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Carbon Emissions Across Country Income Groups

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Abstract

Main Purpose – The purpose of this study is to examine association between economic growth, foreign direct investment (FDI), renewable energy (RE), and financial development (FD) on carbon emissions across countries with different income classifications.

Method - A total of 209 countries from 2000 to 2024 were selected as the subjects of the study and examined through Ordinary Least Squares (OLS) regression.

Main Findings - The study shows that economic growth is positively associated with carbon emissions only in lower-middle income countries. FDI is negatively associated with carbon emissions in all income and high-income countries, whereas RE and FD shows a significant positive associated across all models.

Theory and Practical Implications – This study demonstrate that the determinants of carbon emissions differ across income groups, highlighting the importance of considering countries development stages when designing environmental policies.

Novelty - Unlike prior studies that focus on specific regions, this study provides a comprehensive comparison of the relationships between economic growth, FDI, RE, and FD on carbon emissions across three country income classifications.

Keywords: Carbon Emissions, Economic Growth, Foreign Direct Investment, Renewable Energy, Financial Development.

Abstrak

Tujuan Utama - Penelitian ini bertujuan untuk menganalisis hubungan antara pertumbuhan ekonomi, penanaman modal asing, energi terbarukan, dan pengembangan keuangan terhadap emisi karbon pada negara-negara dengan klasifikasi tingkat pendapatan yang berbeda.

Metode - Sebanyak 209 negara selama periode 2000 hingga 2024 dipilih sebagai objek penelitian dan selanjutnya dianalisis dengan menggunakan regresi Ordinary Least Squares (OLS).

Temuan Utama - Hasil penelitian menunjukkan bahwa pertumbuhan ekonomi memiliki hubungan signifikan positif terhadap emisi karbon hanya pada negara berpendapatan menengah bawah. penanaman modal asing secara berhubungan negatif signifikan emisi karbon pada seluruh pendapatan dan negara berpendapatan tinggi, sedangkan energi terbarukan dan pengembangan keuangan menunjukkan hubungan signifikan positif pada seluruh model.

Implikasi Teori dan Kebijakan - Penelitian ini menunjukkan bahwa faktor-faktor yang memengaruhi emisi karbon berbeda pada setiap kelompok tingkat pendapatan, sehingga penting untuk mempertimbangkan tahapan pembangunan suatu negara dalam merancang kebijakan lingkungan.

Kebaruan Penelitian - Berbeda dengan penelitian terdahulu yang berfokus pada wilayah tertentu, penelitian ini menyajikan perbandingan yang komprehensif mengenai hubungan antara pertumbuhan ekonomi, penanaman modal asing, energi terbarukan, dan pengembangan keuangan terhadap emisi karbon pada tiga kelompok negara berdasarkan tingkat pendapatan.

Kata Kunci: Emisi Karbon, Pertumbuhan Ekonomi, Penanaman Modal Asing, Energi Terbarukan, Pengembangan Keuangan.

INTRODUCTION

Climate change has become one of the most pressing global issues over the past few decades, largely caused by the continuous increase in carbon emissions associated with rapid industrialization and economic growth. The rising levels of greenhouse gas emissions have amplified global environmental threats, such as global warming, extreme climate events, and ecological deterioration, thereby creating substantial challenges to sustainable development across the world (Hesniati et al., 2026; Itan et al., 2023; Raihan et al., 2022; Tripathy et al., 2025). Global carbon emissions remain at historically high levels, indicating that existing mitigation efforts have not yet been sufficient to ensure long-term environmental sustainability (Maydybura et al., 2024; Patel & Mehta, 2023; Raihan et al., 2025; Tripathy et al., 2025).

Reducing carbon emissions remains a complex challenge because environmental quality is closely associated with economic development (Georgescu & Kinnunen, 2023; Ji & Xue, 2022). Over the past several decades, many countries have experienced rapid industrialization, urbanization, and economic expansion that have substantially increased energy demand (Gbadeyan et al., 2024; Nguyen et al., 2025). Although governments have introduced various environmental policies, including renewable energy promotion, carbon taxation, and stricter environmental regulations, economic growth continues to rely heavily on fossil fuel consumption in many parts of the world (Ji & Xue, 2022; Oprea et al., 2025).

Economic growth is widely considered to be associated with carbon emissions because it encourages greater production activities and higher energy consumption. In line with recent findings, economic growth particularly in economies that are highly dependent on fossil fuels continues to contribute to increasing emission levels (Ahmat et al., 2025; Georgescu & Kinnunen, 2023; Nguyen et al., 2025). Empirical evidence consistently indicates that economic expansion is closely associated with rising emissions, especially within developing economies with high dependence on fossil fuels and energy-intensive industries (Georgescu & Kinnunen, 2023; Gershon et al., 2024; Nguyen et al., 2025; Xuan, 2025). Furthermore, the interaction between economic growth and environmental degradation is often nonlinear, as described by the Environmental Kuznets Curve (EKC), where emissions initially increase and subsequently decline after reaching a specific level of income driven by technological advancement and changes in economic structure (Peng et al., 2025; Uddin et al., 2024; Yi et al., 2023).

In addition to economic growth, foreign direct investment (FDI) plays an important and complex role in influencing environmental quality. According to Fikri et al. (2025), FDI contributes to economic growth through capital formation, improvements in productivity, and the transfer of technology, although its environmental impacts remain inconclusive (Nguyen et al., 2025; Xu et al., 2023). In contrast, FDI may lead to increased carbon emissions if investments are directed toward highly polluting or resource extraction industries, as also evidenced in BRICS+ economies (Ganda & Panicker, 2025; Kgomo & Zhanje, 2025; Xu et al., 2023). Empirical studies further reveal that the relationship between FDI and carbon emissions is often nonlinear, exhibiting threshold or U-shaped effects where emissions initially decrease but subsequently increase beyond certain investment levels (Furtuna & Atis, 2024; Maydybura et al., 2024). Xuan (2025) finds that FDI can significantly increase emissions in economies heavily dependent on fossil fuels, reinforcing the pollution haven argument. Moreover, recent studies emphasize that the environmental effects of FDI largely depend on institutional quality, governance, and sectoral composition, resulting in varying outcomes across countries (Ayaydin et al., 2025; Deng et al., 2024; Georgescu & Kinnunen, 2023).

Amid these challenges, renewable energy (RE) has become a vital approach for reducing carbon emissions and achieving environmental sustainability. An expanding body of research shows that RE substantially reduces carbon emissions by substituting fossil fuels and improving energy efficiency. Evidence from recent empirical research also confirms that RE has a significant negative relationship

with emissions, particularly in resource-dependent economies (Chen et al., 2023; Y. Li et al., 2022; Voumik et al., 2023; Xuan, 2025). Moreover, RE not only mitigates environmental degradation but also supports sustainable economic growth and energy transition processes across different income groups (Adebayo et al., 2023; Wang et al., 2023). Empirical findings also confirm that increasing RE adoption results in a lower ecological footprint and reduced environmental pressure, particularly in developing economies (R. Li et al., 2023; Y. Li et al., 2022).

Financial development (FD) also has an important yet uncertain influence on environmental sustainability. Although financial systems support investments in RE, green innovation, and sustainable infrastructure, they can also contribute to higher carbon emissions by financing industrial growth and increased energy consumption (Xu et al., 2023; Xuan et al., 2024). In line with this, green finance and the digital economy have been shown to reduce emissions by promoting technological innovation and energy efficiency improvements (Jin et al., 2025; Zhang et al., 2025). Additionally, the interaction between FD and RE has been shown to influence emissions differently in the short and long term, depending on institutional quality and economic conditions (Xu et al., 2023). Apart from these determinants, technological innovation and green investment have also been recognized as major factors influencing carbon emissions. Advancements in technology contribute to improving energy efficiency and reducing emissions intensity, while green investments promote sustainable production and consumption practices (Adebayo et al., 2023; Liu et al., 2025; Xu et al., 2023).

Despite the growing literature on the determinants of carbon emissions, several gaps remain. First, previous studies report mixed findings regarding the relationship of economic growth, FDI, RE, and FD on carbon emissions, suggesting that these relationships may depend on economic and institutional conditions. Second, although a growing number of studies recognize the importance of income differences, the evidence remains limited regarding whether these four determinants have similar effects across countries at varying stages of economic development. In particular, Andrei et al. (2025) provide closely related evidence by examining the relationships among carbon emissions, RE, FDI, and economic growth across different income groups. However, their framework does not include FD as an additional determinant of carbon emissions. This omission is important because FD represents a distinct financial allocation channel through which economic resources can either support renewable energy, green technologies, and cleaner production or finance industrial expansion and energy-intensive activities. Therefore, incorporating FD into a cross-income-group framework can provide additional insight into why the environmental relationship of economic growth, FDI, and RE may differ across countries.

Building on this gap, this study extends the cross-income-group perspective of Andrei et al. (2025) by jointly examining the relationship between economic growth, FDI, RE, and FD on carbon emissions across different country income classifications. Using a dataset of 209 countries covering 2000–2024, this study compares the full sample with lower-middle-income, middle-upper-income, and high-income countries. The contribution of this study therefore does not simply only compare countries according to income level, but in integrating FD into the existing economic growth–FDI–RE framework and examining whether the relationship of these four determinants differ across income groups within a common empirical framework. This comparison provides more specific evidence for understanding how economic, investment, energy, and financial conditions jointly shape carbon emissions at different stages of economic development.

Previous studies have examined the determinants of carbon emissions using different samples, variables, and methodological approaches. Andrei et al. (2025) investigated the relationships among economic growth, FDI, and RE across different income groups using panel cointegration and causality approaches, but did not incorporate FD as a central determinant. Batool et al. (2022) integrated economic growth, RE, FD, and ICT in developing Asian countries, yet excluded FDI and did not compare countries across income groups. Similarly, Bilgili et al. (2025) focused specifically on the

FD–CO₂ nexus in the United States, while [Deng et al. \(2024\)](#) examined the heterogeneous effects of RE and FDI between developed and developing countries but excluded FD and applied a more limited country classification. [Alam et al. \(2025\)](#) incorporated economic growth, RE, and FD within the BRICS context without considering FDI or income-group heterogeneity. Accordingly, this study extends previous research by jointly examining economic growth, FDI, RE, and FD within a common analytical framework using an unbalanced panel dataset of 209 countries from 2000 to 2024 and examining their relationships with carbon emissions across lower-middle, middle-upper, and high-income countries. By combining these economic, investment, energy, and financial determinants within a global income-group comparison, this study provides broader evidence on how the relationships between key determinants and carbon emissions are observed across various stages of economic development.

LITERATURE REVIEW

Environmental Kuznets Curve Theory

The inverted U-shaped pattern underlying the Environmental Kuznets Curve (EKC) was originally conceptualized by [Kuznets \(1955\)](#) in the context of income inequality, and was later formally adapted to the environmental context by [Grossman & Krueger \(1991\)](#), who demonstrated a similar relationship between per capita income and pollution levels. Building on this foundation, the EKC suggests that at the early stage of economic development, growth tends to raise carbon emissions because of industrialization, urbanization, and a strong dependence on fossil fuels. However, as income levels increase, countries begin adopting cleaner technologies, implement stricter environmental policies, and moving toward more sustainable economic structures, which eventually reduce emissions ([Saglam et al., 2025](#)). Empirical evidence further confirms that although economic growth is a major driver of environmental degradation, the possibility of decoupling between economic and emissions may occur in the long run, particularly in more advanced economies ([Gbadeyan et al., 2024](#); [Ji & Xue, 2022](#); [Khan et al., 2022](#)). This argument is also supported by recent findings showing heterogeneous impacts of growth across income groups and time periods ([Andrei et al., 2025](#)).

Financial Development Theory

The theoretical foundation of financial development, as proposed by [Schumpeter \(1934\)](#), argues that financial institutions actively shape economic outcomes through the allocation of credit toward productive innovation, a premise that underlies the contemporary debate on whether FD generates environmentally beneficial or harmful investment patterns. This theory highlights the dual role of financial systems in influencing environmental outcomes. [Bilgili et al. \(2025\)](#) emphasize that financial systems can act as a key mechanism for supporting environmental sustainability by allocating capital toward low-carbon investments. FD can improve access to capital and encourage investment in RE and green technologies, thereby reducing carbon emissions. However, it can also contribute to higher emissions by financing industrial expansion and energy-intensive production processes. For instance, [Nguyen et al. \(2025\)](#) show that positive shocks in FD may significantly increase carbon emissions in the long run, particularly in developing countries. In contrast, other studies argue that a well-developed and inclusive financial system can mitigate environmental degradation by supporting green innovation and sustainable investments ([Apeaning & Labaran, 2025](#); [Nuta et al., 2025](#)). Additionally, [Alam et al. \(2025\)](#); [Gharbi et al. \(2025\)](#) find that FD, when aligned with RE policies, contributes to emission reduction. Therefore, the overall impact of FD on environmental quality is determined by the quality of institutions, regulatory structures, and the allocation of financial resources ([Emenekwe et al., 2022](#); [Sheraz et al., 2022](#)).

HYPOTHESIS DEVELOPMENT

The Relationship between Economic Growth on Carbon Emissions

Economic growth remains a major determinant of carbon emissions, as increasing production activities, industrialization, and energy consumption intensify environmental pressure, particularly in developing and energy-intensive economies (Dissanayake et al., 2023; Raihan et al., 2025; Sadiq et al., 2024). Empirical evidence consistently shows that economic growth significantly increases carbon emissions as a result of rising fossil fuel consumption and economic expansion, especially in regions with limited technological efficiency and high energy dependency (Dallali & Jebli, 2025; Saqib, 2022). However, this relationship is not entirely linear, as technological innovation, environmental policies, and structural transformation may weaken or reverse the growth of emissions nexus over time (Dong et al., 2024; Gbadeyan et al., 2024; Murshed, 2024; Sadiq et al., 2024). Therefore, the first hypothesis is proposed as follows:

H₁: Economic Growth is positively associated with Carbon Emissions.

The Relationship between Foreign Direct Investment on Carbon Emissions

FDI exhibits a complex and context-dependent relationship with carbon emissions, influenced by institutional quality, sectoral composition, and environmental regulations (Bekun et al., 2024; Razzaq et al., 2023). On one hand, FDI may increase emissions by channelling investments into pollution-intensive industries and energy-demanding sectors, particularly in countries with weaker environmental governance (Raihan et al., 2025; Sadiq et al., 2024; Saqib, 2022). On the other hand, FDI can contribute to reducing emissions through the transfer of technology, innovation diffusion, and improved production efficiency, especially in economies with strong absorptive capacity (Bekun et al., 2024; Dong et al., 2024; Razzaq et al., 2023). Furthermore, recent empirical findings indicate that the FDI and carbon emissions relationship is nonlinear and heterogeneous across countries, depending on economic structure and governance quality (Raihan et al., 2025; Sadiq et al., 2024; Saqib, 2022). Therefore, the second hypothesis is proposed as follows:

H₂: Foreign Direct Investment is positively associated with Carbon Emissions.

The Relationship between Renewable Energy on Carbon Emissions

RE plays a crucial role in mitigating carbon emissions by decreasing reliance on fossil fuels while enhancing energy efficiency across economies (Adebayo et al., 2022; Justice et al., 2024; Shah et al., 2024). Empirical evidence consistently confirms that RE consumption significantly reduces carbon emissions and contributes to environmental sustainability, particularly in carbon-intensive and developing economies (Dallali & Jebli, 2025). In addition, RE transition is a key driver of green growth and environmental improvement when supported by effective governance and technological innovation (Dong et al., 2024; Murshed, 2024). Therefore, the third hypothesis is proposed as follows:

H₃: Renewable Energy is positively associated with Carbon Emissions.

The Relationship between Financial Development on Carbon Emissions

FD exerts a dual and nonlinear effects on carbon emissions, reflecting its role in both promoting economic expansion and enabling sustainable investments (Emenekwe et al., 2022; Tao et al., 2023). On one hand, FD may increase emissions by increasing credit availability, promoting industrial expansion, and raising energy consumption in carbon-intensive sectors (Huang et al., 2023; Patel & Mehta, 2023; Usman et al., 2023). On the other hand, FD can also reduce emissions by promoting green finance, supporting RE investments, and improving resource allocation efficiency toward environmentally friendly sectors (Dincă et al., 2025; Guan et al., 2025; Habiba & Xinbang, 2022). Moreover, recent studies highlight that the relationship between FD and carbon emissions is heterogeneous and nonlinear across countries depending on institutional quality and financial

structure ([Idrees & Majeed, 2022](#); [Ling et al., 2022](#); [Tao et al., 2023](#)). Therefore, the fourth hypothesis is proposed as follows:

H₄: Financial Development is positively associated with Carbon Emissions.

RESEARCH METHOD

This study employs panel data consisting of multiple countries over a specific time period to investigate the relationship among economic growth, FDI, RE, FD, and carbon emissions. The dataset covers 209 countries over the period 2000-2024, providing a comprehensive global perspective on the dynamics between economic and environmental variables. The use of panel data enables the capture of both cross-sectional and time-series variations, thereby providing more robust and efficient estimations compared to single-country studies.

The data are obtained from internationally recognized databases, including the World Bank ensuring reliability and consistency across countries. These sources are widely used in empirical environmental and economic studies due to their comprehensive coverage and standardized measurement. To better capture structural differences across economies, the sample is further classified into three income groups: lower-middle income, middle-upper income, and high income countries, following standard international classifications. This categorization enables a more nuanced analysis of how the relationships between economic growth, RE, FD, and carbon emissions may differ across levels of economic development.

The selection of a cross-country dataset is motivated by the need to capture heterogeneity across different income groups and levels of development, as previous studies indicate that the relationship between economic growth, energy consumption, and carbon emissions varies significantly across countries. For instance, RE and economic growth may have different environmental impacts depending on whether countries are developed or developing ([Dissanayake et al., 2023](#); [Khan et al., 2022](#)). Therefore, a global panel dataset provides a more comprehensive framework for analyzing these relationships.

This study uses carbon emissions as the dependent variable, which represents environmental degradation and is widely used as a proxy for environmental quality. Carbon emissions are measured in metric tons per capita to ensure comparability across countries. Previous studies have consistently used carbon emissions as a key indicator of environmental pressure and climate change ([Raihan et al., 2022](#); [Sadiq et al., 2024](#)). Economic growth that is considered a key determinant of environmental degradation, as higher economic activity often leads to increased energy consumption and emissions, especially in the early stages of development ([Batool et al., 2022](#); [Raihan et al., 2022](#)).

FDI is measured as net inflows relative to GDP. FDI plays an important role in influencing environmental outcomes, as it can either increase emissions through pollution-intensive activities or reduce emissions through technology transfer and innovation, as highlighted in previous empirical studies ([Khan et al., 2022](#)). RE is measured as the share of RE consumption in total energy use. RE is expected to lower carbon emissions through the replacement of fossil fuels and promoting sustainable energy systems. Empirical evidence shows that RE consumption significantly lowers carbon emissions and enhances environmental quality ([Adebayo et al., 2022](#); [Y. Li et al., 2022](#); [Shah et al., 2024](#)).

FD is assessed using indicators such as domestic credit provided to the private sector. FD reflects the ability of financial systems to allocate resources efficiently and support economic activities. However, its impact on the environment remains unclear, as it may increase emissions through industrial expansion or reduce emissions by financing green investments ([Habiba & Xinbang, 2022](#); [Usman et al., 2023](#)).

Table 1. Description and Measurement of Variables

Variables	Measurement	Source
<i>Dependent</i>		
Carbon Emission (CO₂)	CO ₂ emissions per capita / CO ₂ per capita	World Bank – World Development Indicators (WDI)
<i>Independent</i>		
GDP Growth	GDP growth (annual %)	
Foreign Direct Investment (FDI)	FDI net inflows (% of GDP)	
Renewable Energy (RE)	Renewable energy consumption (%)	
Financial Development (FD)	Domestic credit to private sector (% GDP)	

Table 2. Data Observation Country

Type	Year (2000-2024)
1	75 countries
2	54 countries
3	80 countries
Total	209 countries

Although the initial dataset consists of 209 countries observed from 2000 to 2024 (5,225 potential country-year observations), the regression analysis includes 3,169 observations after applying listwise deletion for observations with missing values in one or more variables. Missing values mainly arise because several macroeconomic indicators, particularly FDI, renewable energy, and financial development, are not consistently available across all countries and years in the World Development Indicators database.

This study uses Ordinary Least Squares (OLS) regression to investigate the relationship between GDP Growth, FDI, RE, FD, and CO₂ emissions. OLS is appropriate for this study because it provides unbiased and efficient parameter estimates under the assumptions of the classical linear regression model, including linearity, homoscedasticity, no perfect multicollinearity, and exogeneity (Wooldridge, 2013). Furthermore, are included in the regression model to control for unobserved time-specific factors and common shocks that may influence carbon emissions across countries, thereby improving the reliability of the estimation results.

Given the characteristics of the dataset and the objectives of this study, the OLS estimator is considered the most appropriate estimation technique. This study employs an unbalanced panel dataset covering 209 countries over the period 2000–2024, where missing observations across countries and years reflect the typical nature of global macroeconomic data. Unlike dynamic panel estimation methods such as the Generalized Method of Moments (GMM), which are primarily designed for models involving lagged dependent variables and dynamic endogeneity, this study focuses on estimating the contemporaneous effects while comparing these relationships across different country income classifications. Moreover, the relatively long time dimension and unbalanced structure of the dataset may reduce the efficiency of GMM through instrument proliferation. Therefore, OLS provides a more appropriate and easily interpretable estimator for the research objectives, while heteroskedasticity-robust standard errors are employed to ensure reliable statistical inference. The regression model equation in this study is presented as follows:

$$CO2_{it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 FDI_{it} + \beta_3 RE_{it} + \beta_4 FD_{it} + \epsilon_{it} \quad (1)$$

RESULTS

Descriptive Statistics

Table 3. Descriptive Statistics

	N	Mean	Median	Std.Dev	Minimum
CO2_PER_CAPITA	4975	4.868	8.666	0.000	202.865
GDP_GROWTH	4965	3.377	5.946	-54.402	86.827
FDI	4657	8.945	61.952	-1303.108	1709.827
RE	4522	30.204	29.515	0.000	98.300
FD	4046	53.677	45.022	0.383	301.019

Source: Data processed by researchers, 2026

Table 3 highlights an analysis of the variables used in the research process. CO2_PER_CAPITA had an average value of 4.868, with values ranging from 0.000 to 202.865, indicating substantial differences in CO₂ emissions across observations. GDP_GROWTH averaged 3.377, with a minimum value of -54.402 and a maximum value of 86.827, showing significant fluctuations in GDP growth among countries and periods. FDI recorded an average value of 8.945, with values ranging widely from -1303.108 to 1709.827, reflecting large variations in FDI inflows and outflows. Meanwhile, RE had an average value of 30.204 and ranged between 0.000 and 98.300, suggesting differences in RE usage across observations. Lastly, FD showed an average value of 53.677, with a minimum value of 0.383 and a maximum value of 301.019, indicating varying levels of FD among countries. Overall, the descriptive statistics demonstrate considerable variation in economic, environmental, investment, energy, and financial conditions across the sample observations.

Correlation Test

Table 4. Correlation Test

	CO2_PER_CAPITA	GDP_GROWTH	FDI	RE	FD
CO2_PER_CAPITA	1.000				
GDP_GROWTH	-0.001 (0.965)	1.000			
FDI	-0.021 (0.165)	0.004 (0.761)	1.000		
RE	0.085*** (0.000)	0.091*** (0.000)	-0.038** (0.015)	1.000	
FD	0.407*** (0.000)	-0.036** (0.026)	0.021 (0.209)	0.071*** (0.000)	1.000

Source: Data processed by researchers, 2026

Table 4 shows the output from the correlation test, which examines the relationships between the variables included in the study. The results reveal that CO2_PER_CAPITA has a positive and significant correlation with RE and with FD, indicating that higher RE usage and FD are associated with higher CO₂ emissions per capita. However, CO2_PER_CAPITA has no significant relationship with GDP_GROWTH and FDI. Meanwhile, GDP_GROWTH shows a positive and significant relationship with RE, suggesting that countries with higher GDP growth tend to increase RE usage. On the other hand, GDP_GROWTH has a negative and significant relationship with FD, although the relationship is relatively weak. The variable FDI shows a negative and significant correlation with RE, implying that higher FDI may be associated with lower RE contribution in certain observations, while its relationships with GDP_GROWTH and FD are insignificant. In addition, RE and FD exhibit a positive and significant correlation, indicating that higher FD is associated with greater RE usage.

Overall, the correlation results indicate that most variables have relatively weak correlations, suggesting that the independent variables do not exhibit significant multicollinearity problems.

Regression Test

Table 5. Regression Test

	(1) All Income Countries CO2_PER_CAPITA	(2) Low-Middle Income Countries CO2_PER_CAPITA	(3) Middle-Upper Income Countries CO2_PER_CAPITA	(4) High Income Countries CO2_PER_CAPITA
GDP_GROWTH	0.011 (0.62)	0.101** (2.26)	-0.009 (-0.35)	-0.019 (-0.64)
FDI	-0.005*** (-5.69)	-0.003 (-0.19)	-0.061 (-1.29)	-0.010*** (-5.60)
RE	0.040*** (11.68)	0.028*** (4.69)	0.024** (2.01)	0.160*** (6.99)
FD	0.055*** (27.86)	0.060*** (20.99)	0.057*** (17.01)	0.045*** (11.14)
_cons	0.692 (1.04)	0.709 (0.65)	0.677 (0.78)	0.475 (0.36)
Year FE	Yes	Yes	Yes	Yes
r2	0.199	0.214	0.304	0.216
r2_a	0.192	0.197	0.283	0.196
N	3169	1268	867	1034

Source: Data processed by researchers, 2026

Table 5 presents the regression analysis results examining the relationship between GDP_GROWTH, FDI, RE, and FD and CO2_PER_CAPITA across four models representing different country income groups: Model 1 covers all income countries, Model 2 covers low-middle income countries, Model 3 covers middle-upper income countries, and Model 4 covers high-income countries. Across all groups, GDP_GROWTH is largely insignificant, except in low-middle income countries (Model 2), where it shows a positive and significant association. FDI shows a negative and significant association in all income countries and high-income countries. In contrast, RE and FD are positively and significantly associated with CO₂ emissions per capita in every model, regardless of income group, indicating that these relationships are robust across all levels of economic development. FD consistently shows a strong positive association across all groups, with its largest magnitude in low-middle income countries and smallest in high-income countries, implying that financial sector expansion is associated with industrial activity, investment, and energy consumption in a way that is associated with increased emissions across all income levels, though this association is somewhat more pronounced in less developed economies. Overall, these results suggest that while FDI's emissions-reducing potential varies across country income levels, both FD and current patterns of RE use are consistently linked to higher, not lower, CO₂ emissions per capita across all country groups.

DISCUSSION

The regression results show that GDP growth has a positive coefficient across the four models but is statistically significant only in lower-middle-income countries, while its association is statistically insignificant in the other income models. This finding suggests that the relationship between economic expansion and carbon emissions is more evident in economies where industrialization, rising energy demand, and fossil-fuel dependence remain important components of economic activity. This result is consistent with [Dallali & Jebli \(2025\)](#) and [Saqib \(2022\)](#), who show that economic growth can increase emissions particularly in developing and energy-intensive

economies. However, the insignificant relationship in the higher-income groups is also consistent with the argument that technological innovation, structural transformation, and environmental policies can weaken the growth–emissions relationship as economies develop ([Dong et al., 2024](#); [Gbadeyan et al., 2024](#); [Murshed, 2024](#); [Sadiq et al., 2024](#)). Therefore, the findings provide conditional support for H1, rather than evidence that GDP growth is significantly associated with carbon emissions across all income groups.

FDI exhibits a negative coefficient in the all-income and high-income samples and is statistically significant in both, while its association is statistically insignificant in lower-middle and middle-upper-income countries. The negative relationship, particularly in high-income countries, implies that foreign investment may contribute to environmental improvement through technology transfer, innovation diffusion, and more efficient production practices rather than primarily financing pollution-intensive activities. This interpretation is consistent with [Bekun et al. \(2024\)](#), [Dong et al. \(2024\)](#) and [Razzaq et al. \(2023\)](#), who emphasize the potential environmental benefits of FDI through technological and efficiency improvements. At the same time, the insignificant association in lower-middle and middle-upper-income groups indicates that the environmental benefits of FDI are not automatic and may depend on institutional quality, absorptive capacity, and economic structure ([Raihan et al., 2025](#); [Sadiq et al., 2024](#); [Saqib, 2022](#)). Thus, the findings are more consistent with the pollution-halo mechanism than the pollution-haven mechanism proposed in H2.

Contrary to the hypothesis, RE has a positive and statistically significant coefficient across all four income models, indicating that higher RE consumption is associated with higher carbon emissions during the observed period. This finding differs from the conventional expectation that RE reduces emissions by replacing fossil fuels ([Adebayo et al., 2022](#); [Dallali & Jebli, 2025](#); [Justice et al., 2024](#); [Shah et al., 2024](#)). One possible explanation is that RE expansion may not yet fully substitute for conventional energy sources, particularly when renewable capacity is developed alongside continued fossil-fuel consumption. The environmental effectiveness of RE may therefore depend on the broader energy mix, governance, technological, and the pace of the energy transition ([Dong et al., 2024](#); [Murshed, 2024](#)). Accordingly, the positive coefficient observed across all income groups suggests that RE deployment during the study period may have functioned more as a complement to existing energy systems than as a complete substitute for carbon-intensive energy sources.

FD has a positive association coefficient across all four income models, indicating that greater FD is consistently associated with higher carbon emissions regardless of income classification. This result supports the emission-increasing mechanism proposed in the hypothesis development, whereby greater access to credit and financial resources is associated with greater industrial expansion, investment, and energy consumption in carbon-intensive sectors ([Huang et al., 2023](#); [Patel & Mehta, 2023](#); [Usman et al., 2023](#)). Although FD can also facilitate green finance, RE investment, and environmentally friendly capital allocation ([Dincă et al., 2025](#); [Habiba & Xinbang, 2022](#)), the results suggest that the emission-increasing channel dominates within the sample and study period. This interpretation is consistent with [Emenekwe et al. \(2022\)](#) and [Tao et al. \(2023\)](#), who emphasize the dual and nonlinear nature of the FD emissions relationship, as well as [Idrees & Majeed \(2022\)](#) and [Ling et al. \(2022\)](#), who highlight the importance of institutional and financial structures in determining the environmental consequences of FD. Therefore, H4 receives consistent empirical support across all income classifications.

Overall, these findings address the empirical and income-level research gaps by showing different empirical patterns across country income classifications. GDP growth is positively significant only in lower-middle-income countries, FDI is negatively significant in the all-income and high-income model, while RE and FD are positively and significantly associated with carbon emissions across all models. Therefore, carbon mitigation policies should consider country-specific economic and institutional conditions, with greater emphasis on energy efficiency in lower-middle-

income countries, environmentally sustainable FDI in higher-income economies, green financial allocation across income groups, and effective fossil-fuel substitution alongside RE deployment.

CONCLUSION

This study examines the associations between economic growth, FDI, RE, and FD on carbon emissions using an unbalanced panel of 209 countries over 2000–2024. The result indicate that economic growth has no significant association with carbon emissions in the full sample but has a positive and significant association in lower-middle-income countries, providing partial support for H1. FDI has a negative and significant association with carbon emissions in the full sample and high-income countries, while its association is insignificant in lower-middle and middle-upper-income countries, leading to the rejection of H2. RE has a positive and significant association with carbon emissions across all income groups, contrary to H3, whereas FD has a positive and significant association across all models, fully supporting H4. These findings indicate that the determinants of carbon emissions exhibit different empirical patterns across income classifications, highlighting the importance of income-specific policies that promote energy efficiency, environmentally sustainable FDI, green financial allocation, and effective RE transition.

SUGGESTION

Practical Advice

Lower-middle-income countries should prioritize energy efficiency and green financing because GDP growth and FD are positively associated with carbon emissions in this group. Middle-upper-income countries should strengthen RE integration, fossil-fuel substitution, and green financing because RE and FD is positively related to carbon emissions. High-income countries should promote environmentally sustainable FDI and accelerate fossil-fuel substitution because FDI has a negative association with carbon emissions, while RE and FD continue to exhibit positive associations with emissions.

Theoretical Suggestions

This study has several limitations that provide opportunities for future research. First, although the study employs a global unbalanced panel dataset covering 209 countries from 2000 to 2024, the analysis focuses only on four macroeconomic determinants of carbon emissions, namely economic growth, FDI, RE, and FD. This study relies on complete-case analysis, resulting in the exclusion of observations with missing data. Future studies may employ multiple imputation or other missing-data techniques to evaluate the robustness of the findings. Also, this study applies the Ordinary Least Squares (OLS) estimator because it is appropriate for the characteristics of the unbalanced panel dataset and the objective of comparing countries across income classifications. Nevertheless, future research may validate these findings using alternative panel estimation techniques, such as Feasible Generalized Least Squares (FGLS) or Panel-Corrected Standard Errors (PCSE).

REFERENCES

- Adebayo, T. S., Awosusi, A. A., Rjoub, H., Agyekum, E. B., & Kirikkaleli, D. (2022). The influence of renewable energy usage on consumption-based carbon emissions in MINT economies. *Heliyon*, 8(2), e08941. <https://doi.org/10.1016/j.heliyon.2022.e08941>
- Adebayo, T. S., Ullah, S., Kartal, M. T., Ali, K., Pata, U. K., & Ağa, M. (2023). Endorsing sustainable development in BRICS: The role of technological innovation, renewable energy consumption, and natural resources in limiting carbon emission. *Science of the Total Environment*, 859(August 2022). <https://doi.org/10.1016/j.scitotenv.2022.160181>

- Ahmat, N., Christopher, S., Saputra, J., Sukemi, M. N., & Nawawi, M. N. (2025). The Impact of Energy Consumption, Economic Growth, and Non-Renewable Energy on Carbon Dioxide Emission in Malaysia. *International Journal of Energy Economics and Policy*, 15(1), 143–152. <https://doi.org/10.32479/ijeep.17350>
- Alam, S., Manigandan, P., Kisswani, K. M., & Ali, I. (2025). Achieving goals of the 2030 sustainable development agenda through renewable energy utilization : Comparing the environmental sustainability effects of economic growth and financial development. *Sustainable Futures*, 9(October 2023), 100534. <https://doi.org/10.1016/j.sftr.2025.100534>
- Andrei, J. V., Armeanu, D. Ștefan, Gherghina, Ștefan C., & Joldeș, C. C. (2025). The nexus between CO2 emissions, renewable energy consumption, foreign direct investment, and economic growth: evidence across different income groups of countries. *Environmental Research Communications*, 7(2). <https://doi.org/10.1088/2515-7620/ad8fff>
- Apeaning, R. W., & Labaran, M. (2025). Does financial development moderate the impact of climate mitigation innovation on CO2 emissions? Evidence from emerging economics. *Innovation and Green Development*, 4(2), 100211. <https://doi.org/10.1016/j.igd.2025.100211>
- Ayaydin, H., Ergün, T., Barut, A., Erdem, A., & Pilatin, A. (2025). FinTech driven green energy transition foreign direct investment and ecological footprint in BRICST countries. *Scientific Reports*, 15(1), 1–18. <https://doi.org/10.1038/s41598-025-18898-8>
- Batool, Z., Raza, S. M. F., Ali, S., & Abidin, S. Z. U. (2022). ICT, renewable energy, financial development, and CO2 emissions in developing countries of East and South Asia. *Environmental Science and Pollution Research*, 29(23), 35025–35035. <https://doi.org/10.1007/s11356-022-18664-7>
- Bekun, F. V., Gyamfi, B. A., Olasehinde-Williams, G., & Yadav, A. (2024). Revisiting the Foreign Direct Investment-CO2 Emissions Nexus within the N-EKC Framework: Evidence from South Asian Countries. *Sustainable Futures*, 8(April), 100357. <https://doi.org/10.1016/j.sftr.2024.100357>
- Bilgili, F., Muğaloğlu, E., Kuşkaya, S., Cifuentes-Faura, J., Khan, K., & Alnour, M. (2025). The nexus between the financial development and CO2 emissions: fresh evidence through time–frequency analyses. *Financial Innovation*, 11(1), 58. <https://doi.org/10.1186/s40854-024-00713-4>
- Chen, X. H., Tee, K., Elnahass, M., & Ahmed, R. (2023). Assessing the environmental impacts of renewable energy sources: A case study on air pollution and carbon emissions in China. *Journal of Environmental Management*, 345(June), 118525. <https://doi.org/10.1016/j.jenvman.2023.118525>
- Dallali, A., & Jebli, M. Ben. (2025). The influence of industrial expansion on carbon dioxide emissions in China: The interplay of financial development and renewable energy. *Environmental Progress & Sustainable Energy*, 44(3), 1–11. <https://doi.org/10.1002/ep.14560>
- Deng, W., Meng, T., Kharuddin, S., Ashhari, Z. M., & Zhou, J. (2024). The impact of renewable energy consumption, green technology innovation, and FDI on carbon emission intensity: Evidence from developed and developing countries. *Journal of Cleaner Production*, 483(August), 144310. <https://doi.org/10.1016/j.jclepro.2024.144310>
- Dincă, G., Netcu, I.-C., & Ungureanu, C. (2025). The Role of Climate-Oriented Funding in Advancing Renewable Energy Transition Across the EU. *Energies*, 18(24), 1–34. <https://doi.org/10.3390/en18246616>
- Dissanayake, H., Perera, N., Abeykoon, S., Samson, D., Jayathilaka, R., Jayasinghe, M., & Yapa, S. (2023). Nexus between carbon emissions, energy consumption, and economic growth: Evidence from global economies. *PLoS ONE*, 18(6 June), 1–27. <https://doi.org/10.1371/journal.pone.0287579>

- Dong, K., Wang, S., Hu, H., Guan, N., Shi, X., & Song, Y. (2024). Financial development, carbon dioxide emissions, and sustainable development. *Sustainable Development*, 32(1), 348–366. <https://doi.org/10.1002/sd.2649>
- Emenekwe, C. C., Onyeneke, R. U., & Nwajiuba, C. U. (2022). Financial development and carbon emissions in Sub-Saharan Africa. *Environmental Science and Pollution Research*, 29(13), 19624–19641. <https://doi.org/10.1007/s11356-021-17161-7>
- Fikri, Y., Talaat, R., Shaheen, A., Hassan, A., & Khataan, A. (2025). Through the ARDL Approach: Is There a Nexus Between Renewable Energy Consumption, Economic Growth, and Foreign Direct Investment in the Moroccan Context? *Sustainability (Switzerland)*, 17(21), 1–20. <https://doi.org/10.3390/su17219762>
- Furtuna, O. K., & Atis, S. (2024). Does foreign direct investment affect environmental degradation: Evidence from largest carbon intense countries. *PLoS ONE*, 19(11), 1–14. <https://doi.org/10.1371/journal.pone.0314232>
- Ganda, F., & Panicker, M. (2025). Does access to energy matter? Understanding the complex nexus among energy consumption, ICT, foreign direct investment and economic growth on carbon emissions in Sub-Saharan Africa. *Energy Nexus*, 17(November 2024), 100346. <https://doi.org/10.1016/j.nexus.2024.100346>
- Gbadeyan, O. J., Muthivhi, J., Liganiso, L. Z., & Deenadayalu, N. (2024). Decoupling Economic Growth from Carbon Emissions: A Transition toward Low-Carbon Energy Systems—A Critical Review. *Clean Technologies*, 6(3), 1076–1113. <https://doi.org/10.3390/cleantechnol6030054>
- Georgescu, I., & Kinnunen, J. (2023). The role of foreign direct investments, urbanization, productivity, and energy consumption in Finland's carbon emissions: an ARDL approach. *Environmental Science and Pollution Research*, 30(37), 87685–87694. <https://doi.org/10.1007/s11356-023-28680-w>
- Gershon, O., Asafo, J. K., Nyarko-Asomani, A., & Koranteng, E. F. (2024). Investigating the nexus of energy consumption, economic growth and carbon emissions in selected african countries. *Energy Strategy Reviews*, 51(December 2023), 101269. <https://doi.org/10.1016/j.esr.2023.101269>
- Gharbi, I., Rahman, M. H., Muryani, M., Esquivias, M. A., & Ridwan, M. (2025). Exploring the influence of financial development, renewable energy, and tourism on environmental sustainability in Tunisia. *Discover Sustainability*, 6(1), 127. <https://doi.org/10.1007/s43621-025-00896-5>
- Grossman, G. M., & Krueger, A. B. (1991). Environmental Impacts of a North American Free Trade Agreement. In *NBER Working Paper Series* (Issue 3914). <https://doi.org/10.1093/9780197852712.003.0078>
- Guan, X., Hassan, A., & Nassani, A. A. (2025). Investigating the Role of Environmental Taxes, Green Finance, Natural Resources, Human Capital, and Economic Growth on Environmental Pollution Using Panel Quantile Regression. *Sustainability*, 17(3), 1–20. <https://doi.org/10.3390/su17031094>
- Habiba, U., & Xinbang, C. (2022). The impact of financial development on CO2 emissions: new evidence from developed and emerging countries. *Environmental Science and Pollution Research*, 29(21), 31453–31466. <https://doi.org/10.1007/s11356-022-18533-3>
- Hesniati, H., Barahama, S. M. T., Krisyadi, R., Candy, C., & Arviano, H. (2026). Do Owners Matter ? The Role of Ownership Concentration in the Green Intellectual Capital-Sustainability Nexus. *Global Business & Finance Review*, 4(April), 29–42. <https://doi.org/doi.org/10.17549/gbfr.2026.31.4.29> GLOBAL
- Huang, S. Z., Sadiq, M., & Chien, F. (2023). The impact of natural resource rent, financial development, and urbanization on carbon emission. *Environmental Science and Pollution Research*, 30(15), 42753–42765. <https://doi.org/10.1007/s11356-021-16818-7>

- Idrees, M., & Majeed, M. T. (2022). Income inequality, financial development, and ecological footprint: fresh evidence from an asymmetric analysis. *Environmental Science and Pollution Research*, 29(507), 27924–27938. <https://doi.org/10.1007/s11356-021-18288-3>
- Itan, I., Laudeciska, L., Karjantoro, H., & Chen, R. (2023). Corporate Governance and Environmental Disclosure: Assessing The Role of Environmental Performance. *Riset Akuntansi Dan Keuangan Indonesia*, 8(2), 132–144. <https://doi.org/10.23917/reaksi.v8i2.2457>
- Ji, Y., & Xue, J. (2022). Decoupling Effect of County Carbon Emissions and Economic Growth in China: Empirical Evidence from Jiangsu Province. *International Journal of Environmental Research and Public Health*, 19(6), 3275. <https://doi.org/10.3390/ijerph19063275>
- Jin, W., Wang, Y., Yan, Y., Zhou, H., Xu, L., Zhang, Y., & Xu, Y. (2025). Digital economy, green finance, and carbon emissions: evidence from China. *Sustainability*, 17(12), 5625. <https://doi.org/10.3390/su17125625>
- Justice, G., Nyantakyi, G., & Isaac, S. H. (2024). The effect of renewable energy on carbon emissions through globalization. *Heliyon*, 10(5), e26894. <https://doi.org/10.1016/j.heliyon.2024.e26894>
- Kgomo, D. M., & Zhanje, S. (2025). Foreign Direct Investment, Trade Openness and Carbon Emission Nexus: Brics Plus Analyses. *International Journal of Energy Economics and Policy*, 15(4), 411–421. <https://doi.org/10.32479/ijeep.18672>
- Khan, I., Han, L., & Khan, H. (2022). Renewable energy consumption and local environmental effects for economic growth and carbon emission: evidence from global income countries. *Environmental Science and Pollution Research*, 29(9), 13071–13088. <https://doi.org/10.1007/s11356-021-16651-y>
- Kuznets, S. (1955). Economic Growth and Income Inequality. *American Economic Review*, 45(1), 1–28. <https://www.jstor.org/stable/1811581>
- Li, R., Wang, Q., & Li, Iejia. (2023). Does renewable energy reduce per capita carbon emissions and per capita ecological footprint? New evidence from 130 countries. *Energy Strategy Reviews*, 49(June), 101121. <https://doi.org/10.1016/j.esr.2023.101121>
- Li, Y., Alharthi, M., Ahmad, I., Hanif, I., & Hassan, M. U. (2022). Nexus between renewable energy, natural resources and carbon emissions under the shadow of transboundary trade relationship from South East Asian economies. *Energy Strategy Reviews*, 41(April), 100855. <https://doi.org/10.1016/j.esr.2022.100855>
- Ling, G., Razzaq, A., Guo, Y., Fatima, T., & Shahzad, F. (2022). Asymmetric and time-varying linkages between carbon emissions, globalization, natural resources and financial development in China. *Environment, Development and Sustainability*, 24(5), 6702–6730. <https://doi.org/10.1007/s10668-021-01724-2>
- Liu, X., Chen, L., Lu, Y., Chang, M., Xiao, Y., Yang, H., & Kong, D. (2025). Research on the impact of the digital economy on carbon emissions based on the dual perspectives of carbon emission reduction and carbon efficiency. *cientific reports*, 15(1), 3416. Retrieved from <https://www.nature.com/articles/s41598-025-87098-1>
- Maydybura, A., Chang, A. G., Channa, K. A., Pan, S. H., Alzoubi, H. M., & Chang, B. H. (2024). Carbon emissions and the rising effect of foreign direct investment and trade openness: Evidence from panel data countries. *Advances in Decision Sciences*, 28(4), 1–22. <https://doi.org/10.47654/v28y2024i4p1-22>
- Murshed, M. (2024). Can renewable energy transition drive green growth? The role of good governance in promoting carbon emission-adjusted economic growth in Next Eleven countries. *Innovation and Green Development*, 3(2), 100123. <https://doi.org/10.1016/j.igd.2023.100123>
- Nguyen, Q. K., Tran, D. L., Tran, X. H., Pham, N. T. N., & Nguyen, N. P. L. (2025). The complex relationship between carbon dioxide emissions, foreign direct investment, and economic growth in Asian countries. *Discover Sustainability*, 6(1), 831. <https://doi.org/10.1007/s43621-025-01730-8>

- Nuta, A. C., Abban, O. J., Ayad, H., & Nuta, F. M. (2025). Role of financial development and inclusivity in moderating the environmental effects of human development. *Research in International Business and Finance*, 73(PA), 102623. <https://doi.org/10.1016/j.ribaf.2024.102623>
- Oprea, S. V., Bâra, A., & Georgescu, I. A. (2025). Exploring the relationship between CO2 emissions, economic growth, urbanization, renewables and foreign investment in Iceland. *Energy Strategy Reviews*, 61(January). <https://doi.org/10.1016/j.esr.2025.101835>
- Patel, N., & Mehta, D. (2023). The asymmetry effect of industrialization, financial development and globalization on CO2 emissions in India. *International Journal of Thermofluids*, 20(June 2023), 100397. <https://doi.org/10.1016/j.ijft.2023.100397>
- Peng, W., Xiaoyuan, Y., & Haron, N. A. (2025). Relative improvements between roads and railways and transport carbon dioxide emissions: An environmental Kuznets curve hypothesis test in China. *Sustainable Futures*, 9(January), 100520. <https://doi.org/10.1016/j.sftr.2025.100520>
- Raihan, A., Muhtasim, D. A., Khan, M. N. A., Pavel, M. I., & Faruk, O. (2022). Nexus between carbon emissions, economic growth, renewable energy use, and technological innovation towards achieving environmental sustainability in Bangladesh. *Cleaner Energy Systems*, 3(August), 100032. <https://doi.org/10.1016/j.cles.2022.100032>
- Raihan, A., Ridwan, M., Zimon, G., Rahman, J., Tanchangya, T., Bari, A. M., Atasoy, F. G., Chowdhury, A. I., & Akter, R. (2025). Dynamic effects of foreign direct investment, globalization, economic growth, and energy consumption on carbon emissions in Mexico: An ARDL approach. *Innovation and Green Development*, 4(2), 100207. <https://doi.org/10.1016/j.igd.2025.100207>
- Razzaq, A., Fatima, T., & Murshed, M. (2023). Asymmetric effects of tourism development and green innovation on economic growth and carbon emissions in top 10 GDP countries. *Journal of Environmental Planning and Management*, 66(3), 471–500. <https://doi.org/10.1080/09640568.2021.1990029>
- Sadiq, M., Chau, K. Y., Ha, N. T. T., Phan, T. T. H., Ngo, T. Q., & Huy, P. Q. (2024). The impact of green finance, eco-innovation, renewable energy and carbon taxes on CO2 emissions in BRICS countries: Evidence from CS ARDL estimation. *Geoscience Frontiers*, 15(4), 101689. <https://doi.org/10.1016/j.gsf.2023.101689>
- Saglam, M. S., Yilanci, V., & Kongkuah, M. (2025). Decoupling economic growth and carbon emissions: a time-varying analysis of the environmental kuznets curve hypothesis in France (1890–2019). *Environment, Development and Sustainability*, 0123456789. <https://doi.org/10.1007/s10668-025-06310-4>
- Saqib, N. (2022). Nexus between the renewable and nonrenewable energy consumption and carbon footprints: evidence from Asian emerging economies. *Environmental Science and Pollution Research*, 29(38), 58326–58340. <https://doi.org/10.1007/s11356-022-19948-8>
- Schumpeter, J. A. (1934). The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle. In *Harvard University Press*. <https://doi.org/10.4324/9781003146766>
- Shah, W. U. H., Hao, G., Yan, H., Zhu, N., Yasmeen, R., & Dincă, G. (2024). Role of renewable, non-renewable energy consumption and carbon emission in energy efficiency and productivity change: Evidence from G20 economies. *Geoscience Frontiers*, 15(4). <https://doi.org/10.1016/j.gsf.2023.101631>
- Sheraz, M., Deyi, X., Mumtaz, M. Z., & Ullah, A. (2022). Exploring the dynamic relationship between financial development, renewable energy, and carbon emissions: A new evidence from belt and road countries. *Environmental Science and Pollution Research*, 29(10), 14930–14947. <https://doi.org/10.1007/s11356-021-16641-0>

- Tao, M., Sheng, M. S., & Wen, L. (2023). How does financial development influence carbon emission intensity in the OECD countries: Some insights from the information and communication technology perspective. *Journal of Environmental Management*, 335(December 2022), 117553. <https://doi.org/10.1016/j.jenvman.2023.117553>
- Tripathy, P., Brahmi, M., Pallayil, B., & Mishra, B. R. (2025). Mediating Effects of Foreign Direct Investment Inflows on Carbon Dioxide Emissions. *Economies*, 13(1), 1–29. <https://doi.org/10.3390/economies13010018>
- Uddin, M. M. M., Sharif, T., Islam, A. R. M., & Abedin, M. Z. (2024). Moderating impact of FDI on the growth-environment nexus in the pre-COVID-19 eras. *Research in International Business and Finance*, 67(September 2023). <https://doi.org/10.1016/j.ribaf.2023.102114>
- Usman, M., Kousar, R., Makhdum, M. S. A., Yaseen, M. R., & Nadeem, A. M. (2023). Do financial development, economic growth, energy consumption, and trade openness contribute to increase carbon emission in Pakistan? An insight based on ARDL bound testing approach. *Environment, Development and Sustainability*, 25(1), 444–473. <https://doi.org/10.1007/s10668-021-02062-z>
- Voumik, L. C., Ridwan, M., Rahman, M. H., & Raihan, A. (2023). An investigation into the primary causes of carbon dioxide releases in Kenya: Does renewable energy matter to reduce carbon emission? *Renewable Energy Focus*, 47(June), 100491. <https://doi.org/10.1016/j.ref.2023.100491>
- Wang, J., Ramzan, M., Makin, F., & Mahmood, C. K. (2023). Does clean energy matter? The dynamic effects of different strategies of renewable energy, carbon emissions, and trade openness on sustainable economic growth. *Environment, Development and Sustainability*, 27(9), 21043–21052. <https://doi.org/10.1007/s13132-023-01423-5>
- Wooldridge, J. M. (2013). *Introductory Econometrics: A Modern Approach* (Fifth Edit). Cengage Learning.
- Xu, P., Zhang, J., & Mehmood, U. (2023). How Do Green Investments, Foreign Direct Investment, and Renewable Energy Impact CO2 Emissions? Measuring the Role of Education in E-7 Nations. *Sustainability (Switzerland)*, 15(19), 14052. <https://doi.org/10.3390/su151914052>
- Xuan, V. N. (2025). Determinants of carbon dioxide emissions in technology revolution 6.0: new insights from Brunei. *Energy Strategy Reviews*, 57(January), 101633. <https://doi.org/10.1016/j.esr.2024.101633>
- Xuan, V. N., Huong, L. M., Thu, N. T. P., & Hoa, P. X. (2024). Carbon dioxide emissions, population, foreign direct investment, and renewable energy nexus: New insights from Thailand. *Energy Reports*, 11(April), 4812–4823. <https://doi.org/10.1016/j.egyr.2024.04.045>
- Yi, J., Hou, Y., & Zhang, Z. Z. (2023). The impact of foreign direct investment (FDI) on China's manufacturing carbon emissions. *Innovation and Green Development*, 2(4), 100086. <https://doi.org/10.1016/j.igdr.2023.100086>
- Zhang, Y., Gao, K., Wang, T., Chi, S., Cui, K., & Wen, C. (2025). The development , regional differences , and dynamic evolution of China ' s Green Finance in the context of “ Carbon Peaking and Carbon Neutrality .” *International Review of Economics and Finance*, 100(December 2024), 104100. <https://doi.org/10.1016/j.iref.2025.104100>