


# How Financial Inclusion Affects Environmental Pollution: Using a Threshold and the DID Model

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## Abstract

This study investigates the nonlinear impact of financial inclusion on environmental pollution across 61 developing countries from 2005 to 2022. Using a threshold regression model, the findings reveal a critical threshold at which the impact of financial inclusion changes direction. Below this threshold, financial inclusion tends to increase carbon emissions; however, beyond this point, the relationship reverses, with financial inclusion contributing to pollution reduction. To gain deeper insights, the study further applies the Difference-in-Differences (DID) method. The DID results indicate that the effect of financial inclusion is heterogeneous and depends on the level of financial development, national income, and the timing of each country's participation in the Paris Agreement on climate change. These findings underscore the multidimensional nature of the relationship between financial inclusion and the environment, which is significantly influenced by country-specific economic and policy factors. In addition, the study finds that national income and urbanization levels are associated with increased pollution, while credit to the private sector plays a mitigating role in reducing emissions. These results have important implications that policymakers should consider when designing strategies that promote financial inclusion while aligning with Sustainable Development Goals.

**Keywords:** financial inclusion, environmental pollution, DID method, Panel Threshold Regression

**JEL:** F4, G2, Q4, Q54, Q56

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## Introduction

In recent decades, global economic growth and technological progress have brought prosperity but also intensified environmental degradation, especially in developing countries. Rapid industrialization, urban expansion, and increasing energy consumption have led to severe carbon emissions and environmental pollution, threatening sustainable development goals (Baloch and Wang 2019). These challenges raise a critical question for policymakers: How can countries simultaneously expand financial access, foster economic growth, and protect the environment?

Financial inclusion the process of ensuring access to useful and affordable financial services for individuals and businesses has emerged as an important driver of inclusive growth and social equity (Chibba 2009). However, its environmental implications remain ambiguous. On the one hand, improved financial inclusion may facilitate investment in clean technologies, energy efficiency, and green innovation (Le, Le, and Taghizadeh-Hesary 2020). On the other hand, easier access to credit and capital can accelerate industrial activity and household consumption, increasing energy use and pollution (Qin et al. 2021). Therefore, theoretically, the impact of financial inclusion on environmental pollution can be either beneficial or harmful, depending on a country's stage of development, financial depth, and environmental regulations

Despite growing research interest, existing studies reveal several limitations. First, most prior works have analyzed the relationship between financial inclusion and environmental pollution using linear models (Rehman, Fareed, and Shahzad 2022; Hussain et al. 2024), overlooking potential nonlinear or threshold effects. However, the Environmental Kuznets Curve (EKC) hypothesis suggests that the relationship between growth-related variables and environmental quality often follows a nonlinear pattern with negative effects at low development levels that reverse beyond a certain threshold (Tan, Lean, and Khan 2014; Ali et al. 2021). Second, while some recent studies identify a U-shaped or inverted-U relationship (Renzhi and Baek 2020; Amin, Song, and Khan 2022), they have not formally tested the existence of a specific threshold value of financial inclusion at which its impact on pollution changes direction. Third, prior research rarely considers the heterogeneous impacts across countries, such as differences in income levels or participation in international environmental agreements, which may moderate the relationship between financial inclusion and environmental outcomes.

To address these gaps, this study examines how financial inclusion affects environmental pollution in developing countries, focusing on both nonlinear (threshold) effects and heterogeneous effects using a Difference-in-Differences (DID) approach. Specifically, this study addresses the following research questions:

## Does financial inclusion have a nonlinear (threshold) effect on environmental pollution in developing countries?

1. How does national income moderate the relationship between financial inclusion and environmental pollution?
2. How does participation in the Paris Agreement influence the environmental impact of financial inclusion?

To answer these questions, the study develops a theoretical model based on financial circulation and financial stability theories, combined with the EKC framework. The analysis uses panel data from 61 developing countries covering 2005–2022. The panel threshold regression (PTR) method is applied to identify the critical value of financial inclusion beyond which its environmental effect changes sign, while the DID model is employed to explore heterogeneity across income groups and Paris Agreement participation.

This research contributes to the literature in three main ways. First, it extends the environmental finance literature by revealing the threshold level of financial inclusion at which its impact on pollution shifts from harmful to beneficial. Second, it integrates the DID approach to reveal how country-specific characteristics economic development and environmental commitments shape this relationship. Finally, it discusses the policy implications for achieving inclusive and sustainable finance by aligning financial inclusion strategies with environmental objectives.

The rest of the paper is organized as follows. Section 2 reviews the theoretical framework and empirical evidence. Section 3 presents the data and methodology. Section 4 discusses the empirical results, and Section 5 concludes with policy implications.

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## Literature review

### Theoretical Framework for Financial Inclusion

Financial inclusion plays a crucial role in promoting financial development and inclusive economic growth (Sarma and Pais 2008). It is grounded in financial intermediation theory, which emphasize that expanding access to financial services fosters savings, encourages productive investment, and improves economic resilience.

Financial inclusion is a multidimensional concept that broadly reflects the extent to which individuals and businesses have access to, and make effective use of, formal financial services. In this study, financial inclusion is primarily represented by two measurable dimensions, access and usage, which correspond to the availability and actual utilization of financial resources such as credit, savings, and banking infrastructure (Sarma 2016).

The access dimension determines the extent to which people and firms can obtain financial services and external financing. Expanded access to credit and savings mobilization may initially stimulate industrial activities and energy consumption, but it can also support investment

in cleaner production and renewable technologies when directed through sustainable channels. The usage dimension, on the other hand, reflects how financial services are employed. Greater utilization of financial instruments can enhance investment efficiency, encourage the adoption of green technologies, and promote environmentally responsible business practices.

Beyond these measurable aspects, the quality dimension though not captured in this study's empirical indicators – represents a crucial complementary channel. It includes factors such as financial literacy (knowledge), the technological capacity of financial institutions, and the efficiency of financial regulation, all of which determine how effectively inclusive finance contributes to sustainable outcomes.

Accordingly, this framework recognizes that financial inclusion and economic development are mutually reinforcing. Economic growth facilitates financial participation, while inclusive finance acts as a transmission mechanism that influences whether such growth follows a carbon-intensive trajectory or a sustainable, low-carbon pathway.

It is important to recognize that the relationship between financial inclusion and economic development is inherently bidirectional (Sarma and Pais 2011). While economic and financial progress expands access to financial services by improving education, income, and infrastructure, financial inclusion, in turn, plays a transmission role that shapes how development affects environmental outcomes. Through broader access to credit, savings, and financial technologies, inclusive finance mobilizes resources for productive investment and influences the allocation of capital across sectors. Consequently, financial inclusion determines whether economic growth evolves along a carbon-intensive path or transitions toward green and sustainable development. This reciprocal dynamic justifies the examination of financial inclusion not as an isolated determinant, but as a mediating mechanism linking financial and environmental systems.

According to the financial intermediation theory, financial inclusion promotes economic growth by enhancing the efficiency of financial markets and reducing frictions between savers and borrowers. Financial inclusion supports economic development through three main channels: (1) the direct channel, where individuals previously excluded from formal finance gain access to credit and savings tools; (2) the indirect channel, where small and medium enterprises can invest, create jobs, and stimulate economic activity; and (3) the market channel, where broader financial participation increases liquidity and improves market efficiency.

The principles of financial stability posit that a more inclusive financial system strengthens the overall stability of the economy by diversifying risk and expanding the financial base. When linked with the EKC hypothesis, financial inclusion may exhibit a nonlinear relationship with environmental quality. At early stages, increased financial access may raise emissions due to industrialization, but beyond a certain level, it can facilitate green finance, technological innovation, and investments in renewable energy – ultimately reducing pollution (Tan, Lean, and Khan 2014; Ali et al. 2021).

## The Impact of Financial Inclusion on Environmental Pollution

Existing studies exploring the nexus between financial inclusion and environmental pollution reveal diverse and sometimes contradictory findings.

The first group of studies supports the “pollution haven” hypothesis, suggesting that expanding financial inclusion increases environmental degradation. Wider access to financial services can stimulate consumer demand and enable industrial expansion, leading to higher energy consumption and emissions (Tamazian, Chousa, and Vadlamannati 2009; Renzhi and Baek 2020; Liu, Hong, and Sohail 2022; Wang et al. 2022). Studies in BRICS<sup>1</sup> countries and the Organisation for Economic Co-operation and Development (OECD) countries have also found that financial inclusion tends to increase carbon emissions due to intensified production activities and relaxed environmental regulations (Zaidi, Hussain, and Zaman 2021; Dou and Li 2022).

In contrast, other research demonstrates a “halo effect”, where financial inclusion supports environmental improvement. Greater access to credit and digital finance encourages investment in renewable energy, promotes environmental awareness, and allows firms to adopt cleaner production technologies (Gill, Hassan, and Haseeb 2019; Du et al. 2022). Chaudhry, Yusop, and Habibullah (2022) also confirmed this effect in Organisation of Islamic Cooperation (OIC) countries, emphasizing that financial inclusion facilitates structural transformation toward green and efficient industries.

Some recent studies uncover nonlinear dynamics. Le, Le, and Taghizadeh-Hesary (2020) found that, in Asia, financial inclusion initially worsens CO<sub>2</sub> emissions but later contributes to reduction when combined with green policies. Similarly, Amin, Song, and Khan (2022) reported short-term mitigation but long-term deterioration effects in South Asia. Qin et al. (2021) used quantile regressions and found that the effect varies across emission levels and stages of financial development. However, few studies have explicitly tested for a threshold level of financial inclusion beyond which its environmental impact reverses.

Hence, the literature reveals mixed evidence, highlighting the need to explore whether a critical threshold exists, and to what extent country-specific characteristics such as income levels and climate policy participation alter this relationship. Therefore, the environmental impact of financial inclusion depends not only on its overall expansion but also on the composition of its components. When financial access primarily supports credit for energy-intensive sectors, environmental degradation tends to increase.

It should be noted that greater access to credit does not automatically translate into environmental improvement. The environmental effect of credit depends largely on how and where these financial resources are allocated. When credit is mainly directed toward energy-intensive or resource-consuming industries, it may aggravate environmental degradation. In contrast, when credit supports pro-ecological or green investments such as renewable energy, clean technologies, and energy-efficient infrastructure it can significantly contribute to environmental

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1 The BRICS countries initially comprised Brazil, Russia, India, and China. Today, it includes an additional six countries: Egypt, Ethiopia, Indonesia, Iran, South Africa, and the United Arab Emirates.

sustainability. Therefore, the relationship between financial inclusion and environmental pollution is nonlinear and context-dependent, operating through indirect and conditional channels, determined by the policy framework, the structure of financial markets, and the environmental orientation of financial institutions.

### Moderating Factors: National Income and Environmental Commitments

The interaction between financial inclusion and environmental quality is shaped by macroeconomic and institutional contexts.

Higher-income countries typically have greater technological capacity and regulatory enforcement, enabling financial inclusion to support investments in cleaner production. In contrast, lower-income economies may rely on carbon-intensive growth paths, where expanding finance fuels further emissions.

Participation in international environmental agreements, particularly the Paris Agreement, can also moderate this relationship. Countries with stronger commitments tend to redirect financial inclusion toward green projects and renewable energy initiatives. By contrast, nations that joined the Paris Agreement later or enforce weaker environmental regulations may not realize similar benefits.

Therefore, understanding how income heterogeneity and environmental governance influence the financial inclusion–pollution nexus is essential for designing effective, context-specific sustainable finance policies.

### Research Hypotheses

Based on the theoretical framework and the reviewed literature, the relationship between financial inclusion and environmental pollution is expected to be nonlinear, and its magnitude may differ depending on income levels and environmental policy commitments.

First, the EKC hypothesis implies that the effect of financial inclusion on pollution can vary at different stages of financial and economic development. At lower levels, expanding financial inclusion might intensify energy demand and industrial activities, thereby increasing emissions. However, beyond a certain threshold, it may promote green investments, energy efficiency, and cleaner production. This reasoning leads to the first hypothesis:

**H<sub>1</sub>: There is a nonlinear (threshold) effect of financial inclusion on environmental pollution in developing countries.**

Second, the level of economic development determines how effectively financial inclusion can support green initiatives. Higher-income countries often have better institutional quality, environmental regulations, and technological infrastructure that channel financial inclusion toward sustainable activities. In contrast, in low-income economies, expanding credit access might exacerbate emissions due to industrial expansion without adequate green oversight. Therefore:

**H<sub>2</sub>: The impact of financial inclusion on environmental pollution is moderated by national income; financial inclusion reduces pollution more effectively in higher-income countries.**

Third, international environmental commitments such as the Paris Agreement can strengthen the environmental benefits of financial inclusion. Countries that joined the Agreement earlier or enforce stricter environmental policies are more likely to use inclusive finance as a tool for green transformation. Hence, we propose:

**H<sub>3</sub>: The effect of financial inclusion on environmental pollution is influenced by participation in the Paris Agreement; countries committed to the Agreement experience a stronger pollution-reducing effect of financial inclusion.**

These hypotheses will be tested using a combination of Panel Threshold Regression (PTR) and Difference-in-Differences (DID) methods, allowing the study to capture both nonlinear effects and cross-country heterogeneity.

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## Research method

### Model

Based on the EKC hypothesis, the study constructs a research model with the dependent variable being CO<sub>2</sub> emissions as a function of the following form:

$$CO_2 = f(\text{IFI}, \text{GDP}, \text{URB}, \text{DCP}), \quad (1)$$

where CO<sub>2</sub> is carbon dioxide emissions, IFI represents the financial inclusion variable, GDP is Gross Domestic Product, URB is the urbanization process, and DCP is credit to the private sector.

The indicators used to construct the financial inclusion – the number of bank branches and ATMs per 100,000 adults, the ratio of deposits to GDP, and the ratio of private credit to GDP – were taken from the IMF Financial Access Survey. These indicators are widely used in cross-country studies (Sarma 2008; Ahamed and Mallick 2019) due to their long-term availability and comparability.

Although digital financial services have become increasingly important, comparable cross-country data for digital and account-based indicators remain limited, particularly for developing countries in the early 2000s. Therefore, consistent with prior studies and IMF Financial Access Survey standards, this study employs the number of commercial bank branches and ATMs per 100,000 adults as conventional proxies for financial inclusion. These indicators capture the accessibility of formal financial services in a way that remains relevant for many developing economies.

According to the EKC hypothesis, economic development plays a crucial role in impacting the environment. Therefore, the GDP variable is included in the research model. Previous studies acknowledge that urbanization demands a significant amount of natural resources to produce goods for domestic consumption (Charfeddine and Mrabet 2017). Urbanization also brings about

several changes to the economic development process, such as the expansion of infrastructure and the development of diversified businesses across multiple sectors, thereby affecting the environment. Finally, DCP is included in the study because credit to this sector is substantial, providing businesses with opportunities to innovate, invest in machinery and equipment, and improve technology, consequently impacting environmental pollution (Frankel and Romer 2017).

To test Hypothesis H<sub>1</sub>, based on Renzhi and Baek (2020), we employ the PTR model for panel data. The research model is structured as follows:

$$\text{CO}_{2it} \begin{cases} \mu_i + \beta' X_{it} + \alpha_1 \text{IFI}_{it} + \varepsilon_{it} \text{IFI}_{it} \leq \gamma \\ \mu_i + \beta' X_{it} + \alpha_2 \text{IFI}_{it} + \varepsilon_{it} \text{IFI}_{it} > \gamma \end{cases} \quad (2)$$

Wherein, vector  $\beta' = (\beta_1, \beta_2, \beta_3)$  is the regression coefficient of independent variables that do not change across thresholds.  $X_{it}$  is the vector of explanatory variables that impact environmental pollution, including  $\text{URB}_{it}$ ,  $\text{DCP}_{it}$ , and  $\text{GDP}_{it}$ .  $\gamma$  is the threshold value at which the relationship between financial inclusion and environmental pollution changes. IFI is financial inclusion, which is determined by the Principal Component Analysis (PCA) method from four indicators: the ratio of bank branches per 100,000 adults, the ratio of ATMs per 100,000 adults, the ratio of deposits to GDP, and the ratio of private credit to GDP. These indicators have been widely used in previous studies (Sarma 2008; 2016; Gupte, Venkataramani, and Gupta 2012; Ahamed and Mallick 2019).  $\alpha_1, \alpha_2$  are, respectively, the regression coefficients of IFI when IFI is less than or equal to  $\gamma$  and greater than the threshold value  $\gamma$ ,  $\mu_i$  is the constant term, while  $\varepsilon_{it}$  is the error term of the model, which has an independent and identically distributed random distribution with an expected value of 0 and constant variance.

After determining the appropriate model and collecting research data, we perform descriptive statistics to identify the characteristics of the research data and remove outliers. Subsequently, the study analyzes the correlation matrix to examine the correlation between variables in the model. Due to the data's time dimension spanning 18 years, stationarity testing is necessary. Before conducting stationarity tests, if cross-sectional dependence exists in the research data, second-generation stationarity tests are required; otherwise, first-generation stationarity test methods are applied. If stationarity testing is appropriate, the author proceeds to conduct the F1 statistic test to examine whether there exists a threshold effect of financial inclusion on environmental pollution (Hansen 2000), with the following hypothesis:

$$H_0 : \alpha_1 = \alpha_2 : \text{No threshold exists.}$$

$$H_1 : \alpha_1 \neq \alpha_2 : \text{A threshold exists.}$$

Hansen's method employs the bootstrap technique to simulate an approximate distribution of the standard normal distribution with the LR statistic. If the p-value is statistically significant, it indicates the existence of a threshold effect of financial inclusion on environmental pollution. If the test results show the existence of a threshold effect, the author proceeds to perform PTR model regression to determine how the impact coefficients change in each threshold regime.

To test Hypotheses  $H_2$  and  $H_3$ , we employ the DID approach. The DID model compares changes in environmental pollution between a treated group and a control group before and after a temporal break. In this study, the treatment assignment is based solely on financial inclusion. Specifically, *Post* is a time dummy equal to 1 in the post-policy period and 0 otherwise, while *Treat* equals 1 for countries whose financial inclusion index is above the sample mean and 0 for the rest. The interaction term  $DID = Post \times Treat$  captures the differential change in  $CO_2$  emissions for high-FI countries relative to low-FI countries following the policy shock.

$$CO_{2it} = \beta_0 + \beta_1 post_{it} + \beta_2 treat_{it} + \beta_3 post_{it} \times treat_{it} + \varepsilon_{it}. \quad (3)$$

Hypothesis  $H_2$  examines whether the effect of financial inclusion differs across income levels. For this purpose, income is included strictly as a moderating variable and not as part of the treatment assignment. Countries with income levels above the median value are coded as 1 and those below the median as 0. This classification creates a higher-income (above-median) and lower-income (below-median) group within the sample. An extended interaction term is introduced to evaluate whether the DID effect varies across these income groups.

Similarly, Hypothesis  $H_3$  investigates whether participation in the Paris Agreement strengthens the pollution-reducing effect of financial inclusion. A Paris Agreement dummy (1 = signatory; 0 = non-signatory) is also introduced purely as a moderator. It is not used to construct either *Post* or *Treat*, but interacts with the DID term to capture policy heterogeneity associated with international climate commitments.

## Data research

The study uses data from 61 developing countries over the period 2005 to 2022. The characteristics of the PTR model require balanced data; therefore, to satisfy this condition, the research data is limited to 2022. Data on carbon emissions, urbanization, private sector credit, and economic growth were extracted from the World Bank database, accessed via the website <https://databank.worldbank.org/>. Data on financial inclusion were collected from the International Monetary Fund's Financial Access Survey database, accessed via the website: <https://data.imf.org/>. The data in the paper are winsorized at the 99<sup>th</sup> percentile. Table 1 presents information about the variables in the model.

Table 1. Descriptive variables

Sign	Descriptive	Calculation	Sources
$CO_2$	Carbon emission		WB
IFI	Financial inclusion	PCA method from four indicators: the ratio of bank branches per 100,000 adults, the ratio of ATMs per 100,000 adults, the ratio of deposits to GDP, and the ratio of private credit to GDP.	IMF
GDP	National income	GDP <i>per capita</i>	WB
URB	Urbanization	Ratio of urban population to total population	WB
DCP	Private sector credit	Ratio of private sector credit to GDP	WB

Source: author's elaboration.

## Results

### Descriptive Statistics

Table 2. Descriptive Statistics

Variables	Obs	Average	Std	Min	Max
CO <sub>2</sub>	1098	3.867	4.910	0.086	29.99
IFI	1098	0.465	0.235	0.001	1.216
GDP	1098	8.364	1.012	5.633	10.440
URB	1098	58.396	18.036	14.841	95.603
DCP	1098	55.183	62.082	2.010	525.703

Source: Stata output.

According to the data collected, the average carbon emissions fluctuated around 3.867 tons per person. The highest value was 29.99 tons per person, recorded in Trinidad and Tobago in 2011, while the lowest was found in Madagascar in 2009, reaching 0.086 tons per person. The average value of financial inclusion was 0.465, with the highest value observed in Malta in 2011. The average urbanization rate was 58.39%, the average per capita income was 8,364, and the average value of the urbanization speed index was 55.163%.

### Autocorrelation Matrix

Table 3. Autocorrelation Matrix

Variables	CO <sub>2</sub>	IFI	GDP	URB	DCP
CO <sub>2</sub>	1.000				
IFI	0.3424	1.000			
GDP	0.6219	0.5158	1.000		
URB	0.3430	0.3656	0.5334	1.000	
DCP	0.1390	0.5806	0.2705	0.0691	1.000

Source: Stata output.

The correlation matrix shows that financial inclusion (IFI) is positively correlated with CO<sub>2</sub> emissions ( $r = 0.3424$ ), implying that greater access to financial services may stimulate economic and consumption activities that increase energy use and carbon output. Compared with other variables, GDP ( $r = 0.629$ ) and urbanization ( $r = 0.3430$ ) also exhibit positive links with CO<sub>2</sub> emissions, while domestic credit to the private sector ( $r = 0.1390$ ) shows a weaker relationship. Overall, the moderate correlation between IFI and CO<sub>2</sub> suggests that financial inclusion might influence environmental quality mainly through economic and energy channels.

## Cross-sectional Dependence and Stationarity Tests

Cross-sectional dependence testing of the variables is essential to examine whether there is a relationship between countries. The results of the cross-sectional dependence test, following Pesaran (2004) with the series of variables, are shown in Table 4.

Table 4 indicates that all series reject the null hypothesis at a significant level of 1%. Thus, cross-sectional dependence exists among countries. Therefore, the study employs Pesaran's CADF second-generation stationarity test.

Table 4. Result of Cross-sectional Dependence and Stationarity Tests

Variables	CD Test	P-value	Average $\rho$	Averageabs ( $\rho$ )
CO <sub>2</sub>	20.615	0.0000	0.02173	0.9788
IFI	82.272	0.0000	0.0029	0.8299
GDP	129.889	0.0000	0.6201	0.8877
URB	111.099	0.0000	0.0814	0.9779
DCP	55.696	0.0000	0.4580	0.9412

Source: Stata output.

## Results regression

### Impact of financial inclusion on environmental pollution using the threshold model

Table 5. Regression Results

Threshold Value	5.2500***
(Confidence Interval 95%)	4.9100 – 5.3900
$\alpha_1$	0.5763**
$\alpha_2$	-2.7783**
dGDP	0.0000***
dURB	0.0467***
dDCP	-0.5899***

Note: \*, \*\* and, \*\*\* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Stata output.

Table 5 indicates a non-linear relationship between financial inclusion and environmental pollution within Table 5 shows evidence of a non-linear relationship between financial inclusion and environmental pollution in developing countries. This finding is consistent with Renzhi and Baek (2020), who also document threshold effects in the finance–environment nexus.

The estimated threshold value is 5.25, indicating a statistically significant change in the effect of financial inclusion once this point is crossed. Before the threshold, the coefficient of financial inclusion is positive (0.5763), suggesting that at lower levels of financial inclusion, expanding access to finance may unintentionally increase pollution – possibly reflecting early-stage economic

expansion that prioritizes growth over environmental considerations. Above the threshold, the coefficient becomes negative ( $-2.7783$ ), implying that higher levels of financial inclusion contribute to reducing environmental pollution. This indicates that once a country reaches a sufficiently developed financial inclusion level, financial access begins to facilitate cleaner technologies, improved resource allocation, and environmentally responsible investment.

Our findings simultaneously indicate that the growth rate of gross national income and population urbanization contribute to increasing environmental pollution. It can be observed that economic growth in developing countries relies on heavy industries that require substantial natural resources, which has detrimental effects on the environment. Furthermore, these nations face a trade-off between economic growth and environmental concerns, leading to less stringent processes in treating industrial waste. Moreover, during the development phase, rising incomes often drive increased consumption of durable goods, further contributing to pollution; such a finding was also reported by Baloch et al. (2021). Concurrently, urbanization, which leads to higher concentrations of populations in urban areas, compels leaders to develop infrastructure. The research findings align with Alola, Bekun, and Sarkodie (2019).

Conversely, the variable of credit to the private sector has a mitigating impact on environmental pollution. In many developing countries, the private sector is largely composed of small-scale enterprises that lack experience and credibility, with limited business capacity, making it very difficult to invest in modern, clean technology. Therefore, when credit to the private sector increases, bank loans enable these private enterprises to upgrade equipment, enhance product quality, and maintain and expand markets. This crucial factor helps these enterprises improve their production and business processes, thereby potentially reducing CO<sub>2</sub> emissions.

Furthermore, the LR Statistics value is greater than 8.37 (Figure 1), which is statistically significant, demonstrating that the regression model is appropriate.

The study further investigates whether there are two impact thresholds of financial inclusion on environmental pollution. The bootstrap results show that the p-value at the second threshold is 0.2750, indicating that there is no single impact threshold of financial inclusion on environmental pollution.

Thus, the results provide empirical evidence for the hypothesis regarding the non-linear relationship between financial inclusion and environmental pollution. To test the robustness of these findings, we employ the Ordinary Least Squares (OLS) regression method with the original baseline model and include the squared term of financial inclusion. If the regression coefficient of IFI exhibits a negative value, it signifies the existence of a non-linear relationship. The results are presented in Table 6.

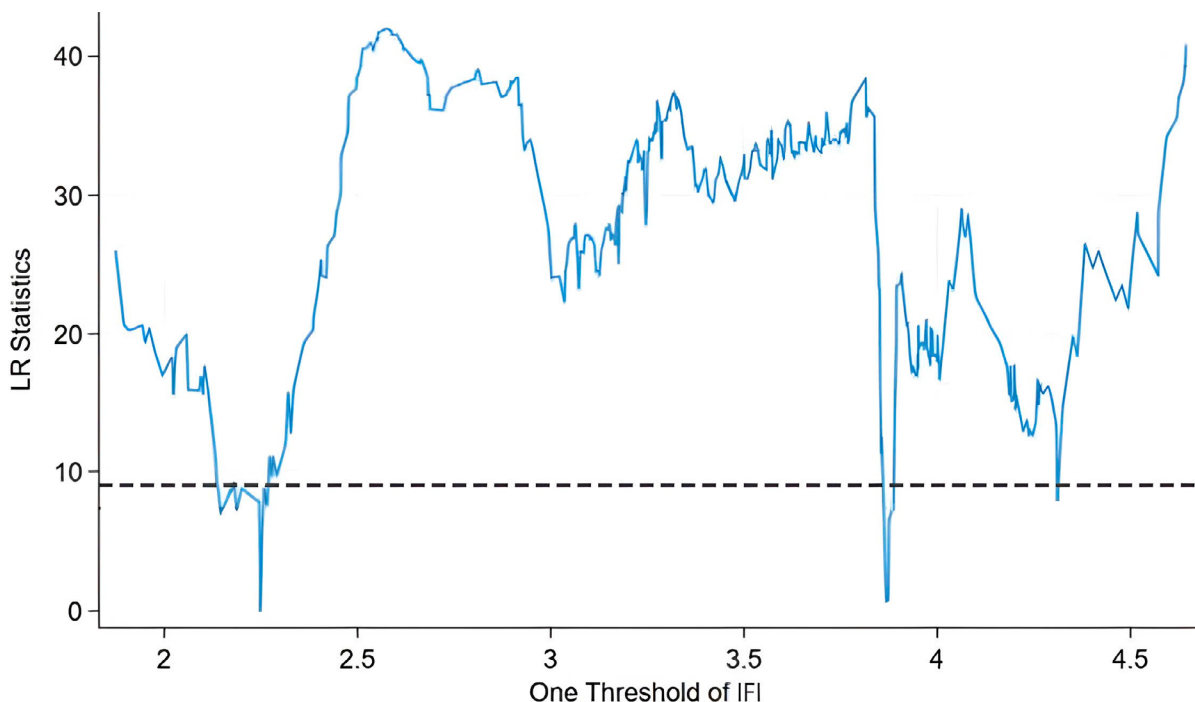


Figure 1. One-threshold test of IFI

Source: Stata output.

Table 6. Non-linear Effect Test Results

Variables	
IFI	3.238*
IFI <sup>2</sup>	-1.707*
GDP	0.000***
URB	0.000
DCP	-0.004***
cons	-0.187*
R <sup>2</sup>	0.5888

Note: \*, \*\* and, \*\*\* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Stata output.

### Impact of Income

In this section, we utilize the DID method to assess how the impact of financial inclusion on environmental pollution differs between countries grouped by *per capita* income and financial inclusion level. Table 7 presents the parameters in the DID model, and Table 9 presents the results.

**Table 7.** Descriptive Statistics of Data in the DID Method

Time variable	Year	Control (Treat = 0)	Treatment (Treat = 1)
Firm		611	505

Source: Stata output

The results in Table 8 indicate a balanced distribution of the sample, with 611 observations in the control group (Treat = 0) and 505 observations in the treatment group (Treat = 1). The clear identification of control and treatment groups based on the treatment variable is essential for evaluating the causal effect within the DID framework. Overall, the sample sizes in both groups are adequate to support reliable conclusions regarding the impact of financial inclusion on environmental pollution.

The results in Table 8 show that the DID coefficient is negative and statistically significant at the 10% level. This suggests that the reduction in environmental pollution is significantly stronger for higher-income countries with higher levels of financial inclusion compared to the lower-income countries.

**Table 8.** DID Method Results

	Coefficient	S. Err.	t	P >  t
DID	-0.405	0.226	1.79	0.073***

Note: \*, \*\* and, \*\*\* denote statistical significance at the 1%, 5%, and 10% levels, respectively.

Source: Stata output.

Based on the analysis results obtained using the DID method, this study accepts hypothesis  $H_2$ , affirming that the income level of countries has a significant influence on the impact of financial inclusion on the environment. The finding suggests that variations in income across different countries may lead to changes in the relationship between financial inclusion and environmental pollution. Consequently, the effectiveness of promoting financial inclusion for environmental protection may not be uniform across countries, but depends heavily on economic characteristics, as represented by the income level of each nation.

## Impact of Paris Agreements

As with the examination of how income levels affect the impact of financial inclusion on environmental pollution, we concurrently examine the effects of two factors: participation in the Paris Agreement and the level of financial inclusion, using the DID method. The results are presented in Table 9 and Table 10, respectively.

**Table 9.** Descriptive Statistics of Data in the DID Method

Time variable	Year	Control (Treat = 0)	Treatment (Treat = 1)
Firm		611	505

Source: Stata output.

Table 10 shows a balanced distribution of the sample, with 611 observations in the control group (Treat = 0) and 505 observations in the treatment group (Treat = 1). Clearly distinguishing the control and treatment groups using the treatment indicator is essential for accurately evaluating the causal effect within the DID framework. The adequate number of observations in both groups ensures the reliability of the conclusions regarding the impact of the Paris Agreement on environmental pollution.

Table 10. DID Method Results

	Coefficient	S. Err.	t	P >  t
DID	-0.634	0.230	2.76	0.006***

Note: \*, \*\* and, \*\*\* denote statistical significance at the 1%, 5%, and 10% levels, respectively

Source: Stata output.

Table 10 presents the estimation results of the DID model for environmental pollution. The DID coefficient is negative and statistically significant at the 1% level. This implies that the environmental pollution reduction effect after the signing of the Paris Agreement is significantly stronger for countries with a high level of financial inclusion.

Based on the analysis results from the DID method, this research further reinforces the study's findings by accepting hypothesis  $H_3$ . This affirms that the Paris Agreement genuinely influences the impact of financial inclusion on the environment. This finding demonstrates that a nation's commitment to and implementation of the Paris Agreement's objectives creates a significant change in how financial inclusion affects environmental pollution. In other words, this result implies that the Paris Agreement is not merely a simple environmental accord, but a crucial factor in reshaping the relationship between financial inclusion and the goal of sustainable environmental development in member countries.

## Discussion

The empirical results provide robust evidence that the relationship between financial inclusion and environmental pollution is nonlinear, confirming the existence of a threshold effect. Specifically, financial inclusion initially increases pollution levels, but the effect changes direction once the inclusion index surpasses the threshold. This finding aligns with the EKC framework, which postulates an inverted U-shaped relationship between economic development and environmental degradation (Tan, Lean, and Khan 2014; Ali et al. 2021).

This result is consistent with Renzhi and Baek (2020), who also reported a nonlinear relationship between financial inclusion and environmental performance, suggesting that inclusive finance can be an effective tool for pollution mitigation when it reaches a certain level of maturity. Similarly, Le, Le, and Taghizadeh-Hesary (2020) found that financial inclusion contributes to emission reduction in the long run once economies develop robust financial systems that promote green investments.

However, the current study diverges from Rehman, Fareed and Shahzad (2022) and Hussain et al. (2024), who found a positive and linear relationship between financial inclusion and environmental

pollution in Asia. The difference may arise from the methodological approach unlike these studies, our analysis employs a panel threshold regression, which captures nonlinearity and identifies critical levels of financial inclusion, and a DID model to account for cross-country heterogeneity.

Regarding the moderating factors, the DID results reveal that both national income and participation in the Paris Agreement significantly influence the environmental outcomes of financial inclusion. Higher-income countries or early participation in the Paris Agreement experience a stronger pollution-reducing effect. This finding supports Chaudhry, Yusop, and Habibullah (2022) and Du et al. (2022), who argued that institutional quality and environmental regulation determine how financial inclusion translates into environmental benefits. It also extends the conclusions of Amin, Song, and Khan (2022) by showing that the positive environmental impact of financial inclusion depends on country-specific policy frameworks and international commitments.

Overall, the results confirm that financial inclusion alone is not a guaranteed path to environmental sustainability. Its effectiveness depends on reaching a certain level of financial development, coupled with strong environmental governance. Therefore, this study contributes to the literature by:

1. Empirically identifying the threshold point at which financial inclusion becomes environmentally beneficial.
2. Highlighting the conditional role of income and international environmental commitments in shaping the inclusion–pollution nexus.
3. Providing policy-oriented insights for promoting inclusive yet environmentally sustainable financial systems.

Unlike most previous studies that view financial inclusion as a linear determinant of environmental outcomes, this research reveals a dynamic mechanism where the composition and maturity of financial inclusion matter. The findings show that inclusive finance exerts a dual effect: it can either exacerbate or alleviate pollution depending on the balance between credit expansion and green investment facilitation. By identifying a quantifiable threshold value and testing cross-country heterogeneity through the DID model, this study provides a novel empirical contribution to the environmental finance literature.

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## Conclusions

This study examined how financial inclusion affects environmental pollution across 61 developing countries between 2005 and 2022, employing both the Panel Threshold Regression (PTR) and Difference-in-Differences (DID) models. The research aimed to identify nonlinear relationships, as well as the moderating roles of national income and participation in the Paris Agreement.

The empirical findings provide strong support for Hypothesis H1, confirming the existence of a nonlinear (threshold) effect between financial inclusion and environmental pollution. Specifically, financial inclusion increases CO<sub>2</sub> emissions at lower levels, but its impact changes direction once it surpasses the threshold, meaning that greater financial inclusion contributes to reducing

environmental pollution beyond this point. This evidence supports the Environmental Kuznets Curve (EKC) framework and highlights that the environmental benefits of financial inclusion only materialize beyond a certain level of financial development.

Hypothesis H2 is also confirmed. The DID results indicate that national income significantly moderates the financial inclusion–pollution relationship. In higher-income countries, financial inclusion plays a more effective role in promoting green investment and cleaner production, while in lower-income countries, expanding financial access still tends to increase emissions due to energy-intensive industrialization.

Similarly, Hypothesis H3 is validated. Participation in the Paris Agreement strengthens the environmental benefits of financial inclusion. Countries that joined the Agreement earlier, or have stronger environmental governance, experience a more pronounced reduction in CO<sub>2</sub> emissions when financial inclusion expands. This finding underscores the importance of global environmental commitments in enabling inclusive finance to support sustainability.

Taken together, these results reveal that financial inclusion can either exacerbate or mitigate environmental pollution depending on its level of development and the broader economic–policy context. The study contributes to the existing literature by:

1. Identifying the threshold level of financial inclusion at which its environmental impact changes direction.
2. Demonstrating the moderate effects of income and international environmental commitments.
3. Integrating the PTR and DID frameworks to provide a more comprehensive understanding of the inclusion–environment nexus.

From a policy perspective, the findings suggest that developing countries should not treat financial inclusion as an end. Instead, they should align financial inclusion strategies with environmental objectives, focusing on green credit, sustainable investment, and inclusive financial technologies that promote carbon dioxide reduction. Strengthening international cooperation under the Paris Agreement framework can further amplify the positive environmental effects of financial inclusion.

Despite its empirical contributions, this study has several limitations that open avenues for future research.

First, the measurement of financial inclusion relies primarily on traditional indicators such as the number of bank branches and ATMs, due to data availability across developing countries. These indicators may not fully capture the current technological dimension of financial inclusion, such as digital payments, mobile banking, and fintech development. Future studies should incorporate digital financial indicators to better reflect the impact of financial innovation on environmental outcomes.

Second, the analysis focuses on the economic and financial channels through which inclusion affects environmental pollution, but it does not explicitly account for institutional or governance

factors that could moderate this relationship. Including these variables could enhance understanding of how institutional quality strengthens or weakens the environmental effectiveness of inclusive finance.

Third, the study uses the timing of Paris Agreement participation as a proxy for environmental commitment. While this captures differences in the adoption of climate policies, future work could employ more granular indicators, such as domestic green finance regulations, environmental stringency indices, or national climate policy scores, to capture policy heterogeneity more precisely.

Addressing these limitations will allow future research to develop a more comprehensive understanding of how inclusive financial systems contribute to sustainable and low-carbon development. Future studies should also incorporate direct measures of financial literacy and digital financial access to disentangle their specific environmental impacts.

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## Jak inkluzja finansowa wpływa na zanieczyszczenie środowiska: zastosowanie modelu regresji progowej i metody DID

W niniejszym badaniu poddano analizie nieliniowy wpływ inkluzji finansowej na zanieczyszczenie środowiska w 61 krajach rozwijających się w latach 2005–2022. Wykorzystanie modelu regresji progowej pozwala na wskazanie krytycznego progu, przy którym kierunek wpływu inkluzji finansowej na zanieczyszczenie środowiska ulega zmianie. Poniżej tego progu inkluzja finansowa ma tendencję do zwiększania emisji dwutlenku węgla, jednak po jego przekroczeniu relacja się odwraca, a inkluzja finansowa przyczynia się do redukcji zanieczyszczeń. Aby uzyskać głębszy wgląd w zagadnienie, w badaniu dodatkowo zastosowano metodę *Difference-in-Differences* (DID). Jej użycie pokazuje, że efekt inkluzji finansowej jest zróżnicowany i zależy od poziomu rozwoju finansowego, dochodu narodowego oraz momentu przystąpienia danego kraju do Porozumienia paryskiego w sprawie zmian klimatu.

Ustalenia zawarte w artykule podkreślają wielowymiarowy charakter relacji między inkluzją finansową a środowiskiem, która jest w znacznym stopniu kształtowana przez czynniki ekonomiczne i polityczne, specyficzne dla danego kraju. Ponadto badanie wykazało, że dochód narodowy i poziom urbanizacji wiążą się ze wzrostem zanieczyszczeń, podczas gdy kredyty dla sektora prywatnego odgrywają rolę łagodzącą w procesie redukcji emisji.

Wyniki niniejszego badania mają istotne implikacje, które decydenci powinni uwzględnić przy projektowaniu strategii promujących inkluzję finansową w zgodzie z celami zrównoważonego rozwoju.

**Słowa kluczowe:** inkluzja finansowa, zanieczyszczenie środowiska, metoda DID, metoda panelowa regresji progowej