

Drivers of Carbon Emissions in Transition Economies: Evidence from Upper-Middle-Income Countries

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Abstract

This study examines the effects of economic growth, foreign direct investment (FDI), renewable energy, and financial development on carbon emissions in upper-middle-income countries from 2000 to 2025. Rapid economic expansion in developing economies has increased environmental pressure through rising carbon emissions associated with energy consumption and industrial activities. To address inconsistencies in prior studies, this research integrates multiple economic determinants into a single analytical framework. Using a quantitative approach, panel data regression analysis was conducted on annual data from 54 upper-middle-income countries obtained from the World Bank's World Development Indicators. Carbon emissions per capita were used as a proxy for environmental degradation, while GDP growth, FDI, renewable energy consumption, and financial development served as explanatory variables. To ensure robustness, alternative estimation techniques, including Clustered Standard Errors, Generalized Least Squares (GLS), and Driscoll-Kraay estimators, were applied. The findings indicate that GDP growth has a positive and significant effect on carbon emissions across all specifications, suggesting that economic expansion continues to generate environmental pressure. Renewable energy consistently reduces carbon emissions and emerges as the most robust determinant of environmental improvement. FDI shows a negative association with carbon emissions, providing partial support for the pollution halo effect, although its significance varies across estimators. Financial development exhibits a positive association with carbon emissions but remains sensitive to alternative estimation techniques. These findings imply that policymakers in upper-middle-income countries should prioritize accelerating renewable energy deployment and embedding emission-reduction measures in growth strategies, while directing financial and foreign investment toward green finance and clean-technology projects.

Keywords: Carbon Emissions, Economic Growth, FDI, Renewable Energy, Financial Development.

1 INTRODUCTION

The increase in global economic activity has the potential to significantly boost economic growth, particularly in emerging and developing economies (EMDEs) [1], including upper-middle-income countries [2], [3]. However, this growth has also been accompanied by increasing pressure on the environment, particularly through rising carbon emissions (CO₂), which are the largest source within the global energy system [4]. Economic activities that rely on fossil fuel-based energy and industrial processes are major contributors to the rise in global carbon emissions [4]. Thus, economic growth is not only linked to development success but also serves as a source of environmental pressure, particularly in the context of rapid economic development, where increases in per

capita Gross Domestic Product (GDP) correlate with increases in carbon emissions [5].

Recent climate-related agreements have increasingly emphasized the need to align economic and financial activities with low-carbon and climate-resilient development pathways [6]. This objective is particularly relevant for upper-middle-income countries, which are currently undergoing economic transitions accompanied by rising energy consumption [5]. In addition, Adebayo & Ullah [6] indicate that rapid economic growth is accompanied by an increase in carbon emissions due to economic activity and energy consumption. Based on these various statements, the relationship between economic development and environmental quality is closely intertwined and cannot be explained by a single factor. Therefore, research on this relationship in developing or upper-middle-income countries is essential.



The relationship between economic growth and environmental degradation is characterized by a U-shaped curve, in which environmental degradation increases during the early stages of development and decreases once a certain income level is reached [8]. Empirical findings show that the environmental consequences of economic growth are not identical across countries. In many cases, expanding economic activity increases carbon emissions as a result of higher energy demand. However, cross-country differences in industrial structures and energy portfolios may lead to varying emission outcomes [5], [6].

Besides economic growth, foreign direct investment (FDI) has been identified as another important determinant of carbon emissions. Existing evidence indicates that larger FDI inflows can increase environmental pressure by promoting industrial activities and raising energy consumption in host countries. As investment-driven industrialization expands, carbon emissions are likely to increase accordingly [9].

Alternatively, the use of renewable energy is one of the key strategies for reducing carbon emissions. Research shows that the use of renewable energy can improve energy efficiency and reduce environmental inefficiencies, which ultimately contributes to improving environmental quality [10].

The development of the financial sector also has a complex impact on carbon emissions. On the one hand, financial development can increase carbon emissions by increasing financing for economic activities that drive energy consumption. On the other hand, however, the financial sector also plays a role in supporting green investment financing, which contributes to reducing carbon emissions [11].

Several studies indicate that developing countries, particularly in Asia, are experiencing rising carbon emissions in tandem with increasing industrialization and global investment flows. This suggests that the relationship between GDP growth, FDI, renewable energy, and financial development and carbon emissions is complex and interrelated, necessitating a more comprehensive analysis [12], [13].

Despite this growing body of literature, three gaps remain. First, prior studies typically examine GDP growth, FDI, renewable energy, and financial development in isolation or in pairwise combinations, or focus on a single country or regional bloc such as ASEAN [9], [11]. As a result, the relative importance of these determinants within a common framework remains unclear. Second, upper-middle-income countries, where industrialization, rising energy demand, and the early stages of the energy transition coexist, are rarely analyzed as a distinct group. Third, the conflicting evidence on FDI and financial development raises the question of whether reported effects depend on the

estimator used, yet few studies show how conclusions change across estimators that address heteroskedasticity, serial correlation, and cross-sectional dependence Adebayo & Ullah [6].

This study addresses these gaps in three ways. First, it jointly estimates the effects of GDP growth, FDI, renewable energy, and financial development on carbon emissions within a single framework. Second, it uses the most recent panel available, covering 54 upper-middle-income countries from 2000 to 2025. Third, it benchmarks the results across OLS, clustered standard errors, GLS, and Driscoll-Kraay estimators to distinguish robust determinants from estimator-sensitive ones. The findings are expected to provide policy insights for balancing economic growth with environmental sustainability.

2 LITERATURE REVIEW

2.1 Carbon Emissions

Carbon emissions represent one of the most widely used indicators of environmental degradation and are closely associated with climate change, global warming, and ecological sustainability [14]. According to Wang et al. [15], carbon-related environmental risks increasingly arise from economic transitions toward lower-emission production systems, driven by regulatory changes, technological innovation, and shifting market preferences. Similarly, Hoque et al. [16] argue that efforts to reduce carbon emissions can generate both costs and opportunities, depending on how governments and economic actors adapt to sustainability requirements. Accordingly, examining the determinants of carbon emissions is vital for establishing appropriate policy frameworks that can achieve a balance between economic advancement, investment activities, financial sector development, and environmental preservation.

2.2 Energy Transition Theory

Energy Transition Theory highlights the importance of shifting energy consumption patterns from fossil fuels to renewable energy sources to achieve sustainable development. Increased adoption of renewable energy reduces dependence on high-carbon fuels and contributes to lowering greenhouse gas emissions. Compared with conventional energy sources, renewable technologies such as solar, wind, hydropower, and biomass generate substantially lower environmental impacts [17], [18]. This theory maintains that greater reliance on renewable energy can help countries balance economic progress with environmental protection. By reducing dependence on fossil fuels, renewable energy contributes to lower carbon emissions and supports the implementation of sustainable, low-carbon development policies.

2.3 Pollution Effect Theories

The relationship between FDI and environmental quality is often examined through two opposing perspectives: the Pollution Haven Hypothesis (PHH) and the Pollution Halo Effect (PHE). The PHH indicates that foreign firms may choose to locate environmentally harmful production activities in countries with relatively lenient environmental policies, allowing them to reduce operational and environmental compliance costs. Consequently, greater FDI inflows may increase environmental degradation and carbon emissions in host countries [19]. In contrast, the PHE argues that foreign investment may enhance environmental quality by facilitating the diffusion of advanced technologies, managerial know-how, and cleaner production practices that improve resource efficiency. Multinational enterprises often possess superior technological capabilities that enable cleaner production processes and more efficient resource utilization, thereby reducing carbon emissions [20], [21]. These competing perspectives explain why empirical studies frequently report mixed findings regarding the environmental impact of FDI.

2.4 Hypothesis Development and Research Model

The relationship between GDP growth and carbon emissions has received considerable attention in environmental economics due to increasing concerns over how to sustain economic development while preserving environmental quality. Research by Dissanayake et al. [22] highlights the relationship between economic growth, energy consumption, and carbon emissions on a global scale. Previous empirical evidence shows that GDP growth is likely to intensify carbon emissions in developing countries, primarily due to increased industrial activities and continued reliance on fossil-based energy. In addition, the presence of a one-way causality from economic growth to carbon emissions implies that expanding economic output tends to generate higher levels of environmental degradation. In line with this, Nawaz et al. [23] also revealed that economic growth contributes to an increase in carbon emissions in the long term, especially when driven by investment and the intensive use of natural resources. Meanwhile, Zhang et al. [24] specifically examined the case of China and found that there is a one-way causal relationship between GDP growth and carbon emissions. This means that increased economic growth directly drives an increase in carbon emissions, particularly during the industrialization phase. Research by Du et al. [25] also shows that GDP growth tends to increase carbon emissions in the early stages of development, due to heavy reliance on fossil fuels and the expansion of industrial activities. Furthermore, Yang et al. [26] states

that, globally, the relationship between GDP growth and carbon emissions has gone through several phases, ranging from expansive coupling to strong decoupling. With ongoing technological progress and structural transformation, economic growth does not necessarily translate into higher carbon emissions. Such a condition reflects the concept of decoupling, whereby economies continue to expand while environmental pressures associated with carbon emissions become less pronounced [25], [26]. Research by Mirziyoyeva & Salahodjaev [27] reinforces this argument by showing that in countries with high levels of globalization, increased use of renewable energy has successfully reduced carbon emissions. Findings by Zhang [28] show that while GDP growth continues to drive carbon emissions, technological innovation has proven to be a crucial factor in reducing pollution and achieving carbon neutrality. Moreover, Gbadeyan et al. [29] emphasize that achieving strong decoupling requires a transition to a low-carbon energy system, allowing economic growth without increasing emissions. Based on these studies, the decoupling literature suggests that growth reduces emissions only after structural transformation and low-carbon energy systems are in place. Upper-middle-income countries are typically in an intermediate position: their growth still relies on manufacturing, transportation, and urbanization powered largely by fossil fuels, while low-carbon capacity is not yet widespread. Therefore, GDP growth is expected to remain coupled with emissions in this group.

H₁ : GDP growth has a positive and significant effect on carbon emissions.

The relationship between FDI and environmental quality, particularly carbon emissions, has been a highly debated topic in the environmental economics literature. Although FDI has traditionally been viewed as a driver of economic growth through technology transfer and increased productivity, its implications for environmental degradation have yielded conflicting results [30]. The debate over the impact of FDI on environmental quality has consistently centered on the contrast between the pollution haven hypothesis (PHH) and the pollution halo effect (PHE) [31]. From the perspective of the PHH, as per the research by Maydybura et al. [32], FDI is viewed as a mechanism for relocating pollution-intensive industries from developed countries to developing countries with less stringent environmental regulations. This argument posits that multinational corporations will exploit lower environmental compliance costs to maximize profits, thereby increasing carbon emissions in host countries. These negative impacts are particularly pronounced in countries with weak institutional governance, where the inflow of foreign capital actually accelerates the rate of

greenhouse gas emissions due to lax regulatory oversight [33], [34]. Conversely, supporters of PHE argue that FDI acts as a catalyst for improving environmental quality through the diffusion of environmentally friendly technologies and more efficient energy management systems [20], [31]. Findings in China's manufacturing sector indicate that foreign investment contributes to emissions reductions, particularly in technology-intensive and labor-intensive industries, where energy efficiency is a top operational priority [21]. Existing literature provides mixed evidence regarding the environmental consequences of FDI. The PHH posits that multinational firms tend to transfer environmentally harmful activities to countries with weaker regulatory frameworks, thereby increasing carbon emissions. Conversely, the PHE emphasizes the beneficial role of FDI in promoting technological innovation, resource efficiency, and cleaner production systems. Although the PHH is most plausible where institutions are weak [33], [34], upper-middle-income countries generally have stronger regulatory capacity and absorptive capacity than lower-income hosts, and they increasingly attract FDI into technology-intensive manufacturing and services. These conditions make the technology and management spillovers emphasized by the PHE more likely to dominate pollution relocation. Therefore, FDI is expected to reduce carbon emissions in this group.

H₂ : FDI has a negative and significant effect on carbon emissions.

The transition to renewable energy has consistently been identified as a key mitigation strategy for reducing global carbon emissions. Various studies show that increased consumption of renewable energy directly contributes to improved environmental quality by reducing carbon footprints and other environmental pressures [35], [36]. This phenomenon is evident on a global scale, encompassing many countries, as well as in specific case studies of developing economies such as Malaysia and the BRICS nations, where clean energy serves as a substitute for polluting fossil fuels [17], [37]. These findings reinforce the argument that the use of renewable energy is a fundamental tool in efforts to reduce carbon emissions in the global economy [36]. Moreover, investments in clean energy sectors such as solar, wind, and biomass have been shown to have a strong correlation with a reduction in emissions intensity over the long term [39]. In addition, the level of economic complexity in a country influences how the energy transition affects air quality. Countries with more advanced and complex economic structures tend to be better able to adopt clean technologies efficiently [17], [38]. This indicates that energy policies must take into account structural readiness and economic capacity to ensure that emissions reductions can proceed optimally.

Therefore, achieving the carbon neutrality targets set forth in international agreements depends heavily on countries' ability to consistently shift energy consumption from conventional sources to environmentally friendly ones [18]. Upper-middle-income countries still depend heavily on fossil fuels, so each additional unit of renewable energy is likely to displace high-carbon generation rather than merely add to total supply. Combined with the energy transition mechanism discussed above, renewable energy is therefore expected to exert a negative effect on carbon emissions.

H₃ : Renewable energy has a negative and significant effect on carbon emissions.

The positive role of financial development is often linked to its ability to mitigate carbon emissions through support for innovation and technology. In OECD countries, financial development has been found to significantly reduce carbon emissions, particularly when combined with advances in information and communication technology (ICT) that improve operational efficiency [40]. In addition, finance-driven development through instruments such as green credit and green investment has been empirically shown to contribute directly to the reduction of carbon emissions in various provinces across China [41]. Although there is positive potential, several studies highlight the presence of asymmetric patterns and nonlinear relationships, indicating that the financial impact on the environment is not always consistent. A study in China revealed that the relationship between these financial variables can vary over time and is influenced by certain economic shocks [42]. Additionally, there is evidence that high carbon emissions can undermine the positive effects of innovation and financial development on long-term economic growth, indicating a dynamic relationship that must be managed carefully [43]. Analysis in the Asia-Pacific region shows that a country's financial development not only affects domestic carbon emissions but also has significant indirect impacts on environmental quality in neighboring countries [44]. The environmental implications of financial development are multifaceted. While financial sector expansion can promote investment in environmentally friendly technologies, it may simultaneously contribute to rising carbon emissions by encouraging economic activities that require substantial energy consumption. Financial development, measured by domestic credit to the private sector, mainly expands credit for industrial investment, construction, and consumption. In upper-middle-income economies, green finance markets are still at an early stage, so the technology-enabling channel observed in advanced economies [40] is likely weaker than the scale effect of

credit-driven energy demand. Therefore, financial development is expected to have a positive effect on carbon emissions.

H₄ : Financial development has a positive and significant effect on carbon emissions.

Based on the proposed hypotheses, this study recognizes the interrelationship among GDP growth, FDI, renewable energy, financial development, and carbon emissions. These hypotheses are developed from established theoretical arguments and supported by prior empirical evidence.

Furthermore, to provide a more comprehensive overview of the relationships among the variables under study, all of these hypotheses are synthesized into a conceptual framework. This model illustrates the direct effects in explaining the relationships among the research constructs.

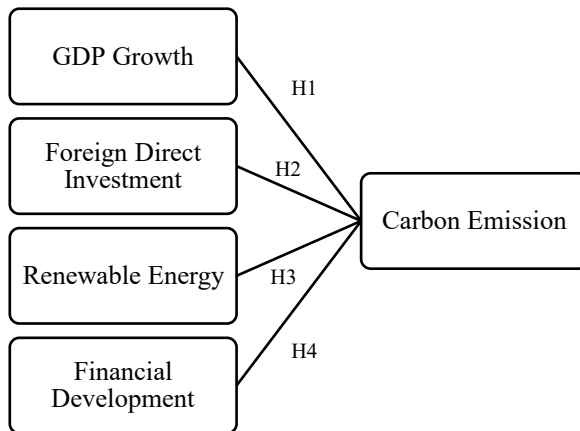


Figure 1. Research Model

3 RESEARCH METHODS

A quantitative framework based on panel data analysis is employed in this study to investigate the associations between the selected explanatory variables and carbon emissions. Using annual data spanning 2000–2025, the study focuses on countries classified as upper-middle-income economies by the World Bank. The use of panel data allows for a more comprehensive assessment by capturing both cross-sectional and time-series variations across countries.

Table 1. Sampling Criteria

Description	Total	
Upper-middle-income countries used as research samples	54	Countries
Research periode	2000 - 2025	Years
Total potential observations	1,404	Data
Observations with missing values	(378)	Data
Final observations used	1,026	Data

Source: data processed by the researcher, 2026

As presented in Table 1, the initial sample consisted of 54 upper-middle-income countries observed from 2000 to 2025. After excluding observations with missing values, the final dataset comprised 1,026 country-year observations, providing sufficient variation for panel data estimation and robustness testing of the effects of GDP growth, FDI, renewable energy, and financial development on carbon emissions.

This study employs a historical research approach by utilizing past data for analysis. Carbon emissions are used as the dependent variable, as they represent a widely recognized indicator of environmental degradation and a major global environmental concern. The ongoing increase in carbon emissions resulting from environmental degradation and global climate change is a major concern that demands the adoption and implementation of policies to mitigate these adverse effects without hindering the pace of global economic growth [45]. Carbon dioxide emissions are emissions resulting from the combustion of fossil fuels and cement manufacturing, including carbon dioxide produced during the consumption of solid, liquid, and gaseous fuels, as well as gas flaring [1]. In this study, carbon emissions were measured in metric tons of carbon per capita, based on data from the World Bank's World Development Indicators (WDI) [1]. Mathematically, the calculation of CO₂ emissions per capita follows the formula as below:

$$CO2_{it} = \frac{\text{Total CO2 Emissions}_{it}}{\text{Population}_{it}} \quad (1)$$

The empirical model applied to examine the relationship among the variables is specified as follows:

$$\ln(CO2_{it}) = \beta_0 + \beta_1 \ln(GDP_{it}) + \beta_2 \ln(FDI_{it}) + \beta_3 \ln(REN_{it}) + \beta_4 \ln(FD_{it}) + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

GDP growth is measured by the annual percentage growth rate of GDP at market prices based on constant local currency, following the World Development Indicators published by the World Bank Group [3]. This measure captures the rate at which economic activity grows within an economy and captures changes in overall economic activity within a country. Economic growth initially increases carbon emissions, although higher income levels may eventually lead to lower emissions. In addition, Stern [46] reveals that GDP growth is closely linked to carbon emissions, especially when a country relies on energy-intensive processes and fossil fuel-based energy sources in its production. Furthermore, Gibba et al. [47] also argue that economic growth has a complex relationship with environmental degradation.

$$GDPG_{it} = \frac{GDP_{it} - GDP_{it-1}}{GDP_{it-1}} \times 100\% \quad (3)$$

The second independent variable is foreign direct investment (FDI), defined as long-term foreign capital invested to obtain ownership or control over businesses in host countries. FDI plays a role in technology transfer and boosting economic productivity. FDI may either increase or reduce carbon emissions depending on the nature of investment activities and the effectiveness of environmental regulations in the host country.

$$FDI_{it} = \frac{FDI \text{ Inflows}_{it}}{GDP_{it}} \times 100\% \quad (4)$$

Renewable energy serves as the third explanatory variable in this study. It represents energy obtained from renewable resources, including solar, wind, hydro, and biomass, and is measured by its share in total final energy consumption. Expanding renewable energy utilization may contribute to lower carbon emissions and improved environmental quality.

$$RE_{it} = \frac{\text{Renewable Energy Consumption}_{it}}{\text{Total Energy Consumption}_{it}} \times 100\% \quad (5)$$

The fourth independent variable is financial development, which captures the extent to which financial institutions facilitate the efficient distribution of capital within the economy. An advanced financial system is generally regarded as a key driver of economic development. However, Shahbaz et al. [48] state that financial development can also influence carbon emissions through increased industrial activity and financing for environmentally friendly technologies.

$$FD_{it} = \frac{\text{Domestic Credit to Private Sector}_{it}}{GDP_{it}} \times 100\% \quad (6)$$

Based on the previous explanation of the variables used, Table 2 shows the operational definitions of the variables used in this study, which consist of carbon emissions as the dependent variable, and GDP growth, foreign direct investment, renewable energy, and financial development as independent variables.

Table 2. Variable Description

Variable	Definition	Description	Source
Dependent	Carbon Emission (CO ₂)	Per capita CO2 emissions from fossil fuel and cement manufacturing (proxy for EQ)	[12]
	GDP Growth (GDP _G)	Annual GDP growth rate (%)	[3]
Independent	Foreign Direct Investment (FDI)	FDI, net inflows (%of GDP)	[12]

Renewable Energy (RE)	Amount of renewable energy used (as a percentage of total use)	[13]
Financial Development (FD)	Domestic credit to private sector (% of GDP)	[12]

The relationship between carbon emissions, GDP growth, foreign direct investment, renewable energy, and financial development was examined utilizing a thorough analytical technique using Stata software. To verify the validity of the research findings, a number of statistical tests were used, such as regression analysis, Pearson's correlation test, and descriptive statistics.

4 RESULTS AND DISCUSSION

Table 3 presents the descriptive statistics for carbon emissions, GDP growth, FDI, renewable energy, and financial development, summarizing the central tendency and dispersion of each variable across the sample period.

Table 3. Descriptive Statistics

Variable	Mean	Median	Std Dev.	Min.	Max.
CO ₂	3.456	2.688	2.793	0.000	15.727
GDP _G	3.569	3.666	6.566	-50.339	86.827
FDI	4.487	3.201	5.600	-37.173	64.384
RE	19.277	13.700	18.347	0.000	91.300
FD	41.145	35.991	27.970	1.266	194.166

Source: data processed by the researcher, 2026

Carbon emissions exhibit a mean value of 3.456 with a standard deviation of 2.793, indicating moderate variation among observations. The variable ranges from 0.000 to 15.727, suggesting substantial differences in emission levels across the sample. GDP growth records an average value of 3.569, with a minimum of -50.339 and a maximum of 86.827, reflecting considerable economic fluctuations during the study period. Similarly, FDI shows notable variability, with a mean of 4.487 and a standard deviation of 5.600, ranging from -37.173 to 64.384.

Renewable energy records the highest average value among the explanatory variables, with a mean of 19.277 and a standard deviation of 18.347. The considerable gap between the minimum value (0.000) and the maximum value (91.300) reflects substantial differences in renewable energy adoption across the sample countries. Meanwhile, financial development has an average value of 41.145 and a median of 35.991, indicating a slightly positively skewed distribution. Its relatively high standard deviation (27.970), along with values ranging from 1.266 to 194.166, suggests considerable variation in the level of financial sector development among countries. This variation reflects differences in financial market maturity, institutional capacity, and access to credit among upper-middle-

income economies. Furthermore, the disparities between mean and median values across several variables suggest the presence of non-normal and potentially skewed distributions. Nevertheless, the observed variability enhances the suitability of the dataset for panel regression analysis by providing sufficient cross-sectional and temporal variation.

Table 4. Pearson Correlation

	CO ₂	GDP _G	FDI	RE	FD
CO ₂	1.000				
GDP _G	0.117*** (0.000)	1.000			
FDI	-0.031 (0.272)	0.187*** (0.000)	1.000		
RE	-0.391*** (0.000)	-0.022 (0.455)	-0.043 (0.144)	1.000	
FD	0.126*** (0.000)	-0.057** (0.046)	0.036 (0.218)	-0.079*** (0.010)	1.000

p-values in parentheses

* *p* < 0.1, ** *p* < 0.05, *** *p* < 0.01

Source: data processed by the researcher, 2026

Table 4 reports Pearson correlation coefficients among carbon emissions, GDP growth, FDI, renewable energy, and financial development, providing an initial assessment of their pairwise relationships and potential multicollinearity.

Carbon emissions exhibit a positive and statistically significant correlation with GDP growth ($r = 0.117$, $p < 0.01$) and financial development ($r = 0.126$, $p < 0.01$). These results suggest that stronger economic growth and financial sector development are generally accompanied by higher carbon emissions, implying greater environmental pressure as economic activities expand. In contrast, renewable energy is negatively and significantly associated with carbon emissions ($r = -0.391$, $p < 0.01$), suggesting that greater reliance on renewable sources contributes to lower emission levels. Meanwhile, FDI exhibits a negative but statistically insignificant relationship with carbon emissions ($r = -0.031$, $p > 0.10$).

Regarding the relationships among the independent variables, GDP growth is positively and significantly correlated with FDI ($r = 0.187$, $p < 0.01$), suggesting that stronger economic performance may be associated with higher foreign investment inflows. Financial development exhibits a weak but statistically significant negative correlation with GDP growth ($r = -0.057$, $p < 0.05$), indicating that countries with more developed financial systems do not necessarily experience higher rates of economic growth during the observed period. In addition, financial development is positively but insignificantly associated with FDI ($r = 0.036$, $p > 0.10$), while its relationship with renewable energy is negative and statistically significant ($r = -0.079$, $p < 0.01$). Furthermore, renewable energy shows

weak and insignificant correlations with both GDP growth and FDI.

Pairwise correlations are modest, with the highest absolute value between carbon emissions and renewable energy ($r = -0.391$). Since all coefficients are well below 0.80, severe multicollinearity is unlikely.

Table 5. Baseline Regression

	(1) CO ₂	(2) CO ₂	(3) CO ₂	(4) CO ₂	(5) CO ₂
GDP _G	0.062*** (4.24)				0.071*** (5.48)
FDI		-0.015 (-1.14)			-0.066*** (-4.83)
RE			-0.059*** (-12.83)		-0.056*** (-12.16)
FD				0.010*** (3.51)	0.008*** (3.28)
_cons	2.596*** (7.93)	3.003*** (8.94)	4.184*** (12.85)	2.569*** (7.44)	3.837*** (11.33)
Year FE	Yes	Yes	Yes	Yes	Yes
r ²	0.027	0.009	0.165	0.022	0.224
r ² _a	0.008	-0.011	0.148	0.000	0.204
N	1026	1026	1026	1026	1026

t statistics in parentheses

* *p* < 0.1, ** *p* < 0.05, *** *p* < 0.01

Source: data processed by the researcher, 2026

Table 5 presents the regression results examining the effects of GDP growth, FDI, renewable energy, and financial development on carbon emissions. Model (1) - (4) report the individual effects of each explanatory variable, while model (5) presents the full specification incorporating all variables simultaneously. Year fixed effects are included in all estimations to control for time-specific heterogeneity.

The results indicate that GDP growth has a positive and statistically significant effect on carbon emissions in model (1) ($\beta = 0.062$, $p < 0.01$). This finding suggests that economic expansion may initially increase environmental degradation before improvements emerge at higher income levels. The positive and significant relationship is further maintained in the full specification ($\beta = 0.071$, $p < 0.01$), indicating that the effect of GDP growth on carbon emissions persists even after controlling for FDI, renewable energy, and financial development. Moreover, the robustness analysis consistently confirms a positive and significant relationship across all alternative estimation techniques. These findings suggest that economic growth remains an important and stable determinant of carbon emissions, thus providing strong support for H₁. This result is also in line with the findings of Dissanayake et al. [22], Nawaz et al. [23], Zhang et al. [24], and Du et al. [25], who reported that economic growth contributes to higher carbon emissions, particularly in developing and transition economies. The increase in carbon emissions accompanying economic growth is likely driven by the

development patterns of upper-middle-income countries, where economic activities remain energy-intensive and largely supported by conventional energy sources. Rapid economic growth increases manufacturing activity, transportation demand, and urbanization, all of which raise energy consumption and greenhouse gas emissions. As many transition economies have not fully adopted low-carbon technologies, economic expansion continues to place pressure on the environment. These results suggest that growth in upper-middle-income countries remains energy-intensive and has not yet achieved strong decoupling between economic performance and environmental sustainability.

Regarding FDI, model (2) reveals an insignificant relationship with carbon emissions ($\beta = -0.015$, $p > 0.10$). However, the full model shows a negative and statistically significant coefficient ($\beta = -0.066$, $p < 0.01$), indicating that foreign investment contributes to reducing carbon emissions rather than exacerbating environmental degradation. Consistent with H_2 , FDI is found to have a negative effect on carbon emissions. This outcome challenges the PHH perspective and instead lends support to the PHE framework, whereby foreign investment acts as a channel for technological diffusion, managerial improvements, and enhanced energy efficiency that contribute to better environmental performance. By introducing advanced technologies and fostering innovation, FDI may encourage cleaner production practices and decrease the use of high-carbon production systems in upper-middle-income countries. This finding is consistent with Wang & Zhang [20] and Yi et al. [21], who documented the environmental benefits of FDI through technological upgrading and improved production efficiency. Nevertheless, the robustness analysis shows that FDI loses significance under the GLS estimator but remains significant under OLS, Clustered SE, and Driscoll-Kraay specifications. Therefore, the negative effect of FDI on carbon emissions can be considered partially robust and should be interpreted with caution. A possible explanation is that foreign investment generates positive spillover effects through the adoption of advanced technologies and improved operational practices, thereby increasing energy efficiency and mitigating environmental degradation. Moreover, multinational corporations are generally subject to international sustainability requirements, encouraging more environmentally responsible production practices in host countries. As a result, FDI may contribute to environmental improvement rather than merely shifting pollution-intensive activities to developing economies.

Renewable energy has a negative and highly significant effect on carbon emissions in both the individual model ($\beta = -0.059$, $p < 0.01$) and the full specification ($\beta = -0.056$, $p < 0.01$), supporting H_3 . This

indicates that a higher share of renewable energy helps reduce carbon emissions and enhances environmental sustainability. This finding aligns with previous studies by Azam et al. [35], Leitão et al. [17], Li et al. [36], and Shan et al. [18], which emphasized the crucial role of renewable energy in replacing fossil fuel dependence and facilitating the transition toward low-carbon development. The robustness analysis further confirms the stability of the finding, as the negative and significant coefficient is consistently maintained across all alternative estimators, reinforcing the role of renewable energy as the most empirically robust determinant of environmental improvement in the sample.

The results indicate that financial development positively influences carbon emissions, with statistically significant coefficients observed in both model (4) ($\beta = 0.010$, $p < 0.01$) and model (5) ($\beta = 0.008$, $p < 0.01$), thereby supporting H_4 . This finding suggests that the expansion of financial systems may stimulate industrial production, investment activities, and energy consumption, which in turn contribute to higher carbon emissions. The result supports the argument that financial development can facilitate environmentally intensive economic activities when sustainability considerations are not fully integrated into financial decision-making processes. This finding is consistent with Shahbaz et al. [48] and Febriana [11], who argued that greater access to financial resources may increase environmental pressure through the expansion of carbon-intensive industries. Nevertheless, the robustness tests reveal that the influence of financial development is not entirely stable under alternative estimation approaches. While the estimated coefficient consistently retains a positive sign, the level of statistical significance differs across specifications. A possible explanation is that financial development expands access to credit, encouraging greater industrial investment and household consumption, both of which increase energy demand. In economies that remain highly dependent on fossil fuels, this increased economic activity may lead to higher carbon emissions. These findings suggest that financial development, in the absence of adequate green finance mechanisms, may unintentionally contribute to environmental degradation. Therefore, the relationship should be interpreted with caution due to its sensitivity across estimation methods. These results suggest that the association between financial development and carbon emissions is influenced by model specifications and the underlying econometric assumptions. Therefore, although the baseline results support H_4 , the evidence should be interpreted with caution, as the environmental impact of financial development does not appear to be as robust as that of GDP growth.

Overall, the results show that GDP growth and renewable energy are the most robust determinants of carbon emissions, consistently maintaining their

direction and significance across all specifications. Financial development is positively associated with emissions in the baseline and most robustness models, but its significance disappears under GLS correction, so the result should be interpreted cautiously. Likewise, FDI is generally negative associated with emissions but becomes insignificant under GLS, indicating only partial robustness. Accordingly, policymakers in upper-middle-income countries should ensure that economic expansion is accompanied by sustainability-oriented measures, including wider renewable energy utilization, improved green financing mechanisms, and investments that support environmental protection.

Table 6. Robustness Check

	(1) CO ₂ OLS	(2) CO ₂ Clustered SE	(3) CO ₂ GLS	(4) CO ₂ Driscoll- Kraay
GDP _G	0.0711*** (5.62)	0.0711*** (5.48)	0.0711** (3.22)	0.0159* (2.29)
FDI	-0.0661*** (-5.17)	-0.0661*** (-4.83)	-0.0661 (-1.78)	-0.0436*** (-6.91)
RE	-0.0564*** (-14.52)	-0.0564*** (-12.16)	-0.0564** (-2.81)	-0.0532*** (-54.90)
FD	0.00830** (3.15)	0.00830** (3.28)	0.00830 (0.88)	0.00666*** (6.81)
_cons	3.837*** (10.48)	3.837*** (11.33)	3.837*** (5.82)	3.884*** (34.60)
Year FE	Yes	Yes	Yes	Yes
Total Obs.	1026	1026	1026	1026

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Source: data processed by the researcher, 2026

Table 6 reports the robustness test results using alternative estimators, including Clustered Standard Errors, GLS, and Driscoll-Kraay estimators. The robustness tests are performed to examine the reliability of the initial estimates under alternative conditions that account for common panel data problems, namely heteroskedasticity, serial correlation, and cross-sectional dependence.

The results show that GDP growth retains a positive and significant effect. Although the coefficient becomes smaller under the Driscoll-Kraay estimator (0.0159) relative to OLS (0.0711), the sign and statistical significance remain unchanged. This stability suggests that GDP growth is a robust determinant of carbon emissions and that the main findings are not affected by alternative estimation techniques. Overall, the results indicate that economic expansion continues to generate environmental pressures regardless of the econometric approach applied.

In contrast, FDI exhibits a negative coefficient but shows mixed significance across estimators. While FDI is statistically significant under OLS, Clustered SE, and Driscoll-Kraay specifications, it loses significance under the GLS estimator. This partial inconsistency

suggests that the environmental benefits associated with FDI should be interpreted with caution, as the evidence is not uniformly robust across all model specifications. The loss of significance under GLS suggests that the FDI effect is sensitive to how observations are weighted, a point discussed below.

Across all estimation approaches, renewable energy shows a stable inverse relationship with carbon emissions. The persistence of both the coefficient sign and statistical significance suggests that the mitigating effect of renewable energy on emissions remains reliable under different econometric frameworks. This evidence underscores the contribution of renewable energy to better environmental performance in upper-middle-income countries.

Financial development demonstrates moderate robustness. The variable is statistically significant under OLS, Clustered SE, and Driscoll-Kraay estimations, but loses significance when the GLS correction is applied. Such variation suggests that the estimated effect may be partly sensitive to the assumptions of specific estimators, particularly those that adjust for heteroskedasticity and autocorrelation structures. Nevertheless, the significance observed across the majority of specifications provides cautious support for financial development as a determinant of carbon emissions, though the relationship should not be considered fully conclusive.

The loss of significance for FDI and financial development under GLS deserves an economic explanation. Cross-sectional dependence is unlikely to be the main cause, because the Driscoll-Kraay estimator, which explicitly corrects for it, retains the significance of both variables ($t = -6.91$ and 6.81). A more plausible explanation is the weighting scheme of GLS. By adjusting for heteroskedasticity and serial correlation, GLS down-weights observations from countries with highly volatile series. The sample contains extreme values, such as FDI inflows ranging from -37.2% to 64.4% of GDP and credit-to-GDP ratios up to 194.2% (Table 3), which are typical of small, open, or crisis-affected economies. Part of the FDI and financial development effects in the OLS-based estimates may therefore come from these volatile observations, and once they are down-weighted, the effects become statistically indistinguishable from zero ($t = -1.78$ and 0.88). This also points to cross-country heterogeneity, foreign capital and credit expansion may lower or raise emissions depending on sectoral destination and domestic regulation, which a pooled coefficient averages out. In contrast, renewable energy and GDP growth remain significant under GLS, indicating that their effects hold across countries with different volatility levels.

Overall, the robustness analysis strengthens confidence in the positive relationship between GDP growth and carbon emissions, as well as in the negative

relationship between renewable energy and carbon emissions, given that both variables consistently maintain their direction and significance across all alternative estimators. By contrast, FDI shows significance in most but not all specifications, while financial development exhibits sensitivity to the GLS correction. These findings imply that GDP growth and renewable energy are the most empirically stable predictors of carbon emissions within the sample, whereas the effects of FDI and financial development warrant more cautious interpretation due to their partial sensitivity to model specification.

5 CONCLUSION

This study investigates the impact of GDP growth, FDI, renewable energy, and financial development on carbon emissions in upper-middle-income countries over the period 2000–2025. The findings indicate that renewable energy consistently lowers carbon emissions across all estimation methods, highlighting its importance in improving environmental quality. Conversely, GDP growth remains a positive and significant contributor to emissions, suggesting that economic expansion continues to generate environmental pressures. Although FDI initially exhibits a negative relationship with carbon emissions, the robustness analysis reveals that the effects of both FDI and financial development vary across estimation approaches and therefore require cautious interpretation.

The present study extends the environmental economics literature by providing a comprehensive assessment of the factors driving carbon emissions in upper-middle-income economies. The results suggest that the emission-reducing effect of FDI is not universal but may arise under specific circumstances consistent with the PHE. In addition, the analysis identifies renewable energy and economic growth as the most robust determinants, while FDI and financial development appear conditional on estimation approach.

The findings offer policy implications that differ in strength according to the robustness of the evidence. First, because renewable energy is the most stable emission-reducing determinant, accelerating its adoption should be the primary strategy, for example through grid access, long-term power purchase arrangements, and investment incentives that displace fossil-based generation. Second, because GDP growth raises emissions in every specification, growth strategies should be accompanied by energy-efficiency standards and clean-technology incentives for energy-intensive sectors such as manufacturing and transportation. Third, since financial development is positively associated with emissions but sensitive to the estimator, policymakers should take a cautious approach by developing green finance frameworks, such as green credit guidelines and

taxonomies, that steer credit toward low-carbon projects, rather than restricting financial deepening itself. Finally, as the emission-reducing effect of FDI is only partially robust, foreign investment should not be relied upon as a stand-alone mitigation tool; attracting it should be conditional on environmental standards and clean technology transfer.

Overall, the study extends existing research by examining how economic and financial factors jointly influence carbon emissions in upper-middle-income economies. The results indicate that sustainable development cannot be achieved solely through economic growth but also requires stronger renewable energy utilization, effective green finance frameworks, and investment policies that support environmental objectives.

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