produce smaller marginal benefits and greater regulatory risks. Therefore, the results support Hypothesis H1, which argues that in economies with high levels of financial development, DFI produces positive effects at lower levels but diminishing returns after the threshold is exceeded.

From a policy perspective, high-financial-development economies should not treat DFI expansion as an unlimited-growth strategy. When DFI remains below the threshold, digital financial innovation can still be promoted. Once it exceeds the threshold, regulators should strengthen supervision to ensure that digital finance supports productive investment rather than excessive risk-taking. Table 3 also reports the MCMC diagnostics, confirming the reliability of the Bayesian estimates. The acceptance rate ranges from 0.91 to 0.93, indicating stable sampling. The sampling efficiency ranges from 0.22 to 0.27, suggesting that the MCMC draws are representative of the posterior distribution. The Gelman-Rubin R statistic is 1.0000 across all models, confirming convergence. Overall, these diagnostics show that the Bayesian estimates are stable and suitable for interpreting the nonlinear effect of DFI on economic growth.

Table 5. The impact probability results

	LFDCs				HFDCs			
	(1)		(2)		(1)		(2)	
Variable	Mean (Std. Dev)	MCSE	Mean (Std. Dev)	MCSE	Mean (Std. Dev)	MCSE	Mean (Std. Dev)	MCSE
Prob(GDP: DFI)>0	0.9968 (0.055)	0.000	0.9475 (0.033)	0.000	0.9956 (0.065)	0.001	0.9996 (0.030)	0.000
Prob(GDP: DFI^2)<0			0.8396 (0.361)	0.003			1.0000 (0.000)	0.000
Prob(GDP: INF) <0	0.8000 (0.399)	0.002	0.8003 (0.397)	0.004	0.9830 (0.133)	0.000	0.9954 (0.06)	0.000
Prob(GDP: UR) <0	0.5707 (0.494)	0.002	0.5433 (0.498)	0.003	0.9919 (0.089)	0.000	0.9991 (0.068)	0.000
Prob(GDP: POP) <0	0.999 (0.043)	0.000	0.991 (0.063)	0.000	0.8531 (0.351)	0.002	0.7446 (0.431)	0.004
Prob(GDP: OPEN) >0	0.9973 (0.050)	0.000	0.9978 (0.046)	0.000	0.7661 (0.431)	0.000	0.9906 (0.369)	0.001
Prob(GDP: UNE) <0	0.928 (0.257)	0.001	0.8885 (0.3144)	0.003	0.9707 (0.168)	0.001	0.8313 (0.381)	0.003

Source: Authors' calculations

An important advantage of the Bayesian approach is that it reports posterior probabilities, allowing more direct interpretation than conventional point estimates. Table 5 shows that the probability of a positive DFI effect differs across the two groups. In low-income economies, the probability that DFI positively affects GDP growth is 0.9968, indicating almost certain support for growth. In high-financial-development economies, this probability remains high, rising from 0.9956 in Model 1 to 0.9996 in Model 2. However, the probability that DFI^2 is negative reaches 1.0000, strongly confirming an inverted-U-shaped relationship. This means that DFI supports growth at lower levels, but its marginal benefit declines after the optimal threshold is exceeded. The reliability of these results is supported by the MCMC diagnostics in Table 3, including Gelman-Rubin Rc values below 1.1 and acceptable efficiency levels, confirming convergence and stable posterior estimates.

CONCLUSION

This study examined the nonlinear effect of digital financial inclusion on economic growth in 117 countries from 2007 to 2022. The results show that digital financial inclusion does not affect growth in the same way across all economies. In low-income economies, digital financial inclusion has a strong, almost linear positive effect on economic growth. This suggests that expanding digital financial services can help improve access to finance, support productive investment, and promote growth. In highly developed financial economies, the effect is different. Digital financial inclusion supports growth at lower levels, but its benefits decline after an estimated threshold of approximately 27.7. Beyond this point, excessive digital financial expansion may create risks such as over-borrowing, credit misallocation, speculative digital lending, and financial instability. Therefore, digital financial inclusion is not automatically growth-enhancing. Its effect depends on the financial system's maturity and absorptive capacity.

The policy implication is clear. Low-income economies should continue expanding digital financial infrastructure, mobile banking, digital payments, affordable digital credit, and financial literacy, especially for underserved households, small firms, rural communities, and informal workers. In contrast, high-financial-development economies should adopt a more cautious approach. Regulators should strengthen consumer protection, data security, digital lending standards, fintech supervision, and risk-based monitoring. This study has one main limitation. The DFI index is constructed from proxy indicators, including mobile subscriptions, internet use, bank branches, ATMs, loans, and deposits. These indicators do not fully capture qualitative aspects such as financial literacy, consumer trust, and regulatory quality. Future research should use more detailed household or firm-level data to better measure the multidimensional nature of digital financial inclusion.

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Appendix 1: The 117 Countries Included in the Study

Group	Countries
Low financial development economies (55 countries)	Albania; Algeria; Angola; Armenia; Azerbaijan; Bangladesh; Belize; Benin; Bhutan; Bolivia; Burundi; Cabo Verde; Cambodia; Cameroon; Chad; Congo, Dem. Rep.; Costa Rica; Dominican Republic; Ecuador; El Salvador; Eswatini; Fiji; Gambia, The; Georgia; Ghana; Guinea; Guyana; Honduras; Kenya; Kyrgyz Republic; Latvia; Lesotho; Madagascar; Malawi; Maldives; Mali; Moldova; Mozambique; Nicaragua; Nigeria; North Macedonia; Pakistan; Paraguay; Romania; Rwanda; Serbia; Slovak Republic; Suriname; Tunisia; Uganda; Ukraine; Uruguay; Zambia; Burkina Faso; Lithuania.
High financial development economies (62 countries)	Austria; Bahamas, The; Barbados; Belgium; Botswana; Brazil; Brunei Darussalam; Chile; Colombia; Croatia; Cyprus; Czechia; Denmark; Egypt, Arab Rep.; Estonia; Finland; Greece; Hungary; Iceland; India; Ireland; Israel; Jamaica; Jordan; Kazakhstan; Kuwait; Malaysia; Malta; Mauritius; Mexico; Mongolia; Morocco; Namibia; New Zealand; Panama; Peru; Philippines; Poland; Portugal; Qatar; Russian Federation; Saudi Arabia; Slovenia; South Africa; Thailand; Trinidad and Tobago; United Arab Emirates; Vietnam; Bulgaria; Indonesia; Australia; Canada; France; Germany; Italy; Japan; Korea, Rep.; Netherlands; Spain; Sweden; Switzerland; Luxembourg.

Appendix 2. Description of Variables

Variable	Symbol	Measurement	Reference	Source
Economic growth	GDP	GDP per capita growth (%)	Karim et al. (2022); Dinh (2024)	WB
Digital financial inclusion	DFI	Composite index of credit, deposits, bank branches, ATMs, internet, and mobile indicators	Karim et al. (2022); Dinh (2025a, 2025b)	WB; IMF
Control variables				
Inflation rate	INF	Inflation rate (%)	Van et al. (2025a, 2025b)	WB
Urbanization rate	UR	Urban population to total population	Li et al. (2022)	WB
Population growth	POP	Annual population growth rate	Karim et al. (2022)	WB
Trade openness	OPEN	Imports plus exports to GDP	Sethi and Acharya (2018)	WB
Unemployment rate	UNE	Unemployed persons to total labor force	Karim et al. (2022)	WB

Source: Compiled by the authors

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