

Thailand's Finance-Growth Nexus: Nonlinear Asymmetry Analysis Using The ARDL And NARDL Techniques With Carbon Emissions, Globalization, And Government Expenditure

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Abstract:

This study examines the causal relationship between financial development and economic growth—the finance-growth nexus—in Thailand from 1970 to 2022. By identifying whether the finance-growth nexus is bidirectional or unidirectional, this research provides Thai policymakers with empirical evidence to balance financial liberalization with macroeconomic stability. Recognizing the non-linearity and asymmetry inherent in Thailand's finance-growth nexus, the study employs two approaches: the Autoregressive Distributed Lag (ARDL) and Nonlinear Autoregressive Distributed Lag (NARDL) techniques. While economic growth is represented by real GDP per capita, financial development is proxied by both financial size (private credit-to-GDP) and financial efficiency (private credit-to-total deposits). The analysis also incorporates critical control variables, including carbon emissions (carbon emissions per capita), globalization (KOF globalization index), and government expenditure (general government final consumption expenditure-to-GDP). Empirical results indicate that financial size and economic growth share a bidirectional, nonlinear causal relationship. In contrast, the results for financial efficiency are more mixed: while efficiency nonlinearly influences growth, there is no evidence of a feedback effect from growth to efficiency. These findings highlight the asymmetric nature of Thailand's financial evolution and its implications for macroeconomic stability. We conclude that Thailand should shift from quantity-based growth toward quality-driven sustainable development, which will enable the country to more efficiently align financial development, environmental responsibility, and global integration with macroeconomic stability.

Key Word: *Economic growth; Financial development; ARDL; NARDL; Thailand*

Date of Submission: 24-06-2026

Date of Acceptance: 04-07-2026

I. Introduction

The role of the financial system in the process of economic growth has been an issue of inquiry for a long time and under various contexts (Arestis et al., 2015). The "finance-growth nexus" has been a central topic in development economics for decades. It originated with Schumpeter (1911), who postulated that innovation, catalyzed by a robust banking system, serves as the primary engine of progress, so that finance is essential to fund innovative entrepreneurs who drive productivity gains. This nexus is often disputed for causality between a country's financial depth and its long-term economic growth. Specifically, it is focused on the "supply-leading" versus "demand-following" debate: whether a sophisticated financial system—comprising banks, stock markets, and other intermediaries—serves as a primary driver of growth or emerges merely as a byproduct of industrial expansion (Silva et al., 2021).

For emerging economies like Thailand, an interesting case study, understanding the finance-growth nexus is not simply an academic topic but important to form sustainable policies. In the Post WWII period, the nation transitioned from an agrarian-based economy to one of emerging economies, experiencing the exogenous shocks of the 1997 Asian Financial Crisis, subsequent global market volatilities, and the COVID-19 pandemic (Ahmad et al., 2022; Asian Development Bank, 2025). A stable and efficient financial sector remains vital for Thailand's economic growth against a backdrop of increasing environmental obligations and globalization.

Several gaps are observed in the literature. First, financial development is a multifaceted phenomenon. Focusing solely on the "size" of the financial sector may overlook the "efficiency" with which capital is allocated. As noted by Levine (2005), a large financial system is not inherently an efficient one; high credit-to-GDP ratios can occasionally signal speculative bubbles rather than productive investment. Second, many empirical studies rely on linear approaches that assume a symmetric, monotonic relationship. Such an assumption often fails in emerging economies where the nexus typically exhibits non-linearities.

This study's objective is to address these gaps. Regarding variable selection, we proxy financial development using measures of both financial size (private credit-to-GDP) and financial efficiency (private credit-to-total deposits). Also, since a bivariate analysis of finance and growth can lead to model misspecification (Cevik & Rahmati, 2020), this research incorporates three control variables: carbon emissions, globalization, and government expenditure. Carbon emissions are included to align the analysis with SDG 12 (Responsible Consumption) and SDG 13 (Climate Action) (United Nations, 2025) as financial depth can either facilitate green technology or inadvertently fund carbon-intensive industries (e.g., Dahmani et al., 2023). Globalization is a driver of growth that creates complex feedbacks; while trade facilitates financial depth, it can also exacerbate environmental degradation through expanded industrial activity (e.g., Sarwar et al., 2021). Government expenditure is a regular policy that influences growth, infrastructure, and environmental outcomes via green subsidies or carbon taxation (e.g., Ullah et al., 2020).

Methodologically, this study departs from standard time-series cointegration analysis by employing the Autoregressive Distributed Lag (ARDL) approach of Pesaran et al. (2001) alongside the Nonlinear ARDL (NARDL) approach developed by Shin et al. (2014). To test for nonlinearity, the ARDL estimation is performed by incorporating the squared terms of the underlying variables. On the other hand, the NARDL approach decomposes variables into positive and negative shocks, capturing the potential asymmetries in the Thai economy's response to these fluctuations.

This study contributes to the literature by analyzing Thailand's finance-growth nexus over a 52-year period (1970–2022). By identifying whether the nexus is unilateral or bilateral, this research provides Thai policymakers with empirical evidence to balance financial development and economic growth. While previous studies—such as Luintel and Khan (1999), Majid (2007), Fukuda (2020), and Okuyan (2022)—examined the Thai finance-growth nexus, they overlooked nonlinearity and asymmetry. The present study addresses this gap by employing ARDL and NARDL techniques to provide new evidence.

The remainder of this paper is organized as follows: Section 2 reviews the literature relevant to the finance-growth nexus; Section 3 describes the data and empirical strategy; Section 4 details the methodology and model specification; Section 5 presents the empirical results; and Section 6 concludes with policy implications. (10)

II. Literature Review

Causal Direction

The finance-growth nexus debate was formalized by Patrick (1966), who proposed three hypotheses underlying this relationship: the supply-leading, demand-following, and feedback hypotheses. First, the supply-leading hypothesis—which posits that financial development actively drives economic growth—was popularized by McKinnon (1973) and Shaw (1973). The McKinnon-Shaw thesis posits that low or negative real interest rates discourage savings, thereby reducing the availability of loanable funds. This scarcity of capital constrains investment and stifles economic growth (Edu, 2020). Consequently, this hypothesis became a foundational argument for financial liberalization policies.

Second, Robinson (1952) remarked that "where enterprise leads, finance follows," which is the demand-following hypothesis. This theory posits that financial development is a passive response to the evolving needs of the real economy. In this view, as the real sector expands, it generates a demand for increasingly sophisticated financial services, which the financial system then organizes to accommodate (Qayyum et al., 2024).

Third, the feedback (bilateral) hypothesis suggests a symbiotic and bidirectional relationship between finance and growth (Demetriades & Hussein, 1996). Financial intermediaries support profitable projects by increasing the rate of return on capital; in turn, this growth leads to an expansion of financial instruments, further augmenting the impact of financial services on economic indicators. Consequently, causality runs in both directions simultaneously (Greenwood & Jovanovic, 1990).

Nonlinearity and Asymmetry

The finance-growth nexus has been considered as a linear relationship. Although many conclusions have been drawn on this basis, every relationship cannot be linear (Kalu et al., 2019); it has evolved from a simple linear assumption into a complex, multifaceted phenomenon (Al khatib, 2025). To address this, we discuss two concepts: nonlinearity and asymmetry.

Nonlinearity suggests that the impact of financial development on economic growth is not constant; rather, it fluctuates as financial depth increases. The most prominent finding is the inverted U-shape hypothesis. At lower levels of development, expanding financial services boosts growth significantly. However, once financial depth crosses a certain threshold—often cited around 80–100% of GDP in private sector credit—the marginal benefit diminishes or may even become negative (Arcand et al., 2015; Law & Singh, 2014).

Asymmetry postulates that the economy responds differently to financial expansion than to contraction. For instance, while a 1% increase in credit might boost GDP by 0.5%, a 1% contraction could trigger a 1.5% drop (Cover, 1992). To analyze the finance-growth nexus, these arguments are underscored by recent market volatility, highlighting how dysfunctional systems can erode savings by incentivizing speculation. Contemporary research (e.g., Chebab et al., 2020) focuses on identifying the threshold of financial depth. As noted by researchers from the IMF and BIS, financial development is beneficial only up to a point; beyond this, excessive depth—often exacerbated by weak regulation—can become a drag on sustainable economic expansion (Dahmani et al., 2023).

Empirical Evidence: ARDL and NARDL Applications

Recent empirical studies have increasingly utilized ARDL and NARDL techniques to examine the finance-growth nexus. These methodologies are effective in evaluating both short-term dynamics and long-term equilibrium while accounting for potential asymmetries in estimation. Some studies utilizing these approaches are discussed below.

Qamruzzaman and Jianguo (2018) investigated the finance-growth nexus in Bangladesh, India, Pakistan, and Sri Lanka by applying these models to capture both short-term fluctuations and long-term equilibrium. According to their findings, while financial innovation supports growth, its effects are frequently non-proportional, validating the need for nonlinear modeling in these countries. Chen et al. (2020) examined the finance-growth nexus in Kenya, accounting for asymmetric effects by incorporating non-linearities in inflation and government expenditure. Their results indicate that while positive shocks to financial development stimulate growth in the short term, negative shocks significantly hinder long-term economic expansion. Mhadhbi and Terzi (2021) extended this analysis to Tunisia (1984–2016), specifically integrating the role of the shadow economy. They found that the presence of a large informal sector fundamentally alters outcomes; specifically, an expansion of the shadow economy can turn the long-term effect of financial development negative.

Al-khatib (2023) examined the Syrian context from 1980 to 2018, confirming a robust long-run equilibrium. The study highlighted that positive shocks to financial development exert a notably stronger and more persistent influence on economic growth than negative shocks, further validating the asymmetric hypothesis. Most recently, Musa (2025) analyzed the joint impact of Foreign Direct Investment (FDI) and financial development in Nigeria (1990–2024). The study concluded that while FDI and positive financial shocks act as significant catalysts for GDP growth in both the short and long run, negative shocks to either variable result in a marked economic contraction.

III. Empirical Strategy And Data

To explain the empirical strategy of investigating Thailand's finance-growth nexus, we present the following four basic equations:

$$EG_t = f_1(FS_t, COTWO_t, GL_t, GE_t) \quad (1)$$

$$FS_t = f_2(EG_t, COTWO_t, GL_t, GE_t) \quad (2)$$

$$EG_t = f_3(FE_t, COTWO_t, GL_t, GE_t) \quad (3)$$

$$FE_t = f_4(EG_t, COTWO_t, GL_t, GE_t) \quad (4)$$

Using Equations 1 and 2, we examine the causal relationship between economic growth (EG), measured by real per capita GDP, and financial size (FS), represented by the ratio of private credit to GDP. In this bivariate framework, EG and FS serve as the dependent variables in turn. Similarly, Equations 3 and 4 assess the relationship between EG and financial efficiency (FE), measured by the ratio of private credit to total deposits, with each acting as the dependent variable respectively. These two financial development indicators have been widely utilized (Beck et al., 2010). To mitigate potential omitted variable bias, we incorporate carbon emissions (COTWO), globalization (GL), and government expenditure (GE) as control variables. We believe that these third variables are particularly relevant given Thailand's commitments to sustainable development, its increasing integration into the global economy, and the role of fiscal policy in driving economic growth. All underlying variables are converted into logarithms.

Data were provided by various databases. Carbon emissions per capita data were obtained from Our World in Data (2025). Globalization was measured using the KOF globalization index provided by the KOF Swiss Economic Institute (2025). Economic growth, the two financial development indicators, and government expenditure (general government final consumption expenditure-to-GDP) was retrieved from the World Bank's World Development Indicators (WDI) (World Bank, 2025). The sample period (1970–2022) was selected primarily based on the availability of the KOF index; the inclusion of data through 2022 ensures that the estimation accounts for the recent exogenous shock of the COVID-19 pandemic on Thailand's finance-growth nexus.

IV. Methodology

Unit Root Tests

Before proceeding with the ARDL and NARDL analyses, we need to check the integration order of the variables. The ARDL bounds testing approach is applicable regardless of whether the regressors are I(0) or I(1), but the presence of any I(2) variable would invalidate the F-statistics provided by Pesaran et al. (2001). Therefore, we employ two unit root tests: the Augmented Dickey-Fuller (ADF) test (Said & Dickey, 1984) and the Phillips-Perron (PP) test (Phillips & Perron, 1988). The null hypothesis for both tests is that the series contains a unit root, implying non-stationarity. If the null is rejected at the first difference but not at levels, the variable is confirmed to be integrated of order one, I(1).

Structural Break Dummy

To make our cointegration analysis more robust, we incorporate level-shift dummy variables into both the ARDL and NARDL estimations as the deterministic component. This approach is vital given Thailand's development profile, where structural breaks can significantly distort the finance-growth nexus. To identify optimal break dates within the real per capita GDP (EG) series, we employ the Lee-Strazicich (2003, 2004) (LS) and Zivot-Andrews (1992) (ZA) tests. By integrating these endogenously determined break dates into our models, we facilitate the identification of a single cointegrating vector ($r = 1$) and mitigate autocorrelation issues.

The LS test is applied to Models A and AA, which account for one- and two-level shifts, respectively. Based on the LS results for Thailand's real per capita GDP series (1970–2022), we constructed two dummy variables: SBONELS capturing a single break in 1998, and SBTWOLS capturing two breaks in 1998 and 2009. These dates align precisely with the 1997–1998 Asian Financial Crisis and the 2008–2009 Global Financial Crisis. In contrast, the ZA test identifies a single level shift in 1987, which is incorporated via the SBONEZA dummy variable.

Model Specification

ARDL and NARDL Estimations

The ARDL and NARDL estimations begin with the bounds test, which utilizes F-statistics to determine the existence of a long-run cointegrating relationship between the underlying variables. If the calculated F-statistic exceeds the upper bound critical value, the null hypothesis of no cointegration is rejected. Conversely, if the F-statistic falls below the lower bound, the null cannot be rejected. If it falls between the bounds, the test is inconclusive. Subsequently, the optimal lag order for each variable is determined using either the AIC or the SBC.

To analyze the Thai finance-growth nexus, both ARDL and NARDL estimations employ the following error correction specification:

$$\Delta Y_t = \alpha Y_{t-1} + \sum_{i=1}^k \gamma_i X_{t-i} + \sum_{j=0}^q \beta_j \Delta Z_{t-j} + DTC_t + inpt + \epsilon_t \quad (5)$$

In Equation 5, Y is the dependent variable (either EG, FS or FE), while X and Z represent the vectors for long-run and short-run variables, respectively. DTC is the deterministic component (either SBONELS, SBTWOLS, SBONEZA or TREND), $inpt$ denotes the intercept, and ϵ signifies the error term. After confirming the existence of cointegration through the bounds test, the empirical strategy proceeds by assessing the significance of the error correction term (ECT), represented by α in Equation 5. For a stable long-run relationship, α must be negative and statistically significant, indicating the speed of adjustment back to equilibrium following a shock.

NARDL Specification: Assessing Asymmetry

Before conducting the NARDL estimation, the variables EG, FS, and FE are decomposed into their positive and negative partial sums to capture asymmetric effects:

$$Y_T^+ = \sum_{j=1}^t \Delta Y_j^+ = \sum_{j=1}^t \max(\Delta Y_j, 0) \quad (10)$$

$$Y_T^- = \sum_{j=1}^t \Delta Y_j^- = \sum_{j=1}^t \min(\Delta Y_j, 0) \quad (11)$$

In Equations 10 and 11, Y represents either EG or FS or FE. Equation 5 is then expanded for the NARDL estimation to account for these asymmetric components:

$$\Delta EG_t = \sum_{i=1}^p \beta_{1i} \Delta EG_{t-i} + \sum_{i=0}^q (\beta_2^+ \Delta FS_{t-i}^+ + \beta_3^- \Delta FS_{t-i}^-) + \sum_{i=0}^{q_2} \beta_{4i} \Delta COTWO_{t-i} + \sum_{i=0}^{q_3} \beta_{5i} \Delta GL_{t-i} + \sum_{i=0}^{q_4} \beta_{6i} \Delta GE_{t-i} + \gamma_1 EG_{t-1} + \gamma_2 FS_{t-1}^+ + \gamma_3 FS_{t-1}^- + \gamma_4 COTWO_{t-1} + \gamma_5 GL_{t-1} + \gamma_6 GE_{t-1} + DTC_t + inpt + \epsilon_t \quad (12)$$

$$\Delta FS_t = \sum_{i=1}^p \beta_{1i} \Delta FS_{t-i} + \sum_{i=0}^q (\beta_2^+ \Delta EG_{t-i}^+ + \beta_3^- \Delta EG_{t-i}^-) + \sum_{i=0}^{q_2} \beta_{4i} \Delta COTWO_{t-i} + \sum_{i=0}^{q_3} \beta_{5i} \Delta GL_{t-i} + \sum_{i=0}^{q_4} \beta_{6i} \Delta GE_{t-i} + \gamma_1 FS_{t-1} + \gamma_2 EG_{t-1}^+ + \gamma_3 EG_{t-1}^- + \gamma_4 COTWO_{t-1} + \gamma_5 GL_{t-1} + \gamma_6 GE_{t-1} + DTC_t + inpt + \epsilon_t \quad (13)$$

$$\Delta EG_t = \sum_{i=1}^p \beta_{1i} \Delta EG_{t-i} + \sum_{i=0}^q (\beta_2^+ \Delta FE_{t-i}^+ + \beta_3^- \Delta FE_{t-i}^-) + \sum_{i=0}^{q_2} \beta_{4i} \Delta COTWO_{t-i} + \sum_{i=0}^{q_3} \beta_{5i} \Delta GL_{t-i} + \sum_{i=0}^{q_4} \beta_{6i} \Delta GE_{t-i} + \gamma_1 EG_{t-1} + \gamma_2 FE_{t-1}^+ + \gamma_3 FE_{t-1}^- + \gamma_4 COTWO_{t-1} + \gamma_5 GL_{t-1} + \gamma_6 GE_{t-1} + DTC_t + inpt + \epsilon_t \quad (14)$$

$$\Delta FE_t = \sum_{i=1}^p \beta_{1i} \Delta FE_{t-i} + \sum_{i=0}^q (\beta_2^+ \Delta EG_{t-i}^+ + \beta_3^- \Delta EG_{t-i}^-) + \sum_{i=0}^{q_2} \beta_{4i} \Delta COTWO_{t-i} + \sum_{i=0}^{q_3} \beta_{5i} \Delta GL_{t-i} + \sum_{i=0}^{q_4} \beta_{6i} \Delta GE_{t-i} + \gamma_1 FE_{t-1} + \gamma_2 EG_{t-1}^+ + \gamma_3 EG_{t-1}^- + \gamma_4 COTWO_{t-1} + \gamma_5 GL_{t-1} + \gamma_6 GE_{t-1} + DTC_t + inpt + \epsilon_t \quad (15)$$

In Equations 12–15, long-run relationships are evaluated based on the significance and signs of the γ coefficients. Most importantly, to test for asymmetric effects within the NARDL framework, the positive and negative partial sums—EG+, EG-, FS+, FS-, FE+, and FE—are incorporated. Long-run asymmetry is formally assessed by the long-run coefficient symmetry test whose null hypothesis $H_0: \gamma_2 = \gamma_3$ using the Wald test. Then, the signs and significance of γ_2 and γ_3 are examined to identify potential complex asymmetric relationships between economic growth and financial development. The long-run impacts of the third variables are captured by γ_4 , γ_5 , and γ_6 , respectively. Short-run inferences are derived from the statistical significance of the β coefficients; in particular, short-run asymmetry is tested by evaluating the coefficients for the differenced lagged terms of β_2 and β_3 .

V. Empirical Results

Unit Root Results

We first conducted both the ADF and PP tests. The ADF test was estimated using the Akaike Information Criterion (AIC) with a maximum lag of 4. The PP test was estimated using the Newey-West automatic bandwidth selection for lag. As reported in Table 1, although results may be different due to specifications, all the variables exhibit non-stationarity at their levels. However, each variable becomes stationary after the first difference, achieving statistical significance at the 1% and 5% levels. Thus, all variables are integrated of order one, I(1), with no I(2) processes detected. This satisfies the prerequisite conditions for proceeding with the ARDL and NARDL estimations.

Table 1: ADF and PP Test Results

	ADF Test		PP Test	
	Inpt. only	Inpt. & Trend	Inpt. only	Inpt. & Trend
EG	-1.856	-1.151	-1.874	-0.684
ΔEG	-4.368***	-4.735***	-4.378***	-4.717***
EGSQ	-1.511	-1.380	-1.478	-0.963
$\Delta EGSQ$	-4.602***	-4.805***	-4.602***	-4.788***
FS	-2.380	-2.025	-2.552*	-1.579
ΔFS	-3.412**	-3.721**	-3.523**	-3.779**
FSSQ	-2.169	-2.044	-2.126	-1.516
$\Delta FSSQ$	-3.474**	-3.673**	-3.584***	-3.732**
FE	-2.042	-2.635	-1.780	-1.944
ΔFE	-5.234***	-5.256***	-5.211***	-5.218***

FESQ	-1.247	-2.534	-1.067	-2.223
Δ FESQ	-5.360***	-5.311***	-5.360***	-5.311***
COTWO	-1.721	-0.344	-2.591	-0.552
Δ COTWO	-4.860***	-5.217***	-4.884***	-5.223***
GL	-1.672	-0.186	-1.636	-0.294
Δ GL	-5.923***	-6.220***	-5.915***	-6.238***
GE	-1.529	-3.234	-0.994	-2.314
Δ GE	-4.205***	-4.161***	-4.039***	-3.994**
Notes: (***) 1%, (**) 5% level of significance.				

ARDL Results

Bounds Testing and Diagnostics

Tables 2–5 present the ARDL results. The following discussion refers to Panel A of each table. Models I-A and I-B utilize financial size as the financial development indicator, while Models II-A and II-B employ financial efficiency. A key feature of these four models is the inclusion of squared terms for economic growth and financial development indicators (EGSQ, FSSQ, and FESQ).

The maximum lag order was set between 2 and 4 for each model; then, the optimal lag order for each underlying variable was selected using either the AIC (for Models I-A and I-B) or the SBC (for Models II-A and II-B). The two growth models (Models I-A and II-A) include a "trend" as the unrestricted deterministic component, whereas Model I-B incorporates SBONELS (break date 1998) and Model II-B incorporates SBONEZA (break date 1987). The bounds test statistics show that all four models exhibit ARDL cointegration at the 1% level. By selecting optimal lags and deterministic components, the four ARDL models demonstrate robust cointegrating relationships. The models are free from significant diagnostic issues while achieving an acceptable goodness-of-fit (R^2) between 0.692 and 0.955. These diagnostics confirm the suitability of the ARDL estimation.

ARDL Economic Growth (EG) and Financial Size (FS)

The ARDL results, using financial size as the proxy for financial development, are presented in Panels B and C of Tables 2 and 3. We first look at the ECT coefficients which are negative (between -1 and 0) and significant at the 1% level for both Models I-A and I-B. This validates the discussion of both long- and short-run estimates.

In the long-run analysis, the impact of financial size on economic growth (Panel B of Table 2), we find an inverted U-shaped relationship; financial size is positive for economic growth, while its squared term (FSSQ) is negative at the 1% level. Likewise, examining the effect of economic growth on financial size (Panel B of Table 3) reveals an inverted U-shaped relationship: economic growth is positive for financial size, and its squared term (EGSQ) is negative at the 5% level. These long-run estimations demonstrate that Thailand's finance-growth nexus is bilateral and non-linear when proxied by financial size.

Conversely, the short-run findings are different. In Model I-A, the short-run effects of financial size and its squared term on economic growth were not captured due to the selected lag orders. However, the short-run growth effects on financial size are as follows: Δ EG is positive, while Δ EGSQ is negative at the 1% level.

ARDL Economic Growth (EG) and Financial Efficiency (FE)

The ARDL results, for which financial efficiency is the proxy for financial development, are presented in Panels B and C of Tables 4 and 5. The ECT coefficients for both Models II-A and II-B are negative (ranging between -1 and 0) and significant at the 1% level, validating both the long- and short-run estimates.

In the long-run analysis, the impact of financial efficiency on economic growth (Table 3, Panel B) depicts an inverted U-shaped relationship. So, financial efficiency is positive for economic growth, while its squared term (FESQ) is negative at the 1% level. On the other hand, the impact of economic growth on financial efficiency is statistically insignificant, despite a positive causal direction (Table 4, Panel B). These long-run estimations suggest that when financial efficiency is the indicator, Thailand's finance-growth nexus is unilateral and characterized by a non-linear structure.

In the short-run results for Model II-A, three of the four Δ FE terms are significant at the 1-5% level; a similar pattern is observed for the Δ FESQ terms, where three of four are also significant. In Model II-B, the short-run growth impact on financial efficiency (Δ EG) is negative; however, Δ EGSQ term was excluded from the model based on lag order selection.

ARDL Effects of Third Variables

The ARDL analysis also reveals the impact of carbon emissions, globalization, and government expenditure on economic growth, financial size, and financial efficiency.

Carbon emissions (COTWO) exert a long-run positive impact on economic growth at the 1% level, regardless of the financial development indicator used. Regarding the short-run impact, a positive Δ COTWO on

economic growth is detected only in Model I-A. Carbon emissions are not significant for financial size across any time span. While carbon emissions remain insignificant for financial efficiency in the long run, specific short-run variations in Δ COTWOs are significant.

The long-run effect of globalization (GL) on economic growth is consistently negative and significant at the 1% level across both Models I-A and II-A. Regarding short-run effects, three of the four Δ GL coefficients are significant at the 1-5% level in Models I-A and II-A. On the other hand, globalization does not show a significant impact on either financial size or financial efficiency, with the exception of Δ GL(-1) in Model I-B, which is significant at the 5% level.

The long-run effect of government expenditure (GE) on economic growth is consistently negative and significant at the 1-5% level across both Models I-A and II-B. Regarding short-run growth effects, three of the four Δ GE coefficients are significant at the 1-5% level in Models I-A and two of the four Δ GE coefficients in Model II-A. While no long-run impact of GE on financial size or efficiency was found, only the short-run coefficient (Δ GE) was detected as significant for financial efficiency at the 5% level in Model II-B.

Table 2: ARDL Results (Model I-A)

Panel A: Bounds and Diagnostics Tests					
Dep. Variable	End. Variables			Det. Components	
EG	FS, FSSQ, COTWO, GL, GE			Trend(unrst.), Inpt(unrst.)	
Maximum lag	Criteria	Selected Lag orders	Bounds Test Statistic		
4	SIC	(1,0,0,1,4,4)	11.49***		
Autocorrelation	Functional Form	Normality	Heteroscedasticity		
2.038 [.148]	0.792 [.380]	0.803 [.669]	1.003 [.478]		.908
Panel B: Long-run Estimation (Conditional Error Correction)					
Variable	Coefficient	Std. Error	t-Statistic	Probability	
EG(-1)	-0.352	.090	-3.916	0.000***	
FS	0.457	.100	4.578	0.000***	
FSSQ	-0.063	.012	-5.372	0.000***	
COTWO(-1)	0.312	.083	3.777	0.001***	
GL(-1)	-0.607	.168	-3.618	0.001***	
GE(-1)	-0.140	.055	-2.525	0.017**	
Panel C: Short-run Estimation (Error Correction)					
Variable	Coefficient	Std. Error	t-Statistic	Probability	
ETC	-0.352	.039	-8.928	0.000**	
Δ COTWO	0.473	.036	12.96	0.000**	
Δ GL	-0.145	.111	-1.297	0.203	
Δ GL(-1)	0.343	.123	2.792	0.008**	
Δ GL(-2)	0.487	.123	3.971	0.000**	
Δ GL(-3)	0.539	.122	4.404	0.000**	
Δ GE	-0.245	.045	-5.388	0.000**	
Δ GE(-1)	0.107	.049	2.178	0.036*	
Δ GE(-2)	-0.077	.049	-1.584	0.122	
Δ GE(-3)	0.229	.046	5.030	0.000**	

Notes: (***) 1%, (**) 5% level of significance.

Table 3: ARDL Results (Model I-B)

Panel A: Bounds and Diagnostics Tests					
Dep. Variable	End. Variables	Det. Components			
FS	EG, EGSQ, COTWO, GL, GE	SBONELS(unrst.), Inpt(rst.)			
Maximum lag	Criteria	Selected Lag orders	Bounds Test Statistic		
2	SIC	(2,1,1,0,2,0)	9.500***		
Autocorrelation	Functional Form	Normality	Heteroscedasticity		
0.010 [.990]	0.068 [.796]	2.585 [.275]	0.977 [.487]	.809	
Panel B: Long-run Estimation (Conditional Error Correction)					
Variable	Coefficient	Std. Error	t-Statistic	Probability	
FS(-1)	-0.250	.047	-5.370	0.000***	
EG(-1)	1.479	.560	2.642	0.012**	
EGSQ(-1)	-0.112	.042	-2.669	0.011**	
COTWO	0.059	.105	0.560	0.579	
GL(-1)	0.692	.440	1.574	0.124	
GE	-0.057	.081	-0.701	0.488	
Panel C: Short-run Estimation (Error Correction)					
Variable	Coefficient	Std. Error	t-Statistic	Probability	
ECT	-0.250	.029	-8.775	0.000**	
ΔFS(-1)	0.352	.073	4.825	0.000**	
ΔEG	7.330	.572	12.662	0.000**	
ΔEGSQ	-0.588	.122	-4.810	0.000**	
ΔGL	-0.311	.299	-1.042	0.303	
ΔGL(-1)	-0.770	.308	-2.496	0.016*	

Notes: (***) 1%, (**) 5% level of significance.

Table 4: ARDL Results (Model II-A)

Panel A: Bounds and Diagnostics Tests					
Dep. Variable	End. Variables	Det. Components			
EG	FE, FESQ, COTWO, GL, GE	Trend(unrst.), Inpt(unrst.)			
Maximum lag	Criteria	Selected Lag orders	Bounds Test Statistic		
4	AIC	(2,4,4,0,4,4)	25.60***		
Autocorrelation	Functional Form	Normality	Heteroscedasticity		
0.715 [.500]	0.068 [.796]	3.984 [.136]	1.037 [.465]	.955	
Panel B: Long-run Estimation (Conditional Error Correction)					
Variable	Coefficient	Std. Error	t-Statistic	Probability	

EG(-1)	-0.636	0	-	0.000***
FE(-1)	0.262	0	6	0.000***
FESQ(-1)	-0.180	0	-	0.000***
COTWO	0.328	0	5	0.000***
GL(-1)	-0.373	0	-	0.007***
GE(-1)	-0.229	0	-	0.000***
Panel C: Short-run Estimation (Error Correction)				
<u>Variable</u>	<u>Coefficient</u>	<u>Std. Error</u>	<u>t-Statistic</u>	<u>Probability</u>
ETC	-0.636	.047	-13.62	0.000**
ΔEG(-1)	0.158	.072	.177	0.038*
ΔFE	0.239	.058	.107	0.000**
ΔFE(-1)	0.055	.059	.935	0.357
ΔFE(-2)	-0.104	.048	-2.163	0.039*
ΔFE(-3)	-0.106	.050	-2.135	0.041*
ΔFESQ	-0.143	.026	-5.396	0.000**
ΔFESQ(-1)	0.012	.027	.436	0.666
ΔFESQ(-2)	0.086	.022	.891	0.001**
ΔFESQ(-3)	0.065	.025	.568	0.016*
ΔGL	-0.208	.107	-1.948	0.061
ΔGL(-1)	0.218	.100	.179	0.038*
ΔGL(-2)	0.481	.098	.924	0.000**
ΔGL(-3)	0.269	.097	.784	0.009**
ΔGE	-0.303	.044	-6.946	0.000**
ΔGE(-1)	0.077	.046	.652	0.109
ΔGE(-2)	-0.059	.049	-1.203	0.239
ΔGE(-3)	0.351	.044	.997	0.000**

Notes: (***) 1%, (**) 5% level of significance.

Table 5: ARDL Results (Model II-B)

Panel A: Bounds and Diagnostics Tests				
<u>Dep. Variable</u>	<u>End. Variables</u>		<u>Det. Components</u>	
FE	EG, EGSQ, COTWO, GL, GE		SBONEZA(unrst.), Intercept(rst.)	
<u>Maximum lag</u>	<u>Criteria</u>	<u>Selected Lag orders</u>	<u>Bounds Test Statistic</u>	
3	AIC	(1,1,0,3,0,1)	5.975***	
<u>Autocorrelation</u>	<u>Functional Form</u>	<u>Normality</u>	<u>Heteroscedasticity</u>	
0.470 [.629]	0.456 [.504]	0.295 [.863]	0.692 [.749]	.692
Panel B: Long-run Estimation (Conditional Error Correction)				

Variable	Coefficient	Standard Error	t-Statistic	Probability
FS(-1)	-0.250	.047	-5.370	0.000***
EG(-1)	1.479	.560	2.642	0.012**
EGSQ(-1)	-0.112	.042	-2.669	0.011**
COTWO	0.059	.105	0.560	0.579
GL(-1)	0.692	.440	1.574	0.124
GE	-0.057	.081	-0.701	0.488
Panel C: Short-run Estimation (Error Correction)				
Variable	Coefficient	Standard Error	t-Statistic	Probability
ECT	-0.250	.029	-8.775	0.000**
ΔFS(-1)	0.352	.073	4.825	0.000**
ΔEG	7.330	.572	12.662	0.000**
ΔEGSQ	-0.588	.122	-4.810	0.000**
ΔGL	-0.311	.299	-1.042	0.303
ΔGL(-1)	-0.770	.308	-2.496	0.016**

Notes: (***) 1%, (**) 5% level of significance.

NARDL Estimates

Bounds Testing and Diagnostics

Tables 6–9 present the NARDL estimates. We first report focusing on Panel A of each table. Financial size is the proxy for financial development in Models III-A and III-B, while financial efficiency is employed in Models IV-A and IV-B. A key advantage of the NARDL framework is its capacity to decompose independent variables (FS, FE, and EG) into their positive (FSPO, FEPO, EGPO) and negative (FSNE, FENE, EGNE) cumulative sums. This allows for the detection of asymmetric long-run relationships based on the direction of change (Shin et al., 2014). Additionally, the error correction representation distinguishes between short-term dynamics and the long-term equilibrium in estimation.

The maximum lag order was set between 1 and 4 for each model; the optimal lag length for each underlying variable was selected based on the AIC for Models III-B, IV-A, and IV-B, and the SBC for Model III-A. Regarding level shift dummies, Model III-A incorporates SBONELS (break date 1998), Model III-B includes SBTWOLS (break dates 1998 and 2009), and Models IV-A and IV-B utilize SBONEZA (break date 1987). Bounds Test statistics indicate that all four models exhibit cointegration at the 1% significance level. These optimal lag selections and deterministic components allow the NARDL models to show robust cointegrating relationships; those are free from diagnostic issues while achieving a strong goodness-of-fit (R^2 values ranging from 0.724 to 0.956).

NARDL Economic Growth (EG) and Financial Size (FS)

The NARDL results, using financial size as a proxy for financial development, are reported in Panels B, C, and D of Tables 6 and 7. The ECT coefficients for Models III-A and III-B are negative (ranging between -1 and 0) and significant at the 1% level. These confirm a long-run error-correcting mechanism, validating the analysis of long-run and short-run effects on economic growth and financial size.

We emphasize the coefficient symmetry tests in Panel B (Tables 6 and 7), which establish a long-run asymmetric relationship between the variables. Specifically, we find a bidirectional impact: financial size influences economic growth (significant at the 1% level), while economic growth conversely affects financial size (significant at the 5% level). Conversely, no significant short-run asymmetries were detected.

Regarding the long-run coefficients: 1) the positive cumulative sums of financial size (FSPO) are positive for economic growth at the 5% level; 2) negative cumulative sums of financial size (FSNE) are negative for economic growth at the 1% level; and 3) both the positive and negative cumulative sums of economic growth (EGPO and EGNE) are positive for financial size in the long run at the 1% level. In the short run, only ΔFSNE is statistically significant; no other variables showed significant effects in the estimations.

NARDL Economic Growth (EG) and Financial Efficiency (FE)

The NARDL findings, using financial efficiency as the financial development indicator, are reported in Panels B, C, and D of Tables 8 and 9. First, the ECT coefficients for Models IV-A and IV-B are negative (ranging between -1 and 0) and significant at the 1% level. Thus, we confirm a long-run error-correcting mechanism and validates the analysis of long-run and short-run effects.

The coefficient symmetry tests in Panel B of Tables 8 and 9 indicate that while financial efficiency influences economic growth in both the long and short run (significant at the 1% level), but economic growth exhibits no asymmetric effect on financial efficiency across any timespan. Regarding the long-run coefficients: 1) the positive cumulative sums of financial efficiency (FEPO) are insignificant for economic growth; 2) the negative cumulative sums (FENE) are negative for economic growth at the 1% level; 3) positive cumulative sums of economic growth (EGPO) are positive for financial efficiency (5% level); and 4) negative sums (EGNE) have no impact on financial efficiency.

The short-run results are as follows: 1) all four Δ FEPO terms are significant at the 1–5% level; 2) two of the four Δ FENE terms are significant at the 1% level; and 3) both Δ EGPO and Δ EGNE are significant at the 1% level.

NARDL Effects of Third Variables

The NARDL analysis also finds out the effects of carbon emissions, globalization, and government expenditure on economic growth, financial size, and financial efficiency.

Carbon emissions (COTWO) exhibit no long-run impact on economic growth, regardless of the financial development indicator used. Regarding short-run impacts, significant effects of Δ COTWO on economic growth are observed in Models III-A and IV-A. While carbon emissions are not significant for either financial size or financial efficiency in the long run, they do show significance in the short run.

The long-run effect of globalization (GL) on economic growth is not significant in either Model III-A or IV-A. In terms of short-run effects, Model III-A does not include Δ GL, while four out of five Δ GL coefficients in Model IV-A are significant at the 1% level. Similarly, globalization has no long-run impact on financial size or efficiency; however, some Δ GL coefficients show significant short-run effects in Models III-B and IV-B.

The long-run effect of government expenditure (GE) on economic growth is positive at the 1% level, regardless of the financial development indicator used. In the short run, the results are more mixed: while Model III-A excludes Δ GE, three out of four Δ GE coefficients in Model IV-A are significant at the 1–5% level. On the other hand, government expenditure exhibits no long-run effect on either financial size or efficiency. Regarding short-run dynamics, Δ GE significantly impacts financial size at the 5% level; however, it is omitted from Model IV-B based on optimal lag selection criteria.

Table 6: NARDL Results (Model III-A)

Panel A: Bounds and Diagnostics Tests					
Dep. Variable	End. Variables	Det. Components			
EG	COTWO, GL, GE, FSPO, FSNE	SBONELS(unrst.), Inpt(rst.)			
Maximum lag	Criteria	Selected Lag orders	Bounds Test Statistic		
2	SIC	(1,1,0,0,1)	6.236***		
Autocorrelation	Functional Form	Normality	Heteroscedasticity		
0.987 [.382]	2.022 [.146]☆	1.435 [.488]	1.131 [.365]	.734	
Panel B: Coefficient Symmetry Tests (Variable: FS)					
		Chi-square	Probability		
Long-run		13.52	0.001***		
Short-run		0.433	0.514		
Panel C: Long-run Estimation (Conditional Error Correction)					
Variable	Coefficient	Std. Error	t-Statistic	Probability	
EG(-1)	-0.048	.072	0	0.508	

COTWO (-1)	-0.026	0	-	0.660	
GL	-0.214	0	-	0.293	
GE	-0.136	0	-	0.001***	
FSPO(-1)	0.093	0	2	0.015**	
FSNE(-1)	-0.194	0	-	0.001***	
Panel D: Short-run Estimation (Error Correction)					
<u>Variable</u>	<u>Coefficient</u>	<u>Std. Error</u>	<u>t-Statistic</u>	<u>Probability</u>	
ETC	-0.048	0	-	0.000***	
Δ COTWO	0.303	0	4	0.000***	
Δ FSPO	-0.096	0	-	0.078	
Δ FSNE	-0.215	0	-	0.005***	

Notes: (***) 1%, (**) 5% level of significance.

Table 7: NARDL Results (Model III-B)

Panel A: Bounds and Diagnostics Tests					
<u>Dep. Variable</u>	<u>End. Variables</u>		<u>Det. Components</u>		
FS	COTWO, GL, GE, EGPO, EGNE		SBTWOLS(unrst.), lnpt(rst.)		
<u>Maximum lag</u>	<u>Criteria</u>	<u>Selected Lag orders</u>	<u>Bounds Test Statistic</u>		
1	AIC	(1,1,1,1,1)	8.464***		
<u>Autocorrelation</u>	<u>Functional Form</u>	<u>Normality</u>	<u>Heteroscedasticity</u>		²
0.244 [.785]	0.995 [.326]	1.773 [.412]	1.244 [.291]		.742
Panel B: Coefficient Symmetry Tests (Variable: EG)					
		<u>Chi-square</u>	<u>Probability</u>		
Long-run		4.982	0.026**		
Short-run		0.915	0.339		
Panel B: Long-run Estimation (Conditional Error Correction)					
<u>Variable</u>	<u>Coefficient</u>	<u>Std. Error</u>	<u>t-Statistic</u>	<u>Probability</u>	
FS(-1)	-0.190	0	-	0.000***	
COTWO (-1)	-0.117	0	-	0.399	
GL(-1)	-0.079	0	-	0.865	
GE(-1)	-0.043	0	-	0.712	
EGPO(-1)	0.409	0	3	0.002***	
EGNE(-1)	1.431	0	3	0.001***	
Panel C: Short-run Estimation (Error Correction)					
<u>Variable</u>	<u>Coefficient</u>	<u>Std. Error</u>	<u>t-Statistic</u>	<u>Probability</u>	
ETC	-0.190	0	-	0.000***	
Δ COTWO	0.492	0	2	0.005***	

ΔGL	-0.794	0	-	0.024**
ΔGE	0.272	0	2	0.050**
ΔEGPO	0.029	0	0	0.914
ΔEGNE	-0.792	0	-	0.072
		.340	2.335	
		.135	.019	
		.268	.109	
		.430	1.843	

Notes: (***) 1%, (**) 5% level of significance.

Table 8: NARDL Results (Model IV-A)

Panel A: Bounds and Diagnostics Tests				
Dep. Variable	End. Variables		Det. Components	
EG	COTWO, GL, GE, FEPO, FENE		SBONEZA(unrst.), Inpt(rst.)	
Maximum lag	Criteria	Selected Lag orders	Bounds Test Statistic	
4	AIC	(3,3,4,4,4)	11.53***	
Autocorrelation	Functional Form	Normality	Heteroscedasticity	2
2.686 [.097]	2.497 [.097]☆	0.191 [.909]	1.052 [.463]	.956
Panel B: Coefficient Symmetry Tests (Variable: FE)				
		Chi-square	Probability	
Long-run		13.67	0.000***	
Short-run		13.17	0.000***	
Panel C: Long-run Estimation (Conditional Error Correction)				
Variable	Coefficient	Std. Error	t-Statistic	Probability
EG(-1)	-0.119	.070	-1.704	0.105
COTWO(-1)	0.096	.082	.170	0.257
GL(-1)	-0.329	.233	-1.409	0.175
GE(-1)	-0.246	.070	-3.502	0.002***
FEPO(-1)	0.030	.045	.658	0.518
FENE(-1)	-0.270	.050	-5.416	0.000***
Panel D: Short-run Estimation (Error Correction)				
Variable	Coefficient	Std. Error	t-Statistic	Probability
ETC	-0.119	.012	-10.31	0.000***
ΔEG(-1)	-0.278	.117	-2.381	0.025**
ΔEG(-2)	-0.463	.122	-3.793	0.001***
ΔCOTWO	0.492	.040	2.22	0.000***
ΔCOTWO(-1)	0.110	.058	.902	0.069
ΔCOTWO(-2)	0.091	.065	.398	0.174
ΔGL	0.134	.117	.142	0.264
ΔGL(-1)	0.388	.119	.268	0.003***
ΔGL(-2)	0.534	.106	.020	0.000***

ΔGL(-3)	0.474	0	4	0.000***
ΔGE	-0.378	0	-	0.000***
ΔGE(-1)	0.005	0	0	0.934
ΔGE(-2)	-0.107	0	-	0.043**
ΔGE(-3)	0.291	0	6	0.000***
ΔFEPO	-0.108	0	-	0.001***
ΔFEPO(-1)	-0.090	0	-	0.008***
ΔFEPO(-2)	-0.117	0	-	0.002***
ΔFEPO(-3)	-0.083	0	-	0.016**
ΔFENE	-0.052	0	-	0.424
ΔFENE(-1)	0.210	0	2	0.006***
ΔFENE(-2)	0.188	0	2	0.008***
ΔFENE(-3)	0.083	0	1	0.125

Notes: (***) 1%, (**) 5% level of significance.

Table 9: NARDL Results (Model IV-B)

Panel A: Bounds and Diagnostics Tests				
Dep. Variable	End. Variables		Det. Components	
FE	COTWO, GL, GE, EGPO, EGNE		SBONEZA(umrst.), Inpt(rst.)	
Maximum lag	Criteria	Selected Lag orders	Bounds Test Statistic	
4	AIC	(1,1,4,0,1)	8.480***	
Autocorrelation	Functional Form	Normality	Heteroscedasticity	2
0.285 [.754]	1.374 [.250]	0.185 [.912]	1.613 [.126]	.724
Panel B: Coefficient Symmetry Tests (Variable: FE)				
		Chi-square	Probability	
Long-run		0.186	0.666	
Short-run		0.574	0.449	
Panel C: Long-run Estimation (Conditional Error Correction)				
Variable	Coefficient	Std. Error	t-Statistic	Probability
FE(-1)	-0.351	.077	-4.537	0.000***
COTWO(-1)	0.090	.224	.401	0.691
GL(-1)	-0.697	.859	-0.811	0.423
GE(-1)	0.044	.222	.196	0.846
EGPO(-1)	0.364	.172	.113	0.042**
EGNE(-1)	0.051	.662	.076	0.940
Panel D: Short-run Estimation (Error Correction)				
Variable	Coefficient	Std. Error	t-Statistic	Probability

ETC	-0.351	0	-	0.000***	
		.042	8.357		
Δ COTW	1.518	0	7	0.000***	
O		.213	.115		
Δ GL	0.206	0	0	0.661	
		.467	.441		
Δ GL(-1)	0.297	0	0	0.543	
		.484	.613		
Δ GL(-2)	0.765	0	1	0.121	
		.483	.586		
Δ GL(-3)	1.687	0	3	0.002***	
		.501	.366		
Δ EGPO	-2.129	0	-	0.000***	
		.424	5.024		
Δ EGNE	-3.055	0	-	0.000***	
		.586	5.214		

Notes: (***) 1%, (**) 5% level of significance.

VI. Policy Implications And Conclusion

This study examines Thailand's finance-growth nexus over the period 1970–2022 using ARDL and NARDL techniques. The ARDL results confirm a non-linear, inverted U-shaped relationship, indicating that financial development—in terms of both size and efficiency—initially boosts economic growth. However, it eventually reaches a threshold beyond which more finance hinders growth. Conversely, the NARDL findings reveal a significant asymmetry: negative shocks to financial size and efficiency significantly hinder growth, while positive shocks have a more varied impact. These findings suggest a critical need to reorient strategic focus from quantitative expansion—simply increasing credit volume—toward qualitative financial development.

Regarding causal direction, Thailand's finance-growth nexus is bidirectional when measuring financial size, as finance and growth mutually reinforce one another. However, when measuring efficiency, the relationship is unilateral: efficiency drives growth, but growth does not necessarily enhance financial efficiency. A key policy implication is that while a large financial sector and a growing economy may support each other, increasing the scale of the financial sector does not automatically translate into improved efficiency or quality. Furthermore, while the ARDL results indicate that carbon emissions significantly drive economic growth, this relationship is insignificant in the NARDL estimation. Carbon emissions also exert no long-run influence on financial size or efficiency, implying that Thailand's "grow now, clean up later" strategy is unsustainable. Additionally, the negative long-run impact of globalization and government expenditure suggests that current levels of openness and public spending are not well-aligned with long-term goals.

Based on these implications—emphasizing "efficiency" and "quality"—we conclude that Thailand should shift from quantity-based growth toward quality-driven sustainable development. This will enable the country to more efficiently align financial development, environmental responsibility, and global integration with macroeconomic stability.

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