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The Impact of Financial Inclusion on CO_2 Emissions: The Mediating Role of Renewable Energy and the Moderating Role of Institutional Quality

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ABSTRACT

This study uses a fixed-effects regression model with robust standard errors, employing data from 52 countries between 2017 and 2022 to examine the impact of financial inclusion (FI) on CO_2 emissions through the mediating role of renewable energy (RE) and institutional quality. The research results present a multifaceted picture of the impact of FI on CO_2 emissions and the role of RE alongside institutional quality. The positive impact of FI on CO_2 emissions suggests that the current expansion of access to finance primarily promotes production and consumption in a way that increases demand for traditional energy, thereby increasing emissions. The estimated indirect effects are all negative and statistically significant, implying that FI has the potential to reduce emissions through RE when supported by appropriate institutional frameworks. Current institutional frameworks are not strong enough to reduce emissions, but the interaction between RE and institutional quality could reverse this trend, helping to slow down the rate of CO_2 increase. Based on the results obtained, the study provides recommendations to policymakers and organizations to reduce CO_2 emissions in countries in the future.

Keywords: Renewable Energy, CO_2 Emissions, Financial Inclusion, Institutional Quality
JEL Classifications: Q21, Q43, Q56, O16, D73

1. INTRODUCTION

Climate change, CO_2, and greenhouse gases have become a major factor of concern for the world today. In the quest for sustainable development, FI, on one side, and RE, on the other, have been established as two key pillars that have the potential to mitigate environmental problems by altering capital, energy, or production-consumption patterns. However, the nexus among FI, RE, and CO_2 is a contested area among academic theorists, presenting multi-dimensional, sometimes inconclusive, results. FI presents a two-sided possibility, where it may be a source of positive as well as a negative impact on the environment. FI may create opportunities for the use of RE resources, contributing to sustainable development, primarily because it might provide access to crucial financial services and resources (Ababio et al.; Li et al., 2022). However, it might also trigger more development, contributing to more use, more production, more demand, thus more pollution, including CO_2 (Gök, 2020).

The number of empirical research on FI and CO_2 remains quite limited and often involves single-country research (Vietnam: Hoang and Ngo, 2023; Le and Ngo 2022; Pakistan: Zhang et al., 2017; China: Zhao et al., 2021) or regional research (South Asia: Murshed et al., 2020; North Africa: El Weriemmi and Bakari, 2024). In addition, some research deals with general financial development without decomposing FI into categories of its own (Gök, 2020; Jiang and Ma, 2019; Zhang et al., 2017). In addition, while some research deals with the moderating role of globalization or information technology (Qin et al., 2021; Pham, 2024), other relatively key elements such as institutional quality or environmental stringency (Gök, 2020; Zhao et al., 2021) are often neglected. For example, institutional quality can affect the role of FI policies on promoting RE (World Bank, 2020).

One major gap in existing studies is the lack of comprehensive models incorporating the joint examination of FI, RE, and CO_2 emissions with mediation (RE) and moderators (institutional quality) together. Although some studies have begun to explore the three-way relationship, more research is needed to fully understand the complex and interactive mechanisms between FI, RE, and CO_2. Another important gap lies in the need to further clarify the mediating and moderating mechanisms within this relationship. There is limited research analyzing the role of moderating variables such as institutional quality and macroeconomic conditions in shaping the nexus among FI, RE, and CO_2.

In this study, we build a moderated mediation model to analyze the impact of FI on CO_2, through the mediating role of RE, and test the moderating role of institutional quality (expressed through the Institutional quality- POL). Although FI helps increase access to capital for individuals and businesses, thereby facilitating investment in clean energy (Li et al., 2022), the extent of FI's impact on RE and the efficiency of converting RE into environmental outcomes (CO_2 reduction) may strongly depend on institutional quality (Acheampong et al., 2024). In transparent and less corrupt institutional environments, financial capital flows tend to be used more efficiently, contributing to increased investment in clean energy and optimizing environmental performance (Trabelsi and Fhima, 2025). Acheampong et al. (2024), using a dataset of 119 countries between 2004 and 2020, found FI has a positive and significant effect on RE, and this effect is strengthened by high political institutions. Importantly, this illustrates that the quality of political institutions has the potential to reinforce the positive impact of FI on RE. This implies that the quality of governance and legal systems can play a critical role as moderators in the FI and RE nexus. The quality of institutions represents the basic factor influencing the evolution of financial structures and environmental policies. The lower extent of corruption and the effectiveness of the rule of law strengthen the implementation potential of policies, lower transaction costs, and improve the confidence of the green energy investment sector (Trabelsi and Fhima, 2025). Existing empirical evidence suggests that the quality of institutions has the potential to strengthen the effectiveness of FI and reinforce the investment attraction potential in RE, thus making a positive contribution to the target of emission reduction (Li et al., 2022; Acheampong et al., 2024).

As such, the proposed research model comprises three steps: Step 1: Examine the total impact of FI on CO_2; Step 2: Investigate the effect of FI on RE with the moderation of institutional quality (POL); Step 3: Examine the impact of RE on CO_2 with the mediation of RE and moderation of POL in the relationship of FI with CO_2. The use of interaction variables FI × POL and RE × POL allows testing the hypothesis that POL has modified the strength or direction of these relationships. The research model thus enriches the theoretical finance-energy-environment model and provides empirical insights into under what institutional settings the optimal impact of FI on sustainable development can be achieved.

Based on the dataset of 52 countries for the years 2017-2022, the research identifies a complex pattern of FI's influence on CO_2 and the interaction of RE and POL. FI has a positive impact on CO_2 emissions, implying that the current financial system's expansion mainly supports activities of production and consumption, which in turn stimulates the demand for conventional energy and, consequently, emissions. The indirect impacts are all negative and significant, implying that FI can mitigate emissions through the RE channel and the right policies. The current policies alone fail to mitigate emissions; however, the interaction of RE and POL can change this situation, which helps slow down the growth of CO_2 emissions.

The remainder of this paper is structured as follows: Section 2 provides a review of the literature, while Section 3 describes data, variables, as well as research models; results on moderation (RE × POL), mediation, and robustness tests are contained in Section 4, which also serves to explain these results, and then Section 5 provides a conclusion.

2. LITERATURE REVIEW

2.1. Impact of Financial Inclusion on CO_2 Emissions

FI is defined as the ability to access, use, and benefit from formal financial services in a fair and equitable manner (World Bank, 2020). Recent studies show that FI can have a two-way impact on the environment. On the one hand, uncontrolled financial expansion can promote personal consumption (e.g., cars, housing, electronic appliances) and investment in high-intensity emission industries, thereby increasing CO_2 (Gök, 2020). Gök (2020), through meta-regression analysis, showed that financial development, including FI, often increases emissions in the early stages of economic development. On the other hand, if properly oriented, FI can facilitate individuals and small businesses to access investment capital in clean technology, renewable energy and circular production models. Regional studies in Asia also support this finding, such as Le et al. (2020) and Qin et al. (2021), who demonstrate that the impact of FI on CO_2 depends on the degree of alignment of FI with RE deployment and globalization. In Vietnam, Hoang and Ngo (2024) find that financial development increases emissions if not linked to the energy transition, while Pham (2024) points to the positive role of financial information technology (FinTech) and telecommunications systems in reducing emissions through improved investment efficiency.

2.2. Impact of Financial Inclusion on Renewable Energy

Financial inclusion (FI) plays an important role in facilitating the energy transition to renewable sources. Financial inclusion helps alleviate the cost of capital associated with investments in solar, wind, biomass and energy efficiency by increasing access to credit, banking, and digital channels for households and small businesses (Li et al., 2022).

There is sufficient evidence from contemporary research showing that FI might also positively influence RE. In fact, Ababio et al. (2023) analyzed the relationship between FI and RE in developing countries and concluded that FI positively impacts RE consumption. This confirms that financial inclusion inspires people and companies to find ways for financing RE projects and other sustainable operations, and therefore suggests FI as an instrument for supporting RE in other countries as well. The positive influence of FI on consumer RE demand is also highlighted in the study by Acheampong et al. (2024). This shows that financial service provision encouraged households and business organizations to buy RE appliances like solar water heaters.

Despite the aforementioned positive impacts, there are potential negative and/or uncertain impacts of FI on RE. Some assessments suggest that broader access to financial services might lead to an increase in the consumption of energy, including fossil fuel-based energy, through the increased purchasing of energy-intensive products like cars, and air conditioning units. Feng et al. (2022) suggest that FI can increase the purchasing capacity of individuals, enabling the procurement of energy-intensive electronic devices. Nonetheless, in the event that the energy demand continues to depend largely on fossil fuel-based energy, the aforementioned increased consumption may lead to negative environmental results. Nevertheless, according to Feng et al. (2022), FI can facilitate RE and decrease the emissions of CO_2 gases through well-designed strategies.

Other studies investigating financial development in general (including FI) and energy use, and then correlating financial development with energy use, produce mixed results. A positive correlation between financial development and CO_2 emissions with energy efficiency driving the reduction in CO_2 emissions has been found by Liu et al. (2022). The analysis of data involving provinces in China from 2000 to 2020 reveals that green finance promotes investment in renewable energy sources, thus improving energy efficiency.

2.3. Impact of Renewable Energy on CO_2 Emissions

RE is often considered a cornerstone of the CO_2 reduction strategies in most countries. A considerable literature observes that increasing the share of RE in consumption helps to alleviate environmental pressure (Zhang et al., 2017; Ababio et al., 2023). Zhang et al. (2017) had noticed in Pakistan, with an increase in the share of RE, the EKC tends to shift to the left and signifies that at lower income levels, the emissions start falling. The research study by Ababio et al. (2023), conducted for developing economies, also made similar observations and pointed out that improved adoption of RE is one of the prime reasons for environmental sustainability in these economies. Le (2024) observed in the Southeast Asia region that though economic growth and material footprint tends to increase the emission burden, RE is the only causative factor which will surely be able to reduce CO_2 in a sustainable manner. Mirziyoyeva and Salahodjaev (2023) argued that to reduce CO_2, policy makers need to increase investment in the RE sector and create conditions and benefits for the rapid adoption of renewable technologies by the private sector and households. Nguyen and Tran (2023) and Nguyen (2022) also confirm RE as the mainstay agent to be used in the green energy transition. Acheampong et al. (2024) also observed, for their sample countries in the MENA region, that RE exerts a significant and negative impact on reducing CO_2. However, other studies caution that the environmental effectiveness of RE is only fully realized when a nation has a competitive electricity market, stable incentive policies, and capacity to integrate RE into the power grid (Hoang and Ngo, 2023; Murshed et al., 2020). Increase in RE consumption is closely associated with reduced greenhouse gas emissions due to substitution of fossil energy sources like coal and oil (Saint Akadiri et al., 2019). In the long-term model of emission reduction, RE is considered a critical stake which can help to achieve carbon neutrality commitment. Bekun et al. (2019) also asserts that in the long term, non-renewable energy consumption and economic growth increase CO_2 while RE consumption reduces CO_2.

Furthermore, RE not only contributes to direct emission reductions but also increases energy efficiency and encourages green technology innovations (Doğan et al., 2021).

2.4. The Financial Inclusion - Renewable Energy - CO_2 Emissions Nexus

Connecting the above two relationships, many recent studies have emphasized the mediating role of RE in the link between FI and environmental performance. FI not only directly affects the level of emissions (through green consumption and production behavior), but also indirectly through promoting investment in RE, thereby contributing to reducing CO_2 (Li et al., 2022; Acheampong et al., 2024). Examining the mediating role of RE thus helps explain the spillover mechanism of FI in sustainable development strategies. Most existing studies still take a bilateral approach, that is, only analyzing the relationship between FI and CO_2 or RE and CO_2 independently. Some pioneering studies have begun to integrate all three factors into the model to clarify the mediating role of renewable energy. Tsimisaraka et al. (2023) suggested that FI can indirectly reduce emissions through promoting investment in RE, however, this mechanism has not been widely tested empirically. In addition, Liu et al. (2022) found that the combination of FinTech, FI and green capital creates a synergistic effect in improving energy efficiency and reducing emissions. In Vietnam, Ngo et al. (2024) also found a statistically significant mediating relationship between FI, environmental tax policy and RE consumption.

Ababio et al. (2023) suggest that through a triadic relationship, FI can positively contribute to environmental sustainability by enabling increased financing of projects related to RE. The results indicate that FI is a significant factor that has the potential to amplify the positive influence of RE on the environment, resulting in the reduction of CO_2 emissions. Similarly, the study by Acheampong et al. (2024) highlights that FI has a positive influence on RE, which further influences the reduction of CO_2 emissions, indicating that there is a sequence here where FI influences the promotion of RE, which, in turn, influences the reduction of CO_2. However, Baskaya et al. (2022) highlight that FI and RE have a combined negative influence on CO_2 emissions among BRICS countries. This is indicative that both FI and RE have equal significance in furthering the reduction of CO_2 emissions in developing countries. Furthermore, Li et al. (2022) highlight that FI is a significant contributor to the growth of RE, specifically wind energy and solar energy, which can further contribute to the reduction of CO_2 emissions.

Taken collectively, these studies highlight that research does exist that supports the hypothesis that FI has the ability to contribute to the reduction of CO_2 emissions through the influence of RE, although this remains a relatively small contribution. Moreover, there are very few studies that have explored the impact of FI on CO_2 through the mediating role of RE and the moderating role of institutional quality (POL).

To explore the impact of FI on CO_2 reduction through the mediating role of RE and the moderating role of POL, we propose the following hypotheses:

Hypothesis H_1: FI has a negative (reducing) effect on CO_2

Hypothesis H_{2a}: FI has a positive effect on RE

Hypothesis H_{2b}: POL moderates the relationship between FI and RE

Hypothesis H_{3a}: RE reduces CO_2

Hypothesis H_{3b}: RE is a mediating variable between FI and CO_2

Hypothesis H_{3c}: POL moderates the relationship between RE and CO_2

H_1. FI reduces CO_2 (total effect). H_{2a}. FI increases RE. H_{2b}. POL strengthens the FI-RE link. H_{3a}. RE reduces CO_2. H_{3b}. RE mediates the FI→CO_2 link. H_{3c}. POL strengthens the RE-CO_2 link.

3. RESEARCH METHODOLOGIES

3.1. Research Model

In this study, we construct a moderated mediation model to analyze the impact of FI on CO_2, through the mediating role of RE, and test the moderating role of institutional quality (represented by the rule of law [POL] index). We choose POL as a moderating variable, because in a highly institutionalized environment, businesses will comply with environmental regulations as monitoring and enforcement increase expected penalties for non-compliance. On the contrary, the absence of effective regulations and enforcement mechanisms creates conditions for businesses and individuals to circumvent the law, use loans to expand production with old technology, causing pollution, leading to the "pollution paradise" effect.

Model (1): Testing the total effect of FI on CO_2 (H_1)

$$LCO_{2it} = \alpha_0 + \alpha_1 IFI_{it} + \alpha_2 LGDPPC_{it} + \alpha_3 MCS_{it} + \alpha_4 UP_{it} + \varepsilon_{it} \quad (1)$$

In which: LCO_2 is the natural logarithm of total CO_2 emissions of country i in year t; FI is the financial inclusion index of country i in year t; control variables: Economic characteristics are the natural logarithm of GDP per capita (LGDPPC) of country i in year t; population characteristics are the proportion of population living in urban areas (UP) of country i in year t; ICT proxy: mobile-cellular subscriptions per 100 people (MCS) of country i in year t; ε is the model error.

Model (2): Testing the impact of FI on RE, moderated by POL (H_{2a}, H_{2b})

$$LRE_{2it} = \beta_0 + \beta_1 IFI_{it} + \beta_2 POL_{it} + \beta_3 (FIxPOL)_{it} + \beta_4 LGDPPC_{it} + \beta_5 MCS_{it} + \beta_5 UP_{it} + \varepsilon_{it} \quad (2)$$

Where: LRE is the natural logarithm of the renewable energy (RE) ratio of country i in year t, which acts as a mediating variable.

POL is the Rule of law of country i in year t, which acts as a moderating variable;

FI × POL is the interaction variable testing whether POL moderates the FI-RE relationship.

If β_3 is significant, it confirms the moderation.

Model (3): Testing the mediating effect of RE in the impact of FI on CO_2, moderated by POL (H_{3a}, H_{3b}, H_{3c})

$$LCO_{2it} = \gamma_0 + \gamma_1 IFI_{it} + \gamma_2 LRE_{it} + \gamma_3 POL_{it} + \gamma_4 (RExPOL)_{it} + \gamma_5 LGDPPC_{it} + \gamma_6 UP_{it} + \gamma_7 MCS_{it} + \varepsilon_{it} \quad (3)$$

Model (3) tests the mediating effect of RE in the impact of FI on CO_2 and tests whether POL moderates the RE-CO_2 relationship through γ_4.

If β_1 in model (2) and γ_2 in model (3) are both significant, then there is a mediating effect of RE in the FI-CO_2 relationship. If β_3 in model (2) is significant, then POL moderates the FI-RE relationship. If γ_4 in model (3) is significant, then POL moderates the RE-CO_2 relationship. If γ_1 in model (3) is no

Table 1: Measure of variables

Dimension	Variable	Indicator	Unit
CO_2 emissions	CO_2	CO_2 emissions	Gg
Renewable energy	RE	Renewable energy consumption (% of total final energy consumption)	%
Financial inclusion	ATM	ATMs per 100,000 adults	Number of ATMs/100,000 adult population
	BRAN	Commercial bank branches per 100,000 adults	Number of commercial bank branches/100,000 adults
	BORR	Borrowers from commercial banks per 1,000 adults	Number of borrowers from commercial banks/1,000 adults
	DEP	Depositors from commercial banks per 1,000 adults	Number of depositors with commercial banks/1,000 adults
Economics	GDPPC	Gross domestic product per capita in constant 2015 dollars	USD/person
General country characteristics	UP	Urban population (% of total population)	%
Technology	MCS	Mobile cellular subscriptions (per 100 people)	Per 100 people

Source: Compiled by the authors

longer significant when RE is present, then RE is likely to play a full mediating role.

In this study, the variables CO_2, RE and GDPPC are normalized by the natural logarithm. In studies on total CO_2 emissions, the CO_2 variable is also often normalized by the natural logarithm (Hoang and Ngo, 2023; Le et al., 2020; Qin et al., 2021). In studies on RE, the RE variable is also normalized by the natural logarithm (Nguyen and Tran, 2023; Qin et al., 2021; and Le, 2024). Table 1 summarises the definitions, measurements, and units of all variables used in the empirical models.

The study of financial inclusion (FI) involves the use of several variables; in this paper, a principal component analysis (PCA) was conducted to combine four financial inclusion variables (ATM, BRAN, BORR, and DEP), which relate to financial access and usage. The PCA technique has been widely adopted by many researchers to combine overall financial variables (e.g., Le et al., 2019; Qin et al., 2021; Tran and Le, 2021). Using the PCA technique, two test conditions were applied to ensure that the data was appropriate for PCA: Bartlett's test of sphericity and the Kaiser-Meyer-Olkin (KMO). The value of the KMO was found to be 0.719 (Appendix 1), which was found to be appropriate to employ in PCA. Additionally, Bartlett's test of sphericity was found to be statistically significant ($\chi^2 = 354.654$, $P < 0.001$). This implies that the observed values are highly correlated and suitable to be combined by PCA. The first principal component had Eigenvalue = 2.374 and explained 59.345% of the total variance, exceeding the 50% threshold. Thus, the results of both tests showed that the use of PCA was appropriate in measuring the comprehensive financial index. The results of the total variance explained for the comprehensive financial index are shown in Appendix 2.

3.2. Data Sources

In the context of available data, this study uses data collected from 52 countries in the period 2017-2022, of which 20 countries are in the Low income and Lower middle income groups (38.46%); 20 countries are in the Upper middle income group (38.46%) and 12 are in the High income group (23.08%). Data reflecting CO_2 emissions are collected from the EDGAR report webpage (https://edgar.jrc.ec.europa.eu/report_2024) and EDGAR_2024_GHG website (https://edgar.jrc.ec.europa.eu/dataset_ghg2024) and/or relevant reports. Data reflecting RE are collected from The Energy Progress Report, World Bank, Washington DC. Data reflecting GDPPC, MCS and UP are collected from the World Bank's open data source.

4. RESULTS AND DISCUSSIONS

4.1. Research Results

Descriptive statistics of the variables used in the study are presented in Table 2.

4.1.1. Results of the direct impact of financial inclusion on CO_2 emissions

The results of model (1) estimation, assessing the direct impact of FI on CO_2 (without intermediate variables) are presented in Table 3.

Table 2: Descriptive statistics

Variables	n	Minimum	Maximum	Mean	Standard deviation
ATM	312	1.3300	315.7483	47.6760	42.3089
BRAN	312	0.8452	48.7997	12.3925	9.2298
BORR	312	7.0696	1122.2932	243.5723	213.2596
DEP	312	25.5132	2847.9936	899.1860	538.9978
CO_2	312	219.0428	12621614.7499	301877.8	1638715
RE	312	0.0000	91.6000	33.6670	25.5394
GDPPC	312	422.9243	67948.8928	9918.8320	13054.2300
UP	312	17.1250	100.0000	57.9360	21.7632
MCS	312	33.3613	190.5250	111.0369	32.4953
POL	312	6.6667	99.0566	44.6646	22.3271

Source: Compiled by the authors

Table 3: Estimation results of direct impact of FI on CO_2

LCO_2	Coefficient	Robust std. err	t	P >|t|
FI	0.16095	0.03748	4.29	0.000
LGDPPC	0.42387	0.17401	2.44	0.018
MCS	−0.00006	0.00112	-0.05	0.960
UP	0.01182	0.01111	1.06	0.292
Constant	5.58106	1.35313	4.12	0.000
Number of obs	312			
F (4.51)	12.79			
Prob>F	0.0000			
R-squared	0.2723			

Source: Compiled by the authors

The estimation results of model (1) using a fixed-effects regression model with heteroskedasticity-robust standard errors (FEM Robust) with log-CO_2 as the dependent variable show that FI only has a positive impact on CO_2. This is contrary to our a priori expectations. This finding is also consistent with some studies by Gök (2020); Chu (2022) when pointing out that financial expansion increases CO_2. GDP per capita (LGDPPC) has a significant positive impact on CO_2, indicating a positive association between the level of economic development and CO_2. In this study sample, there is no statistical evidence showing the influence of the urban population ratio (UP) and mobile phone numbers per 100 people (MCS) on CO_2, indicating that in the context of the study sample, these factors do not significantly affect CO_2.

Thus, FI has a positive and significant impact on CO_2. This finding suggests that FI expansion policies need to be accompanied by investment orientation towards clean energy and energy-saving technologies, otherwise it will exacerbate environmental problems.

4.1.2. Impact of financial inclusion on renewable energy and the moderating role of institutional quality

The estimation results for Model (2), which assesses the impact of FI on RE under the moderation of POL, are presented in Table 4.

The estimation results using FEM Robust with the dependent variable being log (RE) show that there is no clear evidence that FI expansion directly promotes RE. This may reflect that FI development does not automatically lead to an increase in RE usage without policies or supporting factors. The institutional quality (POL) and the interaction variable FI × POL are also not statistically significant, implying that the moderating effect of institutional quality on this relationship is not yet clear, and does not show a significant direct impact on RE expansion. The FI × POL interaction coefficient has a positive sign, suggesting that when institutional quality is higher, the relationship between FI and RE tends to be more positive. However, $P > 0.05$ provides insufficient evidence to conclude the existence of a moderating effect. Nevertheless, the positive sign still suggests a potential research direction: Improving institutional quality can help FI contribute more to RE development. As institutional quality improves, FI can contribute more positively to renewable energy growth. Control variables (LGDPPC, UP, MCS) also do not have a significant impact. This result suggests that the link between FI and RE may be indirect or take time to develop.

4.1.3. Impact of financial inclusion and renewable energy on CO_2 emissions and the moderating role of institutional quality

The estimation results for Model 3, which assesses the impact of FI and RE on CO_2 and tests the moderating role of POL on the RE-CO_2 relationship, are presented in Table 5 below.

The estimation results in Table 5 show that R^2 (within) = 0.5482, so the variables in the model have a fairly high and better ability to explain the change in CO_2 than in Model (2). In Model (3), the FI variable continues to have a significant positive impact on CO_2 (coefficient 0.09785; $P < 0.01$), confirming the results of Model (1). This result is consistent with the argument that financial development can stimulate economic activity, increase energy consumption and thus increase emissions. The share of renewable energy (LRE) is not statistically significant ($P > 0.1$), indicating that at the overall level, the increase in RE is not strong enough to directly impact emissions. That is, there is no evidence that RE directly changes CO_2. This may be due to the low share of RE in total energy supply, which is not enough to produce a clear emission reduction effect. Particularly, the institutional quality variable (POL) shows a significant and positively influential effect on CO_2 of 0.01128 at $P < 0.01$. This is somewhat puzzling, as better institutions are thought to correspond to lower CO_2 emissions in the model specification used here. Perhaps this is driven by more institutionally proficient nations also being more developed and productive, and therefore using more energy and producing more CO_2 (scale effects). The interaction variable RE × POL shows a significantly negative effect with a coefficient of −0.00036 at $P < 0.01$, suggesting a mitigating effect on the rate of CO_2 emissions if expansion in RE is coupled with the right policies. In other words, in countries with better institutions, RE is more effective in reducing emissions. This is an important result supporting the hypothesis that institutional improvements help RE to play its role in environmental protection. This finding emphasizes the role of institutional improvements as a necessary condition for renewable energy to maximize its environmental benefits. GDP per capita still maintains a significant positive impact (0.47452) and is statistically significant ($P < 0.05$), while UP and MCS continue to be statistically insignificant.

Table 4: Estimation results of the impact of FI on RE, moderated by POL

LRE	Coefficient	Robust standard error	t	P >|t|
FI	−0.24493	0.26897	−0.91	0.367
POL	0.00174	0.02097	0.080	0.934
FI_POL	0.00562	0.00428	1.31	0.195
LGDPPC	−0.57740	0.73716	−0.78	0.437
MCS	0.01808	0.01379	1.31	0.196
UP	0.02672	0.05471	0.49	0.627
Constant	3.81317	4.57538	0.83	0.408
Number of obs	312			
F (6,51)	0.77			
Prob>F	0.5995			
R-squared	0.0106			

Source: Compiled by the authors

Table 5: Estimation results of the impact of FI and RE on CO_2, moderated by POL

LCO_2	Coefficient	Robust std. err	t	P >|t|
FI	0.09785	0.02104	4.65	0.000
LRE	0.00142	0.00164	0.87	0.390
POL	0.01128	0.00262	4.30	0.000
RE×POL	−0.00036	0.00006	−5.70	0.000
LGDPPC	0.47452	0.13330	3.56	0.001
MCS	0.00015	0.00066	0.02	0.982
UP	0.00781	0.00794	0.98	0.330
Constant	5.32923	0.98287	5.42	0.000
Number of obs	312			
F (7,51)	14.00			
Prob>F	0.0000			
R-squared	0.5482			

Source: Compiled by the authors

4.1.4. Testing the moderating effect of institutional quality (POL)

4.1.4.1. Testing the impact of renewable energy on CO_2 according to POL levels

To test the effect of RE according to POL levels, the authors conducted a test of the marginal effect of centered RE (c_RE) on CO_2 according to POL at the 25%, 50% and 75% quantiles shown in Table 6. The variables POL and RE were brought to the centered variable in the assessment of the marginal impact of RE on CO_2 according to POL to reduce multicollinearity.

The results in Table 6 show that RE has a negative and statistically significant impact on CO_2 in most institutional quality scenarios (POL). When POL is low, RE has a negative impact on CO_2 but not really strong. However, when POL increases to medium and high levels, the emission reduction impact from RE becomes clear and statistically significant. This implies that the effectiveness of RE depends strongly on the institutional quality, and efforts to expand RE can only be most effective when supported by appropriate environmental policies, thereby creating a resonance effect that helps promote the process of reducing CO_2. The right policies not only encourage investment in clean technology but also increase the absorptive capacity of the market, thereby maximizing the emission reduction impact.

Table 6: Marginal impacts of RE on CO_2 at three POL levels

Level c_ POL	dy/ dx (c_ RE)	Standard error	z	P-value	Confidence interval 95%
25%	−0.0163	0.0036	−4.46	0.0000	(−0.0234; −0.0091)
50%	−0.0210	0.0036	−5.76	0.0000	(−0.0281; −0.0139)
75%	−0.0256	0.0040	−6.38	0.0000	(−0.0335; −0.0178)

Source: Compiled by the authors

Figure 1 shows the downward trend line showing negative simple slopes that gradually strengthen with c_POL. The CI bars are below the zero line, consistent with the P-value results in the table. Thus, c_RE consistently reduced CO_2, and this reduction effect was significantly stronger when c_POL was high, providing clear evidence for a c_RE × c_POL interaction.

4.1.4.2. Testing the marginal effect of FI across POL levels

To test the impact of FI on CO_2 according to POL levels, the authors conducted a test of the marginal impact of FI on CO_2 at three POL levels of 25%, 50% and 75%. The variables FI and POL were brought to the centered variable in the assessment of the marginal impact of FI on CO_2 according to POL to reduce multicollinearity.

The results of Table 7 show that the marginal impact is not statistically significant ($P > 0.1$) at all levels of POL. This implies that FI's impact on RE is not statistically significant across POL levels in Model (2) In addition, the estimation results in models (1) and (3) show that the direct impact of FI increases CO_2. Thus, to reduce CO_2, financial expansion needs to be accompanied by green-oriented mechanisms and institutional reforms to ensure a downward emission trajectory. To reduce CO_2, FI needs to direct capital flows into green production and consumption activities, thereby promoting investment in RE and clean technologies. This result is reflected in the negative and significant coefficient, showing that FI helps reduce emissions through the mechanism of promoting access to resources for environmentally friendly projects. FI only plays a positive role for the environment when accompanied by an oriented institutional quality framework. In other words, FI does not automatically lead to emissions reduction but needs to be supported by policies that shape capital flows towards sustainability. Figure 2 also shows that the marginal impact curve of FI tends to increase as POL increases.

4.1.4.3. Comparison of the impacts of renewable energy and financial inclusion on CO_2 under the moderating role of POL

Considering both channels, institutional quality plays a distinct role in moderating the CO_2 impacts of RE and FI. In the instance of POL being higher, gains from RE become more solid, and RE cements its position in taming emissions. Emissions, in turn, tilt downwards only when POL has reached a threshold of medium-high levels, thus indicating that good institutional quality is a preconditioning factor for FI to actually become a tool for sustainable development. This implies that RE inherently has the potential to reduce emissions, but FI can only play a greening role when placed in a favorable and stable institutional quality. In other words, POL is both a "catalyst" for the effectiveness of FI and an "amplifier" for the emission reduction impact of RE. This comparison confirms the importance of improving institutional quality to maximize both environmental benefits from RE and FI.

Table 7: Marginal impact of FI on CO_2 at three POL levels

Level c_ POL	dy/ dx (c_ FI)	Standard error	z	P-value	Confidence interval 95%
25%	−0.3298	0.2906	−1.13	0.256	(−0.8993; 0.2397)
50%	−0.2018	0.2520	−0.80	0.423	(−0.6958; 0.2921)
75%	−0.0760	0.2754	−0.28	0.783	(−0.6157; 0.4638)

Source: Compiled by the authors

Thus, it can be seen that RE has a direct and clear impact on emission reduction, with a high degree of institutional quality dependence. FI has an indirect impact, mainly through the direction of capital flows, and only becomes effective when there is institutional quality support. Therefore, to achieve the goal of sustainable emission reduction, it is necessary to combine technological tools (RE) with financial-social tools (FI) in a synchronous institutional quality (POL).

4.1.5. Bootstrap results testing indirect effects

The results from bootstrap 2000 samples to estimate confidence intervals and test statistical significance of indirect effects at 3 POL levels of 25%, 50% and 75% are presented in Table 8.

The data in Table 8 show that all three indirect effects are negative and statistically significant at the 1% level ($P < 0.01$) and the 95% confidence interval does not contain zero, thus the moderating

Figure 1: Marginal impact of renewable energy on CO_2 at three POL levels

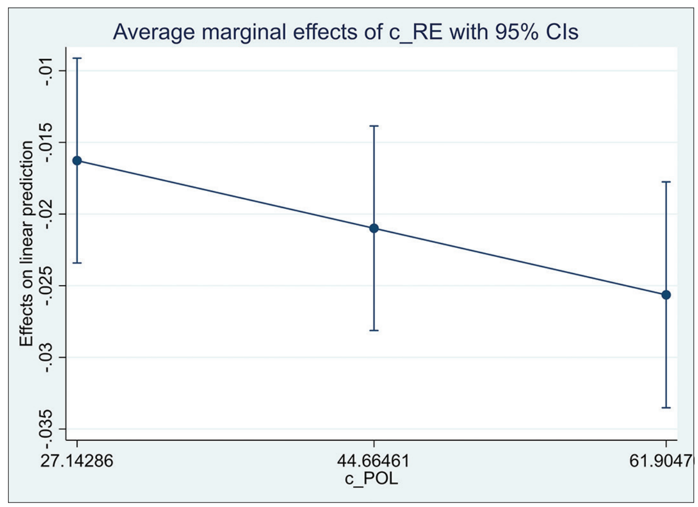

Figure 2: Marginal impact of financial inclusion on CO_2 at three POL levels

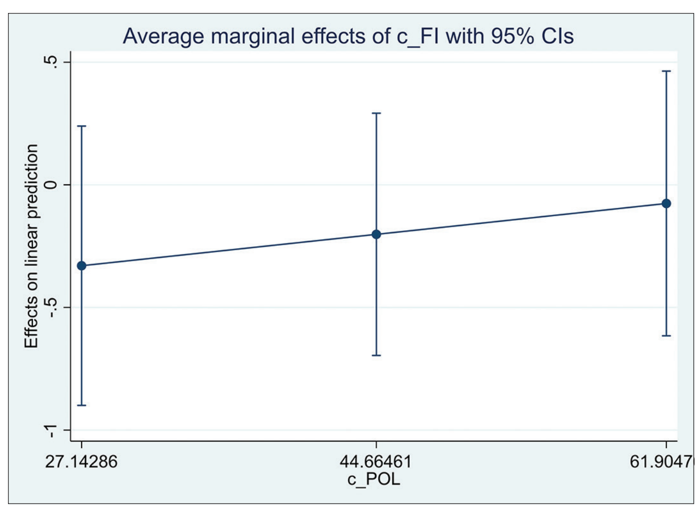

Table 8: Results testing indirect effects

POL level	Indirect effect	Standard error	z	P-value	Confidence interval 95%
25%	−0.0163	0.0034	−4.83	0.0000	(−0.0229, −0.0097)
50%	−0.0210	0.0033	−6.35	0.0000	(−0.0275, −0.0145)
75%	−0.0256	0.0036	−7.10	0.0000	(−0.0327, −0.0186)

Source: Compiled by the authors

mediation effect is clear. The indirect path from FI to CO_2 via RE and institutional quality tends to reduce emissions. The absolute value of the indirect effect increases gradually as POL increases from low (25%) to high (75%). This result shows that as institutional quality (POL) increases, the indirect effect of FI via RE on CO_2 becomes stronger (in the direction of reducing CO_2 more, because the coefficient is negative). This implies that good institutions help FI mechanisms promote RE and thereby reduce CO_2 more effectively. The largest indirect reduction occurs in the group of countries with high POL (75%). However, the magnitude of these effects is relatively small compared to the direct impact, suggesting that the emission reduction impact through the RE channel is still limited in scale, although statistically significant. This suggests that, for FI to truly contribute to emission reduction, a significant increase in investment and institutional quality support for RE is needed.

4.2. Discussions

4.2.1. Direct impact of financial inclusion on CO_2 emissions

The results from Model 1 show that FI has a positive and highly significant impact on CO_2 (coefficient 0.16095; $P < 0.01$). This implies that the expansion of access to financial services - including credit, savings, and payments - is currently mainly promoting investment, consumption, and fossil-fuel-based production. In economic terms, this is evidence of the phenomenon of "scale effects," where economic growth and access to capital boost output, but also comes at the expense of increased emissions. If not complemented with rules and green policies, an increase in financial inclusion can trigger further production and consumption, translating into increased emissions. Our findings also comport with Gök (2020) and Chu (2022), who demonstrate how financial development increases CO_2 emissions. Many other studies in Asia and elsewhere-Le et al. (2020), Qin et al. (2021), Hoang and Ngo (2024), for Vietnam-report that financial inclusion increases CO_2 as long as its growth is not combined with a structural change toward the usage of RE or accompanied by adequate regulatory policy. Mehmood (2022) also reports that financial inclusion increases carbon emissions unless joined to greener environmental policy. Trabelsi and Fhima (2025) report a positive relationship between increased financial inclusion and increased CO_2 per capita in emerging and developing economies.

That said, the opposite idea shows that some studies argue FI helps lower CO_2. For example, Baskaya et al. (2022) find that in the BRICS nations, there is a negative and statistically significant relationship between FI and CO_2 across all quantiles. Li and Ayub (2025) also showed that FI has an important impact on carbon emission reduction in OECD economies. Renzhi & Baek (2020) also found that FI has a negative impact on carbon emissions. This difference can be explained by the characteristics of the sample countries (OECD countries often have different institutions and levels of economic development compared to developing countries), the way FI is measured (traditional indicators vs. non-traditional indicators such as FinTech, green credit) or the study period.

The variable LGDPPC (GDP per capita) has a positive impact (0.42387; $P < 0.05$). This supports the argument for a positive relationship between economic development and CO_2, which is consistent with the results of Hoang and Ngo (2023) in Vietnam, as well as Li and Ayub (2025) in the OECD. Meanwhile, urban population (UP) and mobile subscriptions (MCS) did not have a significant impact on CO_2 in the sample. This may imply that in the context of the countries examined, these factors are not strong enough to make a significant difference to emissions or that their impact is non-linear or requires other moderating variables to be evident. Murshed et al. (2020) also noted that ICT trade can promote CO_2 but not increase the share of renewable energy in total energy consumption in South Asia. Hoang and Ngo (2023) also showed that ICT can have both positive and negative impacts on CO_2.

4.2.2. Transmission channel through renewable energy

Model 2, with log(RE) as the dependent variable, shows that FI has a negative coefficient (−0.24493) but is not statistically significant, indicating that FI expansion has not had a clear impact on promoting RE. Similarly, the POL (institutional quality) variable and the FI × POL interaction are also insignificant, implying that current policies have not created a significant impetus for the link between FI and RE. Economically, this reflects that the financial system in the sample countries is still mainly focused on traditional sectors rather than strongly oriented towards green investments. At the same time, the current institutional quality is not strong enough to encourage the shift of capital sources to RE projects. Possible reasons include: (i) Lack of specific green financial products: The financial system may not have developed enough green credit products, green insurance or specialized capital mobilization channels for RE projects; (ii) High investment barriers: RE projects often require large initial investments and long payback periods, accompanied by high risks that traditional FIs may not be flexible enough or have the necessary incentives to meet; (iii) Low RE share: As the research results have shown, the small scale of the intermediation effect may be due to the low share of RE in total energy or the lack of exploitation of different forms of renewable energy.

Several other studies have also found that FI may have a negative or ambiguous impact on RE, for example through increasing overall energy consumption, including fossil fuel energy, when credit access is easier. Murshed et al. (2020) also noted that ICT trade does not increase the share of RE in total energy consumption in South Asia. In contrast, several recent studies have found that FI has a positive and significant impact on RE. Ababio et al. (2023) showed that FI has a positive impact on RE consumption in developing countries, helping people and businesses have enough resources to invest in RE projects. Acheampong et al. (2024) also pointed out that FI has a positive and statistically significant impact on RE and that the role of strong political institutions can amplify this impact. Li et al. (2022) found that FI promotes the development of RE, especially wind energy and photovoltaic energy. Vo et al. (2023) also pointed out that the development of FinTech promotes RE consumption.

Although the FI × POL interaction variable is not statistically significant, the positive coefficient (0.00562) still suggests that when institutional quality is higher, the relationship between FI and RE tends to be more positive. This suggests a potential avenue for further research, emphasizing that although the statistical evidence is not sufficient in this sample, theoretically and in the context of other studies (Acheampong et al. (2024); Li and Ayub (2025)), good institutions are still a necessary condition for FI to exert its green effect. Transparent, less corrupt institutions and an effective rule of law system help reduce transaction costs, build investor confidence in green energy and improve institutional quality. Trabelsi and Fhima (2025) also found that controlling corruption improves environmental quality.

4.2.3. The role of renewable energy and institutional quality in the financial inclusion-CO_2 nexus

Model 3 integrating FI, RE, POL and interactions shows that FI continues to have a positive and highly significant impact on CO_2 (0.09785; $P < 0.01$), reinforcing the results from Model 1, consistent with the argument that financial development can stimulate economic activity, increase energy consumption and thus increase emissions.

RE has a positive but insignificant coefficient - this is a particularly important result. Although RE is expected to reduce emissions, the results show that, on an overall level, increasing RE is not strong enough to directly impact emissions. This non-significant result contradicts the majority of previous studies. Most studies confirm that RE reduces CO_2. For example, Zhang et al. (2017) and Ababio et al. (2023) both showed that RE helps reduce environmental pressure and is a key factor in improving environmental sustainability. Le (2024) asserted that RE is the only factor that helps to reduce CO_2 sustainably in Southeast Asia. Li and Ayub (2025) also demonstrated that RE plays an important role in reducing carbon emissions in OECD countries. Baskaya et al. (2022) also asserted that RE consumption reduces CO_2. This difference may be due to the low proportion of RE in the total energy supply in the countries in the study sample, not enough to create a clear emission reduction impact or the efficiency of RE technology is not yet optimized. There may exist a threshold impact after which RE becomes clearly effective.

POL has a positive and significant effect (0.01128; $P < 0.01$), reflecting that some existing policies may be promoting economic activity without being closely aligned with environmental goals, especially in the early stages of the environmental Kuznets curve (EKC) when economic growth is initially accompanied by increased pollution. The positive effect of POL on CO_2 is different from some studies that find positive effects of institutions on the environment. For example, Trabelsi and Fhima (2025) found that controlling corruption improves environmental quality. This difference implies that, despite good institutions, in the absence of other strong green policies, the positive effects of institutions on the environment are limited.

Therefore, the key takeaway is the coefficient of the RE × POL interaction, which is negative and highly significant (−0.00036; $P < 0.01$), which is the main finding of the study. That means that RE becomes substantially more effective at cutting emissions if policies are well-designed and support flows in the right direction. Alternatively expressed, RE works better to reduce emissions in countries with stronger institutions. The adoption of transparent institutions, lower corruption, and a strong rule-of-law framework enhances the implementation of policies, reduces transaction costs, increases investor confidence in green energy, and triggers RE investment, hence leading to improved environmental outcomes. This underlines the fact that the improvement of institutions is a necessary requirement for RE to yield its full environmental potential.

Economically speaking, increasing the scale of FI in isolation from building up institutional quality will most likely increase emissions. Conversely, a combination of RE investment and supportive policies can reverse this trend.

4.2.4. Indirect effects analysis using Bootstrap

Bootstrap results for the 25%, 50% and 75% quantiles of the indirect effect are all negative and statistically significant at the 1% level. This suggests that FI may contribute to emissions reductions through the RE channel and supporting policies. However, the magnitude of this indirect effect is relatively small compared to the positive direct effect, implying that this transmission channel is currently not strong enough to fully offset the initial negative impact of FI. In terms of economic significance, the results suggest that the potential of FI to support emissions reductions is real but depends largely on the level of renewable energy development and the quality of coordination policies. This result is consistent with the suggestion of Tsimisaraka et al. (2023) that FI may indirectly reduce emissions through promoting RE investment. Although some studies such as Baskaya et al. (2022) and Li and Ayub (2025) found a negative direct impact of FI on CO_2, but indirect mechanisms through RE and institutional quality remain part of the overall picture of the "green" role of finance.

5. CONCLUSION AND POLICY IMPLICATIONS

This study uses a fixed-effects regression model with heteroskedasticity-robust standard errors with data from 52 countries during the period 2017-2022 to assess the impact of FI on CO_2 through the mediating role of RE and the moderating role of institutional quality. The research results show a multidimensional picture of the impact of FI on CO_2 and the mediating role of RE and the moderating role of institutional quality, specifically:

First, in terms of direct impacts, FI has a positive and highly statistically significant impact on CO_2, showing that the current expansion of financial access mainly promotes production and consumption activities in the direction of increasing traditional energy demand, thereby increasing emissions.

Second, in terms of indirect impacts, FI has the potential to reduce emissions when going through the renewable energy channel and supported by appropriate policies. However, the scale of this impact is still modest.

Third, regarding the role of institutional quality, the current institutional quality is not strong enough to reduce emissions, but the interaction between renewable energy and institutional quality can reverse this trend, helping to reduce the rate of CO_2 increase. Institutional quality is a crucial factor for shifting FI from a CO_2 emissions increaser to a support factor for energy transition. These conclusions point out that institutional quality might be a key enabler of RE abatement potential. When institutional quality and political stability are better developed, it could lead to a more effective allocation of financial resources for clean energy development. However, for politically unstable settings, financial allocations could go to short-term or traditional schemes rather than RE development. On the basis of conclusions, some proposals are formulated and presented for promoting RE development and reducing CO_2 emissions in the future, particularly:

Firstly, governments should continuously improve the legal system and establish transparency and accountability for creating a proper setting for promoting RE development. Policies promoting investments could be strictly concentrated on developing Clean Energy technologies, using tax exemptions, green credits, or transparent bids. When formulating financial policies, governments and authorities should consider and take into account environmental policies for environmentally friendly outputs and proper sustainable development applications. There is a need for a proper link between financial policies and sustainable development strategies for providing proper capital allocation for transitioning to new sustainable energy across nations for proper development and growing attention to green credits, a special system of interest rates for RE technologies development, for Clean Energy development, Enhancing Energy Efficiency precedes secondly.

Secondly, governments are required to increase institutional quality support for promoting RE development, where policies are required to consider scaling up perspectives along with reducing costs for developing RE technologies; simultaneously, governments and policies are required to think about financial motivations encouraging companies and families for proper development.

Mitigating risks from initial emissions growth: Along with developing Clean Energy infrastructure across nations, regulations for emissions control are required to progress parallelly; otherwise, for a short period, innovations of CO_2 emissions could go beyond expectations.

Thirdly, the government should establish a full-scale data gathering and monitoring process to assess the impacts of financial and political elements on the development of renewables and make further adjustments accordingly. Get the data and assess its performance on financial inclusion to emission abatement, paying particular attention to the long term when secondary impacts might emerge.

Fourth, the government should continue to enhance institutional quality. Financial inclusion could have positive impacts on CO_2 emissions, and hence a financial framework must be established to steer financial flows to renewables. Establish "green credit" rules, tax breaks for "green bonds," and "green taxonomies," as well as "disclosures on climate risks."

In conclusion, the results have shown that financial inclusion could be both an opportunity and a challenge to address emissions issues.

5.1. Limitations of the Study

The study has a limited sample size (312 data points and 52 countries). Furthermore, there may be other factors more decisive than FI and POL that can influence the development of renewable energy resources. As such, a future study can make use of a more ample data set or examine the nonlinear relationship between the factors or may introduce another variable along with the moderation of the political factors.

REFERENCES

Ababio, J.O.M., Yiadom, E.B., Mawutor, J.K.M., Tuffour, J.K., Attah-Botchwey, E. (2023), Sustainable energy for all: The link between financial inclusion, renewable energy and environmental sustainability in developing economies. International Journal of Energy Sector Management, 18(5), 1088-1108.

Acheampong, A.O., Rajaguru, G., Campbell, N. (2024), Financial inclusion and political institutions' role in renewable energy transition: What does the data say? Applied Economics, 57, 10719-10734.

Baskaya, M.M., Samour, A., Tursoy, T. (2022), The financial inclusion, renewable energy and CO_2 emissions nexus in the BRICS nations: New evidence based on the method of moments quantile regression. Applied Ecology and Environmental Research, 20(3), 2577-2595.

Bekun, F.V., Alola, A.A., Sarkodie, S.A. (2019), Toward a sustainable environment: Nexus between CO_2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. Science of the Total Environment, 657, 1023-1029.

Chu, K.L. (2022), Ảnh hưởng của phát triển tài chính tới chất lượng môi trường - Kết quả nghiên cứu từ 112 quốc gia [The impact of financial development on environmental quality - Research results from 112 countries]. Tạp Chí Khoa Học Đào Tạo Ngân Hàng, 240,), 11-12.

Doğan, B., Driha, O.M., Balsalobre Lorente, D., Shahzad, U. (2021), The mitigating effects of economic complexity and renewable energy on carbon emissions in developed countries. Sustainable Development, 29(1), 1-12.

El Weriemmi, M., Bakari, S. (2024), The Impact of CO_2 Emissions, Domestic Investment and Trade Openness on Economic Growth: New Evidence from North African Countries. Munich Personal RePEc Archive, MPRA Paper No. 122152.

Feng, S., Zhang, R., Li, G. (2022), Environmental decentralization, digital finance and green technology innovation. Structural Change and Economic Dynamics, 61, 70-83.

Gök, A. (2020), The role of financial development on carbon emissions: A meta regression analysis. Environmental Science and Pollution Research, 27(11), 11618-11636.

Hoang, T.X., Ngo, T.H. (2023), The effects of ICT, GDP, and renewable energy on CO_2 emissions in Vietnam. VNU Journal of Economics and Business, 3(3), 56-65.

Hoang, T.X., Ngo, T.H. (2024), Mối quan hệ giữa tiêu thụ năng lượng, độ mở thương mại, phát triển tài chính và chất lượng môi trường tại Việt Nam [The relationship between energy consumption, trade openness, financial development and environmental quality in Vietnam]. Tạp chí Kinh tế Phát triển, 320, 2-12.

Jiang, C., Ma, X. (2019), The impact of financial development on carbon emissions: A global perspective. Sustainability, 11(19), 5241.

Le, T.H., Anh, T.C., Taghizadeh-Hesary, F. (2019), Financial inclusion and its impact on financial efficiency and sustainability: Empirical evidence from Asia. Borsa Istanbul Review, 19(4), 310-322.

Le, T.H., Le, H.C., Taghizadeh-Hesary, F. (2020), Does financial inclusion impact CO_2 emissions? Evidence from Asia. Finance Research Letters, 34, 101451.

Le, T.S., Ngo, T.H. (2022), Asymmetric impact of economic growth, financial development and energy consumption on CO_2 emissions in Vietnam. Science Technology Development Journal Economics Law and Management, 6(4), 3526-3541.

Lê, T.T.H. (2024), Năng lượng tái tạo, dấu chân vật chất, tăng trưởng kinh tế và ô nhiễm môi trường tại các thị trường mới nổi Đông Nam Á [Renewable energy, physical footprint, economic growth and environmental pollution in emerging Southeast Asian markets]. Tạp chí Kinh tế Phát Triển, 321(2), 1677.

Li, C., Ayub, B. (2025), The green response of financial inclusion, infrastructure development and renewable energy to the environmental sustainability: A newly evidence from OECD economies. PLoS One, 20(1), e0314731.

Li, J., Dong, X., Dong, K. (2022), How much does financial inclusion contribute to renewable energy growth? Ways to realize green finance in China. Renewable Energy, 198, 760-771.

Liu, H., Yao, P., Latif, S., Aslam, S., Iqbal, N. (2022), Impact of green financing, FinTech, and financial inclusion on energy efficiency. Environmental Science and Pollution Research, 29, 18955-18966.

Mehmood, U. (2022), Examining the role of financial inclusion towards CO_2 emissions: Presenting the role of renewable energy and globalization in the context of EKC. Environmental Science and Pollution Research, 29(11), 15946-15954.

Mirziyoyeva, Z., Salahodjaev, R. (2023), Renewable energy, GDP and CO_2 emissions in high-globalized countries. Frontiers in Energy Research, 11, 1123269.

Murshed, M., Chadni, M.H., Ferdaus, J. (2020), Does ICT trade facilitate renewable energy transition and environmental sustainability? Evidence from Bangladesh, India, Pakistan, Sri Lanka, Nepal and Maldives. Energy Ecology and Environment, 5(6), 470-495.

Ngo, T.H., Nguyen, L.Q.A., Nguyen, T.D.T., Pham, N.H., Vu, H.G. (2024), Tác động của thuế môi trường, tăng trưởng kinh tế, phát triển tài chính đối với năng lượng tái tạo: Nghiên cứu thực nghiệm tại Việt Nam [The impact of environmental tax, economic growth, and financial development on renewable energy: An empirical study in Vietnam]. Tạp chí Kinh tế Phát triển, 327, 57-67.

Nguyen, Đ.H. (2022), Mối quan hệ giữa vốn con người, tiêu thụ năng lượng, phát thải khí CO_2 và tăng trưởng kinh tế ở Việt Nam [The relationship between human capital, energy consumption, CO_2 emissions and economic growth in Vietnam]. HCMCOUJS-Kỷ yếu, 17(1), 59-71.

Nguyen, M.H., Bui, H. (2020), Revisiting the relationship between energy consumption and economic growth nexus in Vietnam: New evidence by asymmetric ARDL cointegration. Applied Economics Letters, 2020, 1789543.

Nguyen, M.H., Tran, T.H.Y. (2023), Nghiên cứu mối quan hệ giữa tiêu thụ năng lượng tái tạo và phát thải khí nhà kính tại Việt Nam [Study on the relationship between renewable energy consumption and greenhouse gas emissions in Vietnam]. Tạp Chí Khoa Học Kinh tế, 11(2), 30-47.

Nguyen, T.C.V. (2022), Toàn cầu hóa, phát triển tài chính, tăng trưởng kinh tế, ô nhiễm môi trường và tiêu thụ năng lượng tái tạo ở Việt Nam [Globalization, financial development, economic growth, environmental pollution and renewable energy consumption in Vietnam]. Tạp chí Kinh tế và Phát triển, 299, 34-43.

Phạm, Đ.H. (2024), Ảnh hưởng của phát triển tài chính, đầu tư trực tiếp nước ngoài đến lượng phát thải carbon ở Việt Nam: Xem xét vai trò của công nghệ thông tin và viễn thông [The impact of financial development and foreign direct investment on carbon emissions in Vietnam: Examining the role of information and telecommunications technology]. Tạp Chí Kinh tế và Phát triển, 321(2), 100-108.

Qin, L., Raheem, S., Murshed, M., Miao, X., Khan, Z., Kirikkaleli, D. (2021), Does financial inclusion limit carbon dioxide emissions? Analyzing the role of globalization and renewable electricity output. Sustainable Development, 29(6), 1138-1154.

Renzhi, N. & Baek, Y. J. (2020). Can financial inclusion be an effective mitigation measure? Evidence from panel data analysis of the environmental Kuznets curve. Finance Research Letters, Volume 37, Article 101725.

Saint Akadiri, S., Alola, A.A., Akadiri, A.C., Alola, U.V. (2019), Renewable energy consumption in EU-28 countries: Policy toward pollution mitigation and economic sustainability. Energy Policy, 132, 803-810.

Salahodjaev, R. (2024), Examining the nexus between renewable energy, CO_2 emissions, and economic factors: Implications for countries marked by high rates of coronary heart disease. Energies, 17(23), 6057.

Trabelsi, E., Fhima, T. (2025), Financial inclusion and environmental sustainability in emerging and developing countries: Do control of corruption and trade openness matter? Journal of Economic Analysis, 4(1), 124-149.

Tran, H.T.T., Le, H.T.T. (2021), The impact of financial inclusion on poverty reduction. Asian Journal of Law and Economics, 12(1), 95-119.

Tsimisaraka, R.S.M., Xiang, L., Andrianarivo, A.R.N.A., Josoa, E.Z., Khan, N., Hanif, M.S., Khurshid, A., Limongi, R. (2023), Impact of financial inclusion, globalization, renewable energy, ICT, and economic growth on CO_2 emission in OBOR countries. Sustainability, 15(8), 6534.

Vo, D.H., Pham, A.T., Tran, T., Vu, N.T. (2023), Does income inequality moderate the effect of fintech development on renewable energy consumption? PLoS One, 18(11), e0293033.

World Bank. (2020), Financial Inclusion Overview. Retrieved from https://www.worldbank.org/en/topic/financialinclusion/overview

Zhang, B., Wang, B., Wang, Z. (2017), Role of renewable energy and non-renewable energy consumption on EKC: Evidence from Pakistan. Journal of Cleaner Production, 156, 855-864.

Zhao, J., Jiang, Q., Dong, X., Dong, K. (2021), Assessing energy poverty and its effect on CO_2 emissions: The case of China. Energy Economics, 97, 105191.

APPENDIXS

Appendix 1: KMO and Bartlett's test

Measure		Value
Kaiser-Meyer-Olkin measure of sampling adequacy.		0.719
Bartlett's test of sphericity	Approx. Chi-square	354.654
	df	6
	Significance	0.000

Appendix 2: Total variance explained

Component	Initial eigenvalues			Extraction sums of squared loadings		
	Total	Percenatge of variance	Cumulative %	Total	Percenatge of variance	Cumulative %
1	2.374	59.345	59.345	2.374	59.345	59.345
2	0.700	17.507	76.852			
3	0.616	15.409	92.262			
4	0.310	7.738	100.000			

Extraction method: Principal component analysis