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Research Article

Indirect Effects of Financial Inclusion on Tax Revenue in Selected Developing and Developed Countries

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ABSTRACT

This study employs the Panel Smooth Transition Regression (PSTR) framework to analyze how financial inclusion indirectly shapes tax revenue across 50 countries (28 developing, 22 developed) during 2004–2024. A financial inclusion index, constructed via Principal Component Analysis (PCA) using ATM density, bank branch penetration, and outstanding deposits, serves as the transition variable. Results confirm non-linear relationships between financial inclusion, tariff structures, financial development, institutional quality, economic growth, and tax revenue. For developing nations, the threshold is 4.2240 with slope 2.1008. In Regime 1, bank branches show negative effects (-0.2166), while financial development is positive (0.2849). Beyond the threshold, bank branches remain negative (-0.0626), financial development positive (0.0573), and institutional quality turns favorable (0.0660). For developed economies, threshold is 6.7464 with slope 2.1993×10^{4}. In Regime 1, bank branches are negative (-0.0502) while tariffs are positive (0.0516). In Regime 2, bank branches become positive (0.0077), financial development turns negative (-0.0853), institutional quality becomes strongly negative (-1.1205), and economic growth positive (0.4496). Granger causality tests reveal bidirectional relationships in developing countries, while developed nations show unidirectional causality from tax revenue to financial inclusion. Findings underscore that financial inclusion's influence on tax revenue is non-linear and context-specific. Policy recommendations include strengthening digital financial infrastructure in developing economies and implementing regulatory frameworks to prevent excessive inclusion in developed countries.

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1. Introduction

Financial inclusion has emerged as a critical policy priority for governments pursuing sustainable development. Theoretical arguments suggest that expanding access to financial services stimulates economic activity. Schumpeter's framework posits that the financial sector drives growth by facilitating capital formation, encouraging innovation, improving efficiency, and stimulating investment, ultimately generating output expansion. The banking sector appears particularly cost-effective in promoting growth through capital accumulation and fostering competitive dynamics among financial institutions (Bakar & Sulong, 2018).

Financial inclusion encompasses situations where individuals and enterprises access useful and affordable financial products—including transactions, payments, savings, credit, and insurance—in a responsible manner. It represents a key instrument for improving welfare, alleviating poverty, and strengthening macroeconomic stability (Beck et al., 2007; Chibba, 2009; Hannig & Jansen, 2010; Cull et al., 2012; Morgan & Pontines, 2014; Park & Mercado-Jr, 2015; Kim, 2016; Oz-Yalaman, 2019). Global statistics indicate that between 2014 and 2017, the proportion of adults with formal accounts rose from 62% to 69% worldwide, with 1.2 billion adults gaining access including 515 million in 2014 alone. This rapid expansion generates substantial benefits while presenting challenges for unprepared nations (Cull et al., 2012; Capasso & Jappelli, 2013; Maherali, 2017).

As financial capabilities improve, income levels rise, potentially increasing tax contributions. The global trend toward financial inclusion offers policymakers opportunities to enhance tax collection. Both developed and developing economies face considerable tax collection challenges, making revenue mobilization a policy priority (Maherali, 2017; Oz-Yalaman, 2019). Numerous studies have investigated tax revenue determinants, including GDP per capita, agricultural output, industrial development, capital inflows, trade openness, political stability, corruption, inflation, and accountability (Clist & Morrissey, 2011; Le et al., 2012; Karagöz, 2012; Castro & Camarillo, 2014).

Despite growing scholarly attention, most research has concentrated on linear relationships between financial inclusion and tax revenue (Oz-Yalaman, 2019; Al-Own & Bani-Khalid, 2021; Chebochok & Bayale, 2023). However, emerging evidence suggests non-linear patterns, frequently displaying U-shaped or inverted U-shaped characteristics (Ozili, 2026). Raouf (2022) employed threshold regression for EMEA countries, while Nguyen The et al. (2025) utilized Bayesian approaches across low and high financial development contexts. Limited research has specifically addressed this non-linearity in the financial inclusion-tax revenue nexus.

To our knowledge, no comprehensive study has simultaneously investigated the indirect and threshold effects of financial inclusion on tax revenue using Panel Smooth Transition Regression (PSTR) methodology across both country groups. Existing non-linear studies have not adequately captured smooth transition dynamics and regime-switching behavior characterizing this relationship (Gonzalez et al., 2005; Colletaz & Hurlin, 2006). Financial inclusion potentially exerts significant influence on tax collections, yet this effect may not follow a linear pattern and remains insufficiently studied. Empirical investigation is particularly needed in developing countries. To address this gap, the current study employs PSTR to evaluate financial inclusion's impact on tax revenue using annual data from 50 developing and developed countries spanning 2005-2023.

This research makes several contributions. First, unlike previous studies using linear models or simple threshold regressions, we apply PSTR to capture smooth transition dynamics, avoiding restrictive functional forms and accommodating heterogeneity across countries and time (Gonzalez et al., 2005; Fouquau et al., 2008). Second, building upon recent findings (Nguyen The et al., 2025; Raouf, 2022), we identify threshold levels and investigate indirect impacts of tariff rates and financial development. Third, we explicitly differentiate between developed and developing countries, aligning with studies emphasizing differential effects across varying financial development levels (Kebede et al., 2025; Sebai & Talbi, 2024). Fourth, we conduct comprehensive

diagnostic tests including autocorrelation, heteroskedasticity, and parameter stability assessments (Abrar & Hayat, 2026; Maashani et al., 2025). These contributions provide nuanced understanding and targeted policy recommendations for countries at different financial development stages.

The remainder proceeds as follows. Section 2 outlines theoretical foundations and empirical evidence. Section 3 presents methodology. Section 4 reports results. Section 5 concludes with policy implications.

2. Literature Review

2.1. Theoretical Foundations

The relationship between financial inclusion and tax revenue can be understood through several complementary theoretical perspectives. First, financial development and growth theory, originating with Gurley and Shaw (1955) and McKinnon (1973), proposes that financial institutions influence economic conditions by affecting investment, production, and consumption decisions. These decisions subsequently impact output, economic growth, and ultimately tax revenue generation. From this perspective, financial inclusion expands the formal financial system by incorporating more individuals and businesses into the taxable economy, thereby broadening the tax base and increasing government revenue (Levine, 2005; Nguyen The et al., 2025).

Second, Ozili's (2021) comprehensive financial system theory argues that inclusive financial indicators improve institutional efficiency and encourage broader participation by individuals and small-to-medium enterprises in formal finance. However, this theory also cautions that excessive financial inclusion—beyond certain thresholds—may lead to overcrowded participation in the formal sector, potentially generating disadvantages for economic growth and tax revenue, particularly during financial crises when loan repayment becomes problematic (Ozili, 2026).

Third, the supply-leading hypothesis (Schumpeter, 1911) and economic deterrence theory (Allingham & Sandmo, 1972) offer complementary explanations. The supply-leading perspective suggests that financial system

development facilitates formal economic activity expansion by reducing reliance on informal arrangements, enhancing financial service availability, and lowering transaction costs (Senso et al., 2026). Economic deterrence theory, conversely, posits that taxpayers utilizing formal financial channels perceive higher detection likelihood for non-compliance as their transactions become more traceable and verifiable (Senso et al., 2026). Recent empirical studies have substantiated these theoretical predictions, demonstrating that financial service access and utilization significantly improve tax compliance through enhanced transaction transparency and reduced informality (Maashani et al., 2025; Senso et al., 2026).

Collectively, these theoretical perspectives suggest that financial inclusion's influence on tax revenue may be non-linear. Economic activity formalization is expected to increase tax revenue at moderate financial inclusion levels through improved financial service access. However, beyond specific thresholds, further expansion may generate diminishing returns or negative outcomes due to factors including excessive financialization, over-indebtedness, and misuse of financial services for informal sector activities (Ozili, 2026; Kebede et al., 2025).

2.2. Transmission Mechanisms

Financial inclusion influences tax revenue through multiple channels. First, it promotes conversion of cash payments into financial accounts, enhancing payment efficiency and transparency from households and enterprises. Transactions conducted through formal accounts generate digital traces amenable to monitoring and auditing, resulting in increased government tax revenue (Demirguc-Kunt et al., 2017; Nguyen The et al., 2025).

Second, financial inclusion facilitates economic formalization by integrating previously informal economic activities into the formal financial system. When individuals and businesses access formal financial services—including savings, payments, and investments—this helps reduce shadow economy size and increases transactions captured within the formal tax

system, generating higher tax revenue (Raouf, 2022; Maashani et al., 2025). Recent evidence from Oman confirms that shadow economy reduction significantly enhances tax revenue (Maashani et al., 2025).

Third, financial inclusion enhances tax compliance through improved transparency and accountability. When individuals and businesses access formal financial services, transactions become more readily recorded and monitored, complicating tax evasion attempts. This generates higher compliance levels as taxpayers become more inclined to report income and pay taxes in a timely manner (Raouf, 2022; Senso et al., 2026). Empirical evidence from Tanzania indicates that financial service access and utilization positively impact tax compliance (Senso et al., 2026).

Fourth, financial inclusion promotes economic growth by providing individuals and businesses access to financial services facilitating investment in education, healthcare, and business expansion. This generates increased taxable income and consumption, leading to higher tax revenues through economic growth stimulation, employment creation, and overall income level increases (Inoue & Hamori, 2016; Ozili, 2026). However, as Ozili (2026) notes, positive effects may reach inflection points beyond which further financial inclusion increases generate negative outcomes—a phenomenon termed the "too-much-of-a-good-thing" effect.

2.3. Evidence from Recent Empirical Studies

Recent empirical research has generated valuable insights into the financial inclusion-tax revenue relationship, with growing evidence demonstrating non-linear effects. Oz-Yalaman (2019) investigated this relationship across 137 countries between 2011 and 2017, discovering positive correlations using OLS estimation. Similarly, Chebochok & Bayale (2023) examined financial inclusion's impact on tax revenue in West African Economic and Monetary Union (WAEMU) countries from 2006 to 2019, concluding that financial inclusion exerts positive and significant effects on government tax revenue.

However, more recent research has uncovered non-linear patterns. Raouf (2022) employed threshold regression approaches to investigate financial inclusion's influence on tax revenue in EMEA countries, revealing non-linear relationships with a threshold level of 20.44. Financial inclusion positively impacted tax revenue below this threshold but generated negative effects above it. Nguyen The et al. (2025) extended this analysis using Bayesian methodologies across 21 low financial development countries (LFDCs) and 22 high financial development countries (HFDCs) from 2004 to 2020. Their research demonstrated that financial inclusion negatively affects tax revenue in LFDCs with 100% probability and in HFDCs with 92.45% probability. Financial inclusion thresholds were established at 18.90 for LFDCs and 20.14 for HFDCs, with beneficial impacts below these thresholds and detrimental effects above them.

Senso et al. (2026) utilized PLS-SEM to investigate financial inclusion-tax compliance relationships in Tanzania, finding that financial service access and utilization positively influence tax compliance, while service quality showed no significant effect. Their results emphasize active financial service engagement rather than passive access in promoting compliance. Maashani et al. (2025) examined specific macroeconomic factors' roles in Oman's tax revenue policy using ARDL from 1991 to 2020, demonstrating that economic activity scale and diversification support programs positively impact tax revenue changes, while FDI inflows, inflation, and shadow economy size generate negative effects.

Important insights have also emerged from studies investigating other tax revenue determinants. Abrar & Hayat (2026) employed ARDL bounds testing to examine macroeconomic, structural, and institutional factors influencing Pakistan's tax revenue from 1990 to 2024, finding that democracy, corruption control, urbanization, and GDP per capita positively influence the tax-to-GDP ratio, while agricultural share and income inequality generate negative effects. Ali Al-Tameemi et al. (2026) utilized Hatemi-J asymmetric causality and NARDL to investigate non-linear asymmetric effects of tax revenues on

financial development in Iran, confirming asymmetry through findings that positive tax revenue shocks negatively impact financial development while negative shocks generate positive effects.

Recent studies have reached emergent consensus that the financial inclusion-tax revenue relationship is context-dependent and potentially exhibits non-linear patterns. Consequences differ across countries based on financial development levels, institutional quality, and economic structure. By utilizing PSTR methodology, this study extends these findings by examining indirect and threshold effects of financial inclusion on tax revenue across both developed and developing countries.

2.4. Research Gap and Contribution

Despite growing empirical evidence, several significant research gaps remain. First, the indirect effects of financial inclusion on tax revenue have not been investigated using the Panel Smooth Transition Regression (PSTR) approach, despite existing studies primarily employing linear models or simple threshold regressions. PSTR methodology offers significant advantages over conventional approaches by facilitating smooth transitions between regimes and capturing parameter heterogeneity across countries and over time (Gonzalez et al., 2005; Colletaz & Hurlin, 2006).

Second, while recent research has identified non-linear effects (Raouf, 2022; Nguyen The et al., 2025), it has not investigated how financial inclusion, as a transition variable, indirectly influences other tax revenue determinants' impacts, including tariff rates and financial development. Understanding these indirect effects proves essential for developing comprehensive fiscal policies.

Third, although some studies have differentiated between developed and developing countries (Nguyen The et al., 2025), no study has simultaneously analyzed the non-linear relationship between financial inclusion and tax revenue using PSTR while explicitly distinguishing these two country groups. Kebede et al. (2025) and Sebai & Talbi (2024) have proposed that differential financial inclusion effects across countries with varying financial development levels warrant separate investigation.

Fourth, previous research has been limited in conducting comprehensive diagnostic testing, including assessments for autocorrelation, heteroskedasticity, and parameter stability. Following recent time-series and panel data studies (Abrar & Hayat, 2026; Maashani et al., 2025), this study implements comprehensive diagnostic evaluations to ensure estimated model reliability and validity.

This study addresses these gaps by utilizing PSTR methodology to investigate indirect and threshold effects of financial inclusion on tax revenue across 51 developed and developing countries from 2005 to 2023. By explicitly distinguishing country groups and conducting comprehensive diagnostic tests, this research offers more nuanced insights and specifically tailored policy recommendations for countries at varying financial development stages.

3. Research Methodology

3.1. Panel Smooth Transition Regression Model (PSTR)

Following Gonzalez et al. (2005) and Colletaz & Hurlin (2006), we specify a PSTR model with two limiting regimes and a transition function:

$$Y_{it} = \mu_i + \beta_0 X_{it} + \beta_1 X_{it} F\left(q_{it};\gamma,c\right) + u_{it} \qquad i = 1,...,N$$
$$t = 1,...,T \tag{1}$$

Where the transition function is logistically specified:

$$F\left(\gamma,c,q_{it}\right) = \left[1 + \exp\left(-\gamma \prod_{j=1}^{m}\left(q_{it} - c_i\right)\right)\right]^{-1} \qquad ,\gamma > 0, c_1 \le c_2 \le,..., \le c_m \tag{2}$$

For m=1, the model predicts two limiting regimes below and above threshold (c1), with uniform transition from β0 to β0+β1. As γ approaches infinity, the PSTR converts to the two-regime PTR model (Hansen, 1999). For m=2, the transition function minimizes at (c1+c2)/2. When γ→0, regardless of m, the model simplifies to linear fixed effects regression.

Coefficient estimation varies across sections and time periods. The generalized PSTR with multiple transition functions is:

$$y_{it} = \mu_i + \beta'_0 x_{it} \sum_{j=1}^{r} \left[\beta'_j x_{it}\right] F_j\left(q_{it}^{j}; \gamma_j, c_j\right) + u_{it} \quad (3)$$

Estimation proceeds through: (1) testing linearity against PSTR using Wald (LMw), Fisher (LMF), and likelihood ratio (LR) statistics; (2) if non-linearity is confirmed, determining transition function numbers; (3) selecting optimal threshold points using AIC and SIC criteria.

3.2. Model Specification and Data Analysis

This study aims to examine threshold and indirect effects of financial inclusion on tax revenue across 50 developing and developed countries from 2004 to 2024. To model relationships among study variables, PSTR econometric techniques and non-linear approaches are employed. The general model, based on Maherali (2017), Oz-Yalaman (2019), and Nguyen The et al. (2025), is specified as:

$$LTAX_{it} = f(LINCLUSION_{it}, LTARIFF_{it}, LCREDIT_{it}, LREG_{it}, LGDPP_{it}) \quad (7)$$

Table 1. Information on construct measures

Variables	Symbol	Source
Domestic credit to private sector by banks (% of GDP)	LCREDIT	WDI
Tax revenue (% of GDP)	LTAX	
Tariff rate, applied, simple mean, all products (%)	LTARIFF	
GDP per capita (constant 2015 US$)	LGDPP	
Regulatory Quality - Governance score (0-100)	LREG	WGI
Financial inclusion:		
- Number of ATMs per 100,000 adults	ATM	IMF FAS
- Number of commercial bank branches per 100,000 adults	BB	
- Outstanding deposits with commercial banks (% of GDP)	OD	

$lTAX_{it}$: The tax revenue logarithm; following Akram (2016), Ajide et al. (2017), Maherali (2017), and Oz-Ylaman (2019), this data has been used.

Inclusion_{it}: Financial inclusion index. Several studies have emphasized multidimensionality of financial inclusion indices measured through multiple

variables (Amidzic et al., 2014; Camara & Tuesta, 2014; Park & Mercado, 2018; Sharma, 2016;). Following El Bourainy et al. (2021), Principal Component Analysis (PCA) was utilized. Information analysis relies heavily on multiple data analysis techniques. Multiple datasets contain multiple states or variables per observation. If each dataset contains n variables, each may have multiple dimensions. PCA reduces all data dimensions based on combined index and related observation classification since multidimensional space often proves difficult to comprehend and visualize. Following Akram (2016), Ajide et al. (2017), Goel & Sharma (2017), Maherali (2017), Neaime & Gaysset (2018), Oz-Yalaman (2019), Ahamed & Malik (2019), and Anarfo et al. (2020), the ATM, BB, and OD indicators listed in Table 1 are implemented. Equation 8 yields the financial inclusion index:

$$linclusion = \sum_{i=1}^{3} a_{ij} X_{ij} \quad (8)$$

Where linclusion represents the financial inclusion index, X_{ij} denotes variable i in year j (original dataset), and a_{ij} indicates factor loadings derived from PCA.

Table 2. Results of Principal Component Analysis and Sensitivity Analysis for Financial Inclusion Index for financial inclusion index

Developing Countries (N=28)		**Developed Countries (N=22)**	
KMO	0.612	KMO	0.483
Bartlett's Test	159.581***	Bartlett's Test	103.760***
Component	Eigenvalue (variance %)	Component	Eigenvalue (variance %)
PC1	1.798 (59.94%)	PC1	1.477 (49.24%)
PC2	0.631 (21.05%)	PC2	0.990 (32.99%)
PC3	0.570 (19.01%)	PC3	0.533 (17.77%)
Variable	PC1 loading	Variable	PC1 loading
LATM	0.588	LATM	0.703
LBB	0.563	LBB	0.645
LOD	0.582	LOD	0.300

Note: KMO>0.50 and significant Bartlett's tests (p<0.001) confirm PCA appropriateness. PC1 selected for index construction in both groups.

Source: Research findings

According to Table 2, Kaiser-Meyer-Olkin (KMO) sampling adequacy measures and Bartlett's sphericity tests confirm PCA appropriateness for both groups. In developing countries, KMO value (0.612) exceeds the 0.50 recommended threshold, with all factor loadings balanced and exceeding 0.60, indicating uniform indicator contributions. Developed countries show slightly lower KMO (0.483), as anticipated, due to low LBB-LOD correlation (0.014), reflecting distinct access versus depth dimensions. Nevertheless, significant Bartlett's tests ($p<0.001$) support PCA utilization. The first principal component (PC1) suffices for constructing financial inclusion indices in both categories, explaining 54.73% of variance in developing countries and 49.24% in developed countries.

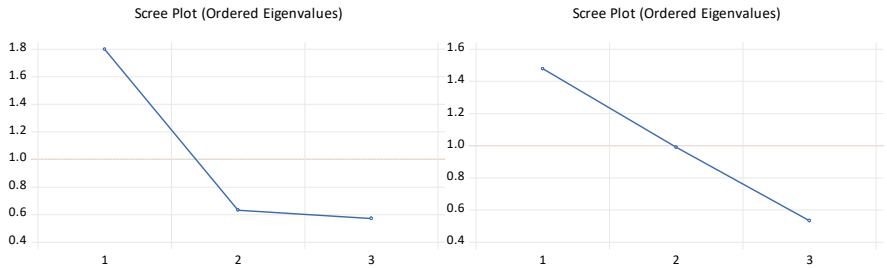

Fig 1. Eigenvalues of principal components for Developing Countries and Developed Countries
Source: Research findings

Figure 1 illustrates principal component eigenvalues for both country groups. Most variance is captured by PC1, evidenced by abrupt decline following the initial component. Subsequent components contribute only marginally to explanation. This pattern justifies selecting PC1 as the financial inclusion index foundation in both developing and developed countries.

The subsequent PSTR econometric model is suggested to investigate financial inclusion index indirect effects on tax revenue:

$$ltax_{it} = a_1 linclusion_{it} + a_2 ltariff_{it} + a_3 lcredit_{it} + a_4 lreg_{it} + a_4 lgdpp_{it} + \sum_{j=1}^{r} [\beta_1 linclusion_{it} + \beta_2 ltariff_{it} + \beta_3 lcredit_{it} + \beta_4 lreg_{it} + \beta_4 lgdpp_{it}] F(q_{it}; \gamma, c) + u_{it} \quad (9)$$

For model estimation, financial inclusion index serves as transition variable with non-linear relationships. Tax revenue is recognized as dependent variable, with other variables—including inclusion index itself, tariff rates, financial development, institutional quality, and GDP per capita—treated as explanatory variables.

4. Model Estimation and Experimental Results

4.1. Static Variable Testing

Variables must be stationary prior to estimation to prevent spurious regression emergence, consistent with econometric literature. Spurious regression issues will not affect estimates if model variables are stationary. Variables were assessed for stationarity using Levin-Lin-Chu (LLC) tests, where null hypothesis assumes unit root presence. Table 3 summarizes test results, indicating all variables are stationary at 5% significance level in both country categories.

Table 3. Results of the unit root test (individual effects, individual linear trends)

Variable	Developing Countries	Developed Countries
LTAX	-5.0189***	-1.6949**
LINCLUSION	-7.7955***	-1.6970**
LTARIFF	-6.5675***	-9.9718***
LCREDIT	-5.5270***	-3.2682***
LBB	-2.5940***	-22.5642***
LREG	-6.3335***	-1.8098**
LGDPP	-6.0066***	-6.4061***

Note: Values are t-statistics. *** p<0.01, ** p<0.05 (all variables stationary).
Source: Research findings

4.2. Model Estimation and Outcome Interpretation

Using financial inclusion index as transition variable from Albiman & Sulong's (2017) study, null hypothesis of linearity and PSTR model presence hypothesis are assessed according to methodology section discussions. Table 4 displays test program output. Wald Lagrangian coefficient, Fisher Lagrangian

coefficient, and likelihood ratio statistics for one and two thresholds (m=1 and m=2) confirm PSTR model existence for both country groups at α=0.05 significance level.

Table 4. Nonlinear relation test

Test	Developing Countries		Developed Countries	
	One threshold (m=1)	Two thresholds (m=2)	One threshold (m=1)	Two thresholds (m=2)
LMw	45.286 (0.000)	58.217 (0.000)	20.717 (0.001)	41.450 (0.000)
LMF	9.382 (0.000)	6.179 (0.000)	4.068 (0.001)	4.265 (0.000)
LR	48.154 (0.000)	63.077 (0.000)	21.323 (0.000)	43.976 (0.000)

Note: r denotes number of transition functions. Probabilities associated with each statistic are denoted by values in parentheses.

Source: Research findings

Next, residual non-linear relationship existence must be assessed to determine transition function quantity. Results suggest null hypothesis—implying single transition function suffices—has not been rejected at either one or two criteria for either country group.

Table 5. Test for residual nonlinear relationship

Test	Developing		Developed	
	m=1	m=2	m=1	m=2
LMw	4.811 (0.439)	11.593 (0.313)	3.569 (0.613)	14.085 (0.169)
LMF	0.866 (0.504)	1.047 (0.403)	0.648 (0.663)	1.297 (0.231)
LR	4.841 (0.436)	11.770 (0.301)	3.586 (0.610)	14.362 (0.157)

Note: r denotes the number of transition functions. The probabilities associated with each statistic are denoted by the values in parentheses.

Source: Research findings

Optimal threshold point number must be determined after verifying non-linearity and identifying transition function numbers necessary to characterize model accurately. According to Jude's (2010) algorithm, optimal model is determined by comparing Schwarz and Akaike information criteria. Results

in Table 6 indicate PSTR model with single threshold (m=1) is preferred over two-threshold model (m=2) for both country groups, as indicated by minimal AIC and SIC values.

Table 6. Determining the number of threshold points in a transition function

Country	m	AIC	SIC	RSS	Selection
Developing	1	-5.0417	-4.9524	3.5675	✓
Developing	2	-5.0369	-4.9401	3.5664	
Developed	1	-5.2608	-5.1534	2.2129	✓
Developed	2	-5.2542	-5.1378	2.2129	

Source: Research findings

A two-regime model is estimated for both country groups after the number of transition functions and the optimal threshold limit are assigned. The results are presented in Table 7.

Table 7. PSTR model estimation results

Variable	Developing Countries		Developed Countries	
	Linear (Regime 1)	Non-linear (Regime 2)	Linear (Regime 1)	Non-linear (Regime 2)
LBB	-0.2166***	—	-0.0502***	—
LBB	—	0.1540***	—	0.0579**
LCREDIT	0.2849***	—	0.0167	—
LCREDIT	—	-0.2276***	—	-0.1020***
LTARIFF	0.0096	—	0.0516***	—
LTARIFF	—	-0.0294	—	0.0146
LREG	-0.4443***	—	-0.1676	—
LREG	—	0.5103***	—	-0.9529***
LGDPP	0.0082	—	0.0477	—
LGDPP	—	-0.1592***	—	0.4019***
Threshold (c)	4.2240		6.7464	
Slope (γ)	2.1008		2.1993×10^{4}	

Note: *** p<0.01, ** p<0.05, * p<0.10; values in parentheses are heteroskedasticity-consistent standard errors; values in brackets are t-statistics.

Source: Research findings

The estimation results of the PSTR model for both developing and developed countries are presented in Table 7. In parentheses, the coefficients are reported with their heteroskedasticity-consistent standard errors, and the t-statistics are in brackets. Despite the potential heteroskedasticity in the panel data, the use of robust standard errors guarantees valid inference. The slope parameter (γ) of 2.1008 for developing countries suggests a moderate rate of transition between regimes, with a threshold (c) of 4.2240. The slope parameter is significantly larger (2.1993×10^4) in developed countries, suggesting a highly sharp transition between regimes. This model is effectively functioning as a threshold regression model, with a threshold of 6.7464.

The initial limiting regime pertains to a scenario in which the transition variable's value is less than the threshold and the slope parameter approaches infinity. The transition function has a numerical value of zero and the model is linear in this state. The model for developing countries is delineated as follows:

LTAX = -0.2166 LBB + 0.2849 LCREDIT + 0.0096 LTARIFF - 0.4443 LREG + 0.0082 LGDPP

The initial regime paradigm is defined as follows for developed countries:

LTAX = -0.0502 LBB + 0.0167 LCREDIT + 0.0516 LTARIFF - 0.1676 LREG + 0.0477 LGDPP

The second limiting regime is characterized by the transition function having a numerical value of one, as the slope parameter approaches infinity but the transition variable (financial inclusion) exceeds the threshold. The model for developing countries is defined by this regime as follows:

LTAX = -0.0626 LBB + 0.0573 LCREDIT - 0.0198 LTARIFF + 0.0660 LREG - 0.1510 LGDPP

The second regime paradigm is defined as follows for developed countries:

LTAX = 0.0077 LBB - 0.0853 LCREDIT + 0.0662 LTARIFF - 1.1205 LREG + 0.4496 LGDPP

According to the findings in Table 7, the coefficients for LBB, LCREDIT, and LREG are statistically significant in developing countries in the linear part (Regime 1), whereas LBB and LTARIFF are significant in developed countries. The coefficients for LBB, LCREDIT, LREG, and LGDPP are statistically significant in both country groups in the nonlinear part (Regime 2). The coefficients reported in Table 7 cannot be directly evaluated due to the fact that they vary across countries and over time based on the value of the transition variable (financial inclusion) and the slope parameter. Additionally, it is imperative to evaluate solely the indicators.

Figure 2 illustrates the non-linear impact of financial inclusion (commercial bank branches per 100,000 adults) on tax revenue in both country groups. PSTR model estimation results indicate LBB coefficient exhibits non-linear behavior in both groups. In developing countries, the coefficient is negative and significant in Regime 1 (-0.2166) below the 4.2240 threshold. The non-linear coefficient becomes positive and significant at 0.1540 in Regime 2 as the composite financial inclusion index increases and crosses the threshold. However, cumulative effect in Regime 2 (sum of linear and non-linear coefficients) remains negative at -0.0626, indicating that increased aggregate financial inclusion reduces the negative impact of bank branches but does not fully reverse it to positive. In developed countries, the non-linear coefficient is negative and significant in Regime 1 (-0.0502) but becomes positive and significant (0.0579) after crossing the 6.7464 threshold. The total effect of 0.0077 in Regime 2 indicates that increased overall financial inclusion transforms the negative impact into a small positive effect. These findings suggest that bank branch expansion in developing countries insufficiently augments tax revenue, requiring service quality and institutional enhancements. Ozili's (2026) "too-much-of-a-good-thing" theory aligns with the finding that high-level financial inclusion generates minor positive effects on tax revenue in developed countries.

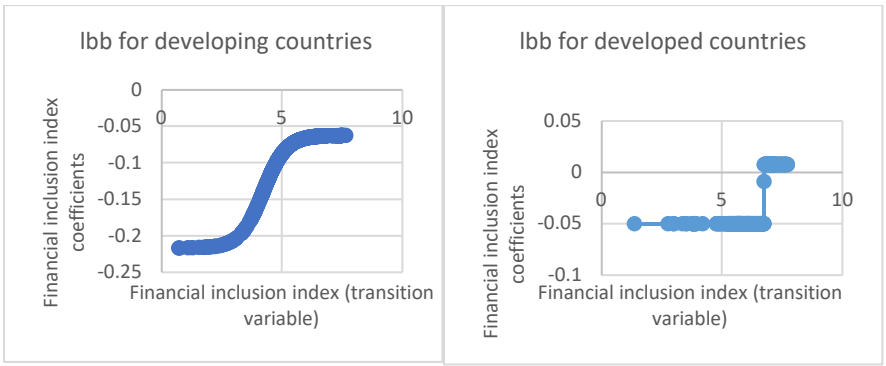

Fig 2. Coefficients of the financial inclusion index vs transition variable (financial inclusion index) for both developed and developing countries

Source: Research findings

Figure 3 illustrates tariff rate impacts on tax revenue in both country categories. PSTR estimation results indicate LTARIFF coefficients exhibit distinct behavior across groups. In developing countries, coefficients are positive but insignificant in Regime 1 (0.0096) and negative but insignificant in Regime 2 (-0.0294), with total effect of -0.0198 suggesting tariff rates lack significant impact on tax revenue, and the relationship remains uninfluenced by aggregate financial inclusion increases. In developed countries, coefficients are positive and significant in Regime 1 (0.0516) and remain positive but become insignificant in Regime 2 (0.0146). Total effect in Regime 2 is 0.0662, suggesting tariff increases generate higher tax revenue in both regimes, though magnitude decreases in Regime 2. This finding implies that the positive tariff-tax revenue impact diminishes with increased financial inclusion in developed countries as domestic tax systems become more efficient and trade tax significance declines.

Figure 4 depicts financial development-tax revenue correlations in both country groups. PSTR estimation results reveal LCREDIT coefficients demonstrate non-linear behavior in both groups. In developing countries, coefficients are positive and significant in Regime 1 (0.2849) and negative and significant in Regime 2 (-0.2276), with total effect of 0.0573 indicating positive but diminished impact in Regime 2. This suggests increased

aggregate financial inclusion reduces positive financial development impacts but does not transform them into negative effects. In developed countries, coefficients are positive and insignificant in Regime 1 (0.0167) and become negative and significant in Regime 2 (-0.1020), with total effect of -0.0853 indicating detrimental tax revenue impacts at high financial inclusion levels. This transformation may reflect financial system complexities and increased tax evasion risks at advanced financial development stages.

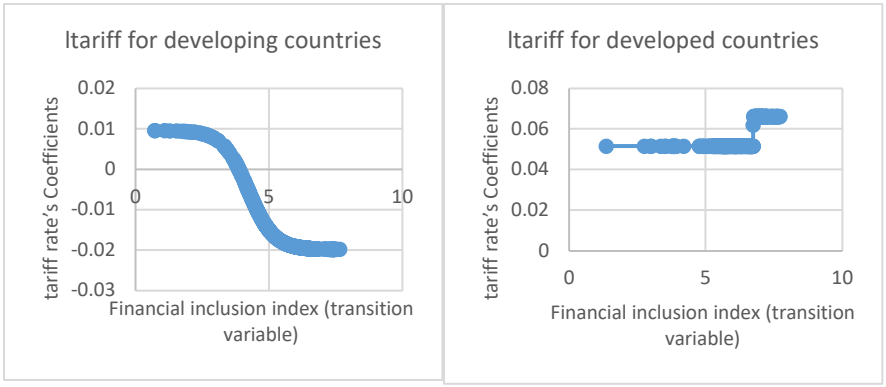

Fig 3. Tariff rate coefficients with respect to the transition variable (financial inclusion index) for developing countries and developed countries
Source: Research findings

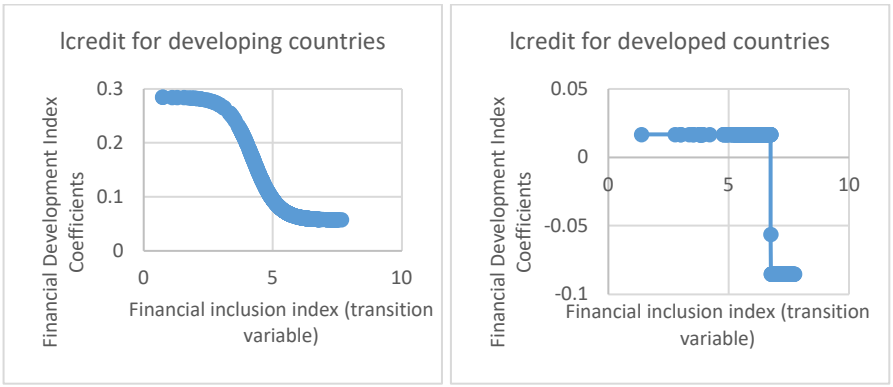

Fig 4. Coefficients of financial development vs the transition variable (financial inclusion index) for developing countries and developed countries
Source: Research findings

Figure 5 presents institutional quality effects on tax revenue in both country groups. PSTR results indicate LREG coefficients exhibit distinct behaviors. In developing countries, coefficients are negative and significant in Regime 1 (-0.4443) and positive and significant in Regime 2 (0.5103), with total effect of 0.0660 suggesting transformation from negative to positive influence as financial inclusion increases. This implies weak institutions impede positive tax revenue effects at low financial inclusion levels, but as financial inclusion surpasses thresholds, institutional quality improvements can substantially increase tax revenue. In developed countries, coefficients are negative and insignificant in Regime 1 (-0.1676) but become negative and significant in Regime 2 (-0.9529), with cumulative effect of -1.1205 indicating significant negative institutional quality impacts at high financial inclusion levels. This underscores institutional reform importance in developing countries, as suggested by Abrar & Hayat (2026) and Ali Al-Tameemi et al. (2027).

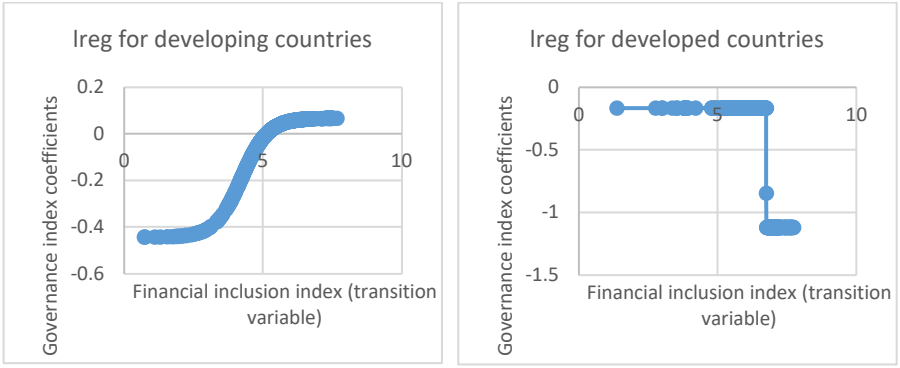

Fig 5. Coefficients of Governance index vs the transition variable (financial inclusion index) for developing countries and developed countries
Source: Research findings

Figure 6 shows economic growth impacts on tax revenue in both groups. PSTR results indicate LGDPP coefficients act entirely differently between country groupings. In developing countries, coefficients are positive and

insignificant in Regime 1 (0.0082) and become negative and significant in Regime 2 (-0.1592), with total effect of -0.1510 suggesting increased financial inclusion renders effects from insignificant to negative. This implies high financial inclusion levels may reduce tax revenue, potentially through informal sector expansion or transition to less taxable service-based activities concurrent with economic growth. In developed countries, coefficients are positive and insignificant in Regime 1 (0.0477) and become positive and significant in Regime 2 (0.4019), with total effect of 0.4496 suggesting increased financial inclusion transforms economic growth impacts from insignificant to positive and robust. This indicates developed economies possess stronger formal institutions and more effective tax collection mechanisms converting growth into fiscal revenues. This contrast underscores structural distinctions between developing and developed economies in growth-to-fiscal-revenue conversion processes, consistent with Maashani et al. (2025) and Abrar & Hayat (2026).

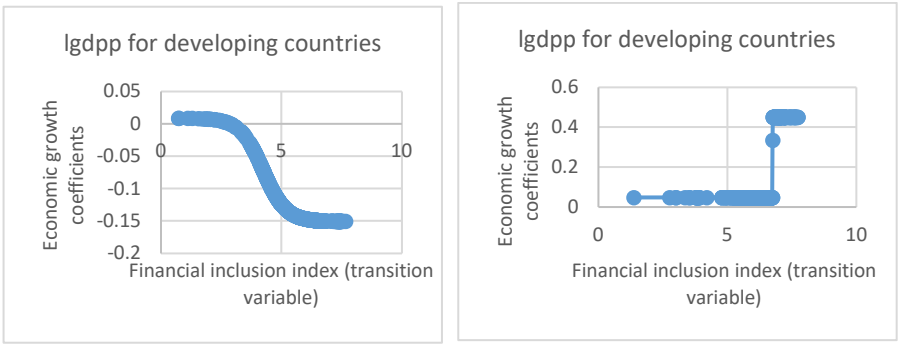

Fig 6. Coefficients of Economic growth vs the transition variable (financial inclusion index) for developing countries and developed countries

Source: Research findings

4.3. Diagnostic Test Results for Developing and Developed Countries

Following PSTR model estimation, diagnostic tests evaluated model validity and robustness for both country groups. Tests included Jarque-Bera normality, Ljung-

Box autocorrelation, Breusch-Pagan heteroskedasticity, and Variance Inflation Factor (VIF) multicollinearity assessments. Results are summarized in Table 8.

Table 8. Diagnostic Test Results for Developing and Developed Countries

Test	Developing Countries	Developed Countries
Normality (Jarque-Bera)	$p<0.01$ (not normal)	$p<0.01$ (not normal)
Autocorrelation (Ljung-Box)	$\chi^2=96.9123$, $p<0.01$	$\chi^2=71.4362$, $p<0.01$
Heteroskedasticity (Breusch-Pagan)	LM=14.3245, p=0.0137	LM=13.8506, p=0.0166
VIF (max)	2.3225 (no multicollinearity)	2.1182 (no multicollinearity
LBB	1.7341	1.2185
LCREDIT	1.5681	1.8472
LTARIFF	1.4394	1.3035
LREG	2.2809	2.1182
LGDPP	2.3225	1.1530
Result	✓ No serious multicollinearity	✓ No serious multicollinearity

Source: Research findings

Diagnostic test results for both groups indicate residuals are not normally distributed (Jarque-Bera, $p<0.01$), significant autocorrelation exists (Ljung-Box, $p<0.01$), and heteroskedasticity is detected (Breusch-Pagan, $p<0.05$). However, these classical assumption violations are not uncommon in non-linear panel models such as PSTR, where Nonlinear Least Squares (NLS) estimators remain consistent and asymptotically normal under general conditions. Moreover, hypothesis testing validity is guaranteed through heteroskedasticity-consistent standard errors (reported as beta_std in model output), which effectively mitigate both autocorrelation and heteroskedasticity concerns. Crucially, VIF tests verify all values significantly below the conventional threshold of 10 (maximum 2.3225 for developing countries and 2.1182 for developed countries), indicating no significant multicollinearity among explanatory variables. Consequently, the PSTR model is adequately

specified, and estimated coefficients are both reliable and interpretable despite minor classical assumption violations.

4.4. Granger Causality Analysis

Panel Granger causality testing, based on Dumitrescu-Hurlin (2012) approach, investigated causal relationships between tax revenue and financial inclusion. This procedure proves particularly suitable for panel data as it accommodates cross-country heterogeneity and does not require variable stationarity. Akaike Information Criterion (AIC) selected two delays for testing. Individual country test statistics were aggregated using Fisher combination tests. Table 9 presents findings.

Table 9: Panel Granger Causality Test Results

Country Group	Null Hypothesis (H_0)	χ^2 Statistic	df	P-Value
Developing Countries (N=28)	LINCLUSION → LTAX	83.2272	56	0.0106
	LTAX → LINCLUSION	96.3404	56	0.0007
Developed Countries (N=22)	LINCLUSION → LTAX	59.4828	44	0.0596
	LTAX → LINCLUSION	68.1120	44	0.0113

Source: Research findings

Panel Granger causality test results reveal bidirectional causal relationships between financial inclusion (LINCLUSION) and tax revenue (LTAX) in developing countries. Specifically, the null hypothesis that financial inclusion does not Granger-cause tax revenue is rejected (P-Value = 0.0106), and the null hypothesis that tax revenue does not Granger-cause financial inclusion is also rejected (P-Value = 0.0007). This indicates feedback effects between variables, suggesting financial inclusion formalizes economies and improves transparency, thereby increasing tax revenue, while increased tax revenue enables further financial inclusion through investment in financial infrastructure and improved fiscal capacity.

In developed countries, results indicate unidirectional causal relationships. The null hypothesis that tax revenue does not Granger-cause financial inclusion is rejected (P-Value = 0.0113), implying tax revenue significantly drives financial inclusion. However, the null hypothesis that financial inclusion does not Granger-cause tax revenue is not rejected (P-Value = 0.0596), suggesting financial inclusion lacks significant tax revenue impacts in developed countries. This finding aligns with the "too-much-of-a-good-thing" theory (Ozili, 2026) and Nguyen The et al.'s (2025) empirical evidence, indicating that in countries with pre-existing high financial inclusion levels, further expansion may generate diminishing or negligible tax revenue effects.

These findings confirm non-linear relationships and endogenous interactions between variables, substantiating PSTR model utilization. They also underscore the importance of financial inclusion policies customized to each country's developmental stage. In developing countries, financial inclusion expansion can significantly boost tax revenue, while developed countries should prioritize financial service quality and efficiency rather than quantity.

5. Conclusion and Recommendations

This study examined the indirect impact of financial inclusion on tax revenue across 50 developing (28) and developed (22) countries from 2004 to 2024. The Panel Smooth Transition Regression (PSTR) model, developed by Gonzalez et al. (2005) and Colletaz & Hurlin (2006), was implemented for this objective. Estimation results verified non-linear relationships among financial inclusion, tariff rates, financial development, institutional quality, economic growth, and tax revenue. Findings indicate single transition functions with single thresholds adequately describe non-linear behavior in both country groups. Using three indicators—bank branches per 100,000 adults (LBB), ATMs per 100,000 adults (LATM), and outstanding deposits as GDP percentage (LOD)—a composite financial inclusion index was constructed through Principal Component Analysis (PCA). This index serves as transition variable (threshold), while commercial bank branches (LBB) are incorporated as an independent

explanatory variable. This distinction proves crucial because country governance (low or high level) is determined by overall financial inclusion levels, whereas individual financial inclusion components' (such as bank branches) tax revenue impacts are separately analyzed.

Regime transitions occur in developing countries when the composite financial inclusion index surpasses the threshold of 4.2240, with slope parameter of 2.1008. In the initial regime (below threshold), bank branches (LBB) demonstrate negative and significant tax revenue effects (-0.2166), while financial development (LCREDIT) shows positive and significant effects (0.2849), and institutional quality (LREG) exhibits negative and significant effects (-0.4443). With increased overall financial inclusion, total bank branch effects remain negative (-0.0626) in the second regime (above threshold), though magnitude decreases; financial development remains positive (0.0573); and institutional quality becomes positive (0.0660). Economic growth (LGDPP) transitions from insignificant in the first regime to negative and significant in the second regime (-0.1510).

Regime switching in developed countries occurs when the composite financial inclusion index exceeds the threshold of 6.7464, with slope parameter of 2.1993×10^4, indicating very sharp regime transitions. In the first regime, tariff rates show positive and significant effects (0.0516), while bank branches demonstrate negative and significant effects (-0.0502). In the second regime, total bank branch effects become positive but modest (0.0077), financial development turns negative and significant (-0.0853), institutional quality becomes strongly negative (-1.1205), and economic growth becomes positive and significant (0.4496) as overall financial inclusion increases.

These findings demonstrate that financial inclusion's tax revenue impacts are non-linear and context-dependent, varying across financial inclusion levels and between developing and developed countries. Households and small enterprises can benefit from financial inclusion, generating economic growth and macroeconomic stability. However, results suggest positive effects may diminish or reverse beyond specific thresholds, particularly in

developed countries where financial inclusion is already high. The study also confirms transmission mechanisms through which financial inclusion affects tax revenue, including formal tax base expansion, tax enforcement facilitation, shadow economy reduction, and improved transaction transparency. These findings align with theoretical frameworks of Ozili (2021, 2026), Raouf (2022), and Senso et al. (2026).

Granger causality analysis further demonstrates bidirectional relationships between financial inclusion and tax revenue in developing countries (χ^2 = 83.2272, p = 0.0106 for LINCLUSION → LTAX; χ^2 = 96.3404, p = 0.0007 for LTAX → LINCLUSION), indicating feedback effects. However, developed countries show unidirectional causality: financial inclusion is Granger-caused by tax revenue (χ^2 = 68.1120, p = 0.0113), while reverse causality from financial inclusion to tax revenue is not statistically significant (χ^2 = 59.4828, p = 0.0596). This aligns with the "too-much-of-a-good-thing" hypothesis (Ozili, 2026), positing that further expansion impacts may be negligible or diminishing in countries with pre-existing high financial inclusion levels. Diagnostic tests verify PSTR model robustness, with all VIF values below 5 indicating no significant multicollinearity.

By employing PSTR methodology, this study addresses research gaps identified in previous studies primarily using linear models or simple threshold regressions, contributing empirical evidence on financial inclusion threshold effects on tax revenue. Findings can assist policymakers in developing more effective financial inclusion expansion strategies while ensuring contributions to tax revenue increases. Results also underscore robust regulatory frameworks and institutional quality importance in mitigating potential negative consequences associated with increased financial inclusion, particularly in developed countries.

Several policy recommendations emerge from empirical findings. For developing countries, modern technologies including digital banking and mobile payments are recommended to improve financial inclusion and reduce financial service access costs. This is necessary because composite financial

inclusion indices in developing countries currently remain below thresholds, requiring further expansion. Supporting fintech companies to ensure accessible and affordable financial services for low-income populations and underserved regions is imperative. Moreover, negative bank branch impacts in initial regimes can be mitigated through digital tax system development linked to bank accounts and financial transactions, increasing transparency and reducing tax evasion. Promoting small and medium-sized enterprise (SME) integration into formal economies through tax incentives and banking services is imperative, as institutional quality becomes positive in the second regime. As tariff rates have insignificant tax revenue impacts in developing countries, adjusting them to strengthen domestic industries while minimizing negative import/export effects is advisable. Providing tax incentives to organizations contributing to financial inclusion and infrastructure development may prove advantageous. Since economic development negatively impacts tax revenue in the second regime, growth alone proves insufficient without adequate financial education. Consequently, implementing educational programs promoting financial literacy and familiarizing individuals with formal financial services is crucial. Finally, strengthening governance and regulatory frameworks is imperative, as institutional quality transforms from negative in the first regime to positive in the second, demonstrating critical tax revenue increase roles.

For developed countries, acknowledging that composite financial inclusion indices are already high and further expansion generates diminishing returns, expanding advanced and innovative digital financial services to ensure all societal segments have access is advisable. Supporting sustainable and social banking systems designed to assist vulnerable groups is crucial. To guarantee financial development enhances rather than diminishes transparency, enhancing oversight of intricate financial markets is imperative. Since financial development negatively affects tax revenue in the second administration, positive outcomes may be fostered through tax incentives for organizations and financial institutions advocating for financial inclusion. Allocating tariff revenues to financial inclusion projects, particularly in underdeveloped regions,

is advisable, as tariff rates positively impact tax revenue in both regimes. Reducing unnecessary tariffs on technology-driven goods facilitating financial infrastructure development may prove advantageous. Employing data obtained from banking and digital systems to identify financial inclusion deficiencies and develop targeted policies is imperative, given the second regime's significant negative institutional quality impacts. The "too-much-of-a-good-thing" effect (Ozili, 2026) evident in developed countries where financial inclusion exceeds optimal thresholds makes implementing appropriate regulatory measures to monitor and control financial inclusion expansion crucial.

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Authors' contributions

All authors had contribution in preparing this paper.

Conflicts of interest

The authors declare no conflict of interest

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Appendix A: The list of countries

developing countris	**developed countries**
Albania	Australia
Bangladesh	Belgium
Bhutan	Chile
Botswana	Czech Rep.
Brazil	Denmark
Bulgaria	Estonia, Rep. of
China	France
Costa Rica	Greece
Dominican Republic	Hungary
Egypt, Arab Rep.	Ireland
Georgia	Italy
Honduras	Korea, Rep. of
India	Luxembourg
Indonesia	Netherlands, The
Iran, Islamic Rep.	New Zealand

developing countris	developed countries
Kazakhstan	Poland, Rep. of
Madagascar	Portugal
Malaysia	Russian Federation
Mauritius	Saudi Arabia
Mexico	Singapore
Moldova	Sweden
Morocco	Switzerland
Mozambique	
Nicaragua	
Philippines	
Thailand	
Turkiye	
Ukraine	