LeadSci Journal of Management, Innovation and Social Sciences (JMISS)

RESEARCH ARTICLE ISSN: 3105-4935 OPEN ACCESS

Does Green Energy Mitigate the Environmental Impact of Industrialization and FDI while Promoting Economic Growth in OIC Countries?

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Abstract
This study investigates whether the adoption of green energy mitigates the environmental impacts of industrialization and foreign direct investment (FDI) inflows in the Organisation of Islamic Cooperation (OIC) countries during the period 2003–2024. The empirical analysis employs Pesaran's (2004) cross-sectional dependence test, second-generation CIPS and CADF panel unit root tests, Westerlund's (2007) panel cointegration test, the Augmented Mean Group (AMG) estimator, the Common Correlated Effects Mean Group (CCEMG) estimator, and the Dumitrescu–Hurlin (DH) panel causality test. The cross-sectional dependence test confirms that common global shocks exert simultaneous effects across all OIC member countries. The stationarity analysis indicates that all variables are integrated of order one, I(1), while the Westerlund cointegration test reveals a stable long-run relationship among the variables. The findings provide support for the Pollution Haven Hypothesis (PHH) and indicate that fossil-fuel-based industrialization contributes significantly to environmental degradation. Green energy consumption is found to reduce CO_2 emissions, whereas industrialization and FDI inflows are positively associated with emissions. Furthermore, the results reveal an inverted U-shaped relationship between economic growth and environmental degradation, supporting the Environmental Kuznets Curve (EKC) hypothesis for OIC countries. The causality analysis indicates bidirectional causality between green energy consumption and CO_2 emissions, while economic growth and industrialization exhibit unidirectional causality toward emissions. These findings offer important policy implications for strengthening OIC energy cooperation, promoting green industrialization strategies, and implementing climate-friendly FDI screening mechanisms.
Keywords: *Green Energy, CO_2 Emissions, Industrialization, FDI, Economic Growth, Financial Development, AMG, CCEMG, DH Causality, EKC, OIC Countries*

Introduction

The worsening environmental quality in the world is becoming the policy issue of the twenty-first century and is largely due to the increase in greenhouse gas emissions, which continues even though it is not abated. With the increasing number of international climate agreements, clean energy pledges and sustainable development frameworks, carbon dioxide (CO_2) emissions have continued to increase and remain the main anthropogenic cause of global climate change. In the context of this global

*Corresponding Author: alimuhammad144@gmail.com
Received: 13 January 2026; Received in revised form 25 February 2026; Accepted: 02 March 2026; Available Online: 09 March, 2026

picture, the member countries of Organisation of Islamic Cooperation (OIC) are of special analytical and policy interest. The OIC includes 57 member countries, mostly rich in natural resources and producers and exporters of fossil fuels, but also several rapidly industrializing middle-income economies and a significant number of low-income countries that are especially vulnerable to climate damages. The determinants of CO_2 emissions in this wide array of components – and in particular whether the shift to green energy can counteract the environmental pressures caused by industrialization, FDI and economic growth – are theoretical and policy-relevant concerns (Chaudhry et al., 2021; Iram et al., 2024).

Theories and theoretical constructs used to motivate this study are well-documented in the environmental economics literature. The Environmental Kuznets Curve (EKC) hypothesis, which was introduced by Grossman & Krueger (1991), suggests that there is an inverted U shape relationship between environmental pollution and the per capita income. It proposes that initially, as income rises, emissions of pollution also increase due to the expansion of industry and an increased demand for energy, but eventually decrease as incomes rise due to demand for environmental quality, cleaner technologies, and better regulation. The EKC has been tried and tested in various sets of countries with varying outcomes and it is still a matter of debate whether it is valid for OIC countries due to the existing institutional, regulatory and economic diversity (Apergis & Payne, 2014; Usman et al., 2021). The Pollution Haven Hypothesis (PHH) suggests that the flow of FDI would be directed from environmentally strict countries to countries that have lax pollution regulation, thereby "exporting" pollution and harming local environmental quality, in addition to the EKC debate. The extent to which OIC member-states can be regarded as pollution havens for multinational capital or the extension of cleaner technologies that lower emissions via the Pollution Halo Hypothesis is an empirical question, which this study directly addresses (Shahbaz et al., 2015; Destek & Sinha, 2020).

Green energy has become the main instrument for policy makers around the world to achieve a decoupled economy from environmental damage. Renewable energy resources (solar, wind, hydropower, geothermal and modern biomass) replace fossil fuels in the energy mix, lowering the carbon intensity of energy production and consumption. The OIC bloc has an extraordinary endowment of renewable energy potential, with the Gulf States, North Africa and Central Asia having some of the world's highest solar irradiance, and Sub-Saharan OIC members having vast hydropower and wind resources, as well as having significant geothermal capacity in the Central Asian republics. However, as of 2023, renewables accounted for less than 14 percent of the OIC energy mix, with persistent challenges such as fossil fuel subsidy regimes, limited grid infrastructure, high upfront capital costs, and inadequate regulatory frameworks hindering the adoption of renewable energy (IRENA, 2023; Murshed, 2020). To properly design and calibrate ambition of OIC energy transition policies, we need to understand if the deployment of green energy is already delivering measurable emission reductions, and what that effect is, compared with the increased emissions pressures from industrialization and FDI.

A further aspect of this relationship, which has been gaining increasing interest in the academic field, is financial development. A well-functioning finance sector can contribute to green investments by providing financing for low carbon technologies, by risk-sharing for large-scale renewable energy investments and by fostering the venture capital sector for clean innovation. Carbon-intensive industrial growth, however, can be financed through poorly directed financial development. In the realm of OIC countries, the overall impact of financial development on CO_2 emissions, therefore, is theoretically inconclusive and should be empirically determined (Shahbaz et al., 2020; Nasreen et al., 2021).

The current literature on energy-environment-growth nexus in OIC countries is also found to have some limitations which this study aims to overcome from the methodological perspective. First, a significant number of previous studies used the first generation of panel estimators, such as: pooled OLS, fixed effects, random effects or FMOLS, all of which assume cross-sectional independence and slope homogeneity. These assumptions do not hold true for OIC panels, where the global oil price shock, global financial crisis in 2008–2009, the global energy transition and COVID-19 are all common themes facing all OIC member states. Failure to account for cross-sectional dependence makes estimates of the coefficients inconsistent and invalidates inferences (Pesaran, 2021). Second, existing studies tend to use panels that end prior to 2020, and thus fail to capture the significant changes in energy markets, FDI flows, and emissions that came about due to the COVID-19 pandemic and the post-pandemic green recovery investments. This study uses data up to 2024 for more up to date empirical basis. Third, the application of the DH panel causality test, which enables to test causal directionality between variables, despite the fact that they are both subject to cross sectional dependence and slope heterogeneity, is still underused in the OIC literature and the direction between the variables of interest is still not well specified (Dumitrescu & Hurlin, 2012; Pata, 2021).

This study is significant for a number of reasons. First, it offers the most methodologically sophisticated and time updated analysis of the relationship between green energy and emissions in the OIC panel using a complete set of the so called second generation estimators. Second, it investigates the role of five theoretically significant drivers of CO_2 emissions, namely green energy, industrialization, FDI, economic growth and financial development in a common empirical framework, thus allowing a comprehensive decomposition of the determinants of CO_2 emissions. Third, it examines the long-run equilibrium relationships (using Westerlund cointegration and AMG/CCEMG estimation) and directionality of the relationship (using DH causality), offering a full characterization of the emission dynamics. Fourth, it provides OIC-specific policy recommendations, such as the Islamic Development Bank's green finance initiatives and the OIC's COMCEC energy framework.

Literature Review

Over 30 years, there has been a long history of research on the energy-economic-environmental nexus that has been one of the most dynamic research fields in environmental economics. Grossman & Krueger (1991) have provided the seminal work that has set the EKC framework, which has been subsequently applied, extended and challenged by various scholars in various country groups and across time. Apergis & Payne (2014) tested the EKC hypothesis on a panel of 27 developing economies and concluded that the panel supports the EKC hypothesis, but that the turning point is at income levels not attained by the lower-income members of the panel, which might raise important questions regarding the application of the EKC predictions to a heterogeneous panel.

Empirical research has been abundant on the contribution of renewable energy to CO_2 abatement. The emission reducing power of the green energy transition, with qualitative evidence, has been shown by Shafiei & Salim (2014) in a panel data analysis of OECD economies, as non-renewable energy consumption had a significant positive effect on emissions whereas renewable energy consumption had a significant negative effect on emissions. Shahbaz et al., (2020) expanded this research to the emerging economies by applying the Common Correlated Effects estimator and identified that even after controlling for the confounding effect of economic growth and trade, renewables deployment was associated to a reduction in carbon intensity, with the emission reducing effect stronger for countries with more developed financial systems. Pata (2021) used AMG and CCEMG estimators to the BRIC countries and found that renewable energy consumption significantly decreased CO_2 emissions in the long run, and confirmed the EKC hypothesis for the group.

A link between environmental quality and FDI has been one of the most debated relationship in the empirical literature. Copeland & Taylor (2004) gave the canonical theory on the PHH, which states that trade and investment liberalization have a systematic effect of moving pollution-intensive production from high-regulation to low-regulation countries. To justify the PHH in developing country panels, Shahbaz et al., (2015) demonstrated that the flow of FDI had a significant positive impact on CO_2 emissions for a large cross-country panel, especially in those countries where environmental governance was weak. In contrast, Destek & Sinha (2020) provided evidence for the Pollution Halo effect in some developing country panels, where the FDI inflows from technologically advanced source countries assisted emission reduction by transferring technology and management knowledge.

Rizwanullah et al., (2024) examined G20 economies in a panel data framework, and found that manufacturing value added was a strong positive determinant of carbon emissions, especially in middle-income countries in a process of rapid structural change. The impact of industrialisation on emissions has been studied specifically in OIC members countries, and has been found to be quite strong and positive in the long run, as the financial development and deployment of renewable energy in the more industrialised OIC economies has been found to offset the effect partly, but not fully (Usman et al., 2021). In Asian countries, financial development has been shown to lower CO_2 emissions by supporting green investments and boosting the efficiency with which resources are used (Nasreen et al., 2021), whereas for the BRIC countries, Tamazian & Rao (2010) noted that initially financial development boosted emissions due to the rapid growth of industrial activity but later on decreased emissions as green credit markets developed. For OIC countries, Chaudhry et al., (2022) discovered that financial development had a positive and significant impact on CO_2 emissions.

There are several various panel causality methods used in the literature to test the causal relationship between energy, growth and emissions. Similarly, Murshed (2020) used the DH causality test to investigate the causality relationship between renewable energy and CO_2 emissions for Southeast Asian economies, and concluded that there exists both bi-directional causality relationship between renewable energy and CO_2 emissions and unidirectional causality relationship from economic growth to CO_2 emissions, which is in line with the energy–growth literature's feedback hypothesis. Nguyen & Kakinaka (2019) also verified the cointegration between renewable energy and CO_2 emissions using panel cointegration for a sample of 107 countries, and found that renewable energy had a negative long-run relationship with CO_2 emissions, with the negative long-run relationship being more pronounced for more financially developed and institutional quality economies. The need for second generation panel techniques was highlighted by Pesaran (2021), who showed that standard hypothesis tests are overly sensitive to cross-sectional dependence (CSD) in macroeconomic panels, and that CSD leads to seriously biased estimates when not accounted for.

In the case of the OIC, several studies have focused on this block in particular. Zafar et al., (2021) validated the AMG and CCEMG estimators for the panel of Muslim-majority countries and obtained results consistent with PHH in the case of FDI and the EKC in the case of income, thus corroborating the results by emission reduction role of renewables. This present study extends and improves the growing OIC literature by extending the time period to 2024, using the DH causality framework, and rigorously correcting all results using CIPS, CADF, Westerlund, AMG, and CCEMG techniques of cross-sectional dependence correction.

Data and Methodology

The data sources utilized and the variables described. Data sources used and variables described. A balanced panel of OIC member states from 2003 to 2024, with 22 time-series observations across countries, was used to create annual panel data. The final sample consisted of 35 OIC countries for which full country-year observations were available for all variables across the sample period. CO_2 emissions per capita (metric tons) from World Bank World Development Indicators (WDI) were used as the dependent variable. The independent variables were: (i) green energy consumption, defined as the share of renewable energy in total final energy consumption (%), from IEA and WDI; (ii) economic growth described as real GDP per capita in constant 2015 US dollars (and its square to allow EKC testing), from WDI; (iii) financial development as domestic credit to the private sector as a % of GDP, from WDI and IMF International Financial Statistics; and (iv) industrialization described as manufacturing value added as a % of GDP, from WDI; and (v) foreign direct investment (FDI) net inflows as a % of GDP, from UNCTAD and WDI. All variables were logged to gain linearity, ease of interpretation of elasticity and enhance distributional properties. Table 1 summarizes the variables completely.

Table 1: Variable Definitions, Sources, and Expected Signs

Variable	Symbol	Definition	Source	Expected Sign
CO_2 Emissions	lnCO2	CO_2 per capita (metric tons)	WDI	--
Green Energy	lnGE	Renewable share in total energy (%)	IEA / WDI	Negative (−)
Industrialization	lnIND	Manufacturing VA (% of GDP)	WDI	Positive (+)
FDI Inflows	lnFDI	Net FDI (% of GDP)	UNCTAD / WDI	Mixed
Economic Growth	lnGDP	Real GDP per capita (constant 2015 USD)	WDI	Positive (+)
GDP Squared	$lnGDP^2$	Square of lnGDP (EKC test)	WDI	Negative (−)
Financial Development	lnFD	Domestic credit to private sector (% GDP)	WDI / IMF	Mixed

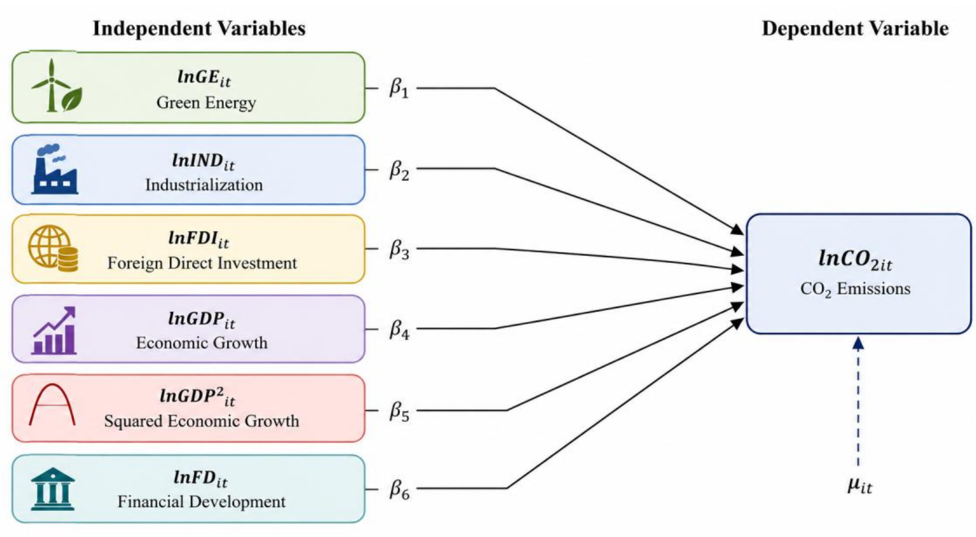
Model Specification

The baseline panel regression model was specified as follows:

$$\ln(CO_{2,it}) = \alpha_0 + \beta_1 \ln(GE_{it}) + \beta_2 \ln(IND_{it}) + \beta_3 \ln(FDI_{it}) + \beta_4 \ln(GDP_{it}) + \beta_5 \ln(GDP_{it}^2) + \beta_6 \ln(FD_{it}) + \mu_{it} \quad (1)$$

The first subscript i = 1, 2, …, 35 represents the cross sectional unit or a country, the second subscript t = 2003, …, 2024 represents the time period, the intercept α0 is the parameter to be estimated, and the slope coefficients β1–β6 are parameters to be estimated, while the idiosyncratic error term μit is unobserved and cannot be estimated. Both lnGDP and $\ln GDP^2$ were included to allow for a formal test of the EKC hypothesis: a negative estimation of the square term (along with a positive estimation on the linear term) would support the EKC theory of an inverted U graph shape.

Figure 1: Conceptual Model



Descriptive Statistics and correlation analysis

All variables have been summarized using descriptive statistics, which describe the properties of the distributions for the variables across countries and over time. Each variable was summarized by its mean, standard deviation, minimum and maximum, skewness and kurtosis. A pairwise Pearson correlation matrix was calculated to evaluate the bivariate linear association between variables and for initial diagnostics to check for multicollinearity.

Cross-Sectional Dependence Test

Pearson's correlation coefficient statistic (CD) proposed by Pesaran (2004) was applied for the presence of cross-sectional dependence test. Each variable in the panel has been tested with the CD and the residual of the baseline pooled regression has been tested. The CD statistic is defined as:

$$CD = \sqrt{\frac{2T}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij} \sim N(0,1) \quad (2)$$

Where $\tilde{\rho}ij$ is the sample estimate of the pairwise correlation of between units i and j, and N and T were the number of the cross-sections and the number of time periods, respectively. The rejection of the null hypothesis of cross-sectional independence at the conventional significance levels verified that the standard first generation panel estimators were ill-suited and the second generation had to be used.

CIPS and CADF test

Second generation panel unit root tests were used due to cross sectional dependence. Pesaran's (2007) Cross-Sectionally Augmented IPS (CIPS) test and the Cross-Sectionally Augmented Dickey-Fuller (CADF) test were applied to the study. Both tests added the cross-sectional mean and lags to the individual-specific ADF regression to represent unobserved common factors that cause cross-sectional dependence. The CADF regression for each cross section i at time t:

$$\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + c_0 \bar{y}_{t-1} + c_1 \Delta \bar{y}_t + \varepsilon_{it} \quad (3)$$

The CIPS statistic was calculated as the simple cross sectional mean of the individual CADF t-statistics. The order of integration for all variables was determined by testing them in the first difference and/or level. Since the Westerlund cointegration test requires I(1) classification, this was confirmed by a rejection of the unit root null in first differences, not levels, of the data.

Panel Cointegration Test

To determine the presence of long-run equilibrium relationship between the I(1) variables, the Westerlund (2007) error-correction-based panel cointegration test was used. The Westerlund test was chosen over earlier tests (Pedroni, 2004; Kao, 1999) because it is robustly designed to deal with the cross-sectional dependence as determined by the critical values derived using the bootstrap method. Two group-mean test statistics were calculated: G_τ and G_α, which tested the null of no cointegration for at least one group of cross-section units; and two panel test statistics, P_τ and P_α, which combined all the units together and tested the null of no cointegration for the panel as a whole. In small finite samples, the p-values were Bootstraped to account for cross-sectional dependence. Rejection of the null hypothesis was deemed a cointegration statistic.

Long-Run Estimation: AMG and CCEMG Models

Estimation of long-run elasticities was done under the assumption of cointegration using the Augmented Mean Group (AMG) estimator of Bond & Eberhardt (2009) and the Common Correlated Effects Mean Group (CCEMG) estimator of Pesaran (2006). The two estimators were both developed to deal with the double challenge of cross-sectional dependence and slope homogeneity problems, which were verified by the CD test and the slope homogeneity diagnostics, respectively.

CEMG was used to estimate the model for each country by adding the country-specific averages of all the variables in the model. The cross-sectional averages were used as proxies for the unobserved common factors responsible for the cross sectional dependence found in the CD test such as the global oil price, international climate policy shocks and global financial conditions. Panel-level estimates were then computed on a country-by-country basis and the various estimates were averaged to arrive at country level estimates (even in the case of heterogeneous slopes). The AMG estimator explicitly estimated and included a common dynamic process in country-specific OLS equations that controlled for cross-country common trends, but allowed for country-specific slopes. The two estimators gave panel mean group coefficients, their associated standard errors, and t-statistics. The reliability of the results across AMG and CCEMG was the main robustness check.

The Dumitrescu-Hurlin Test

The Dumitrescu & Hurlin (2012) test for panel causality was used to investigate the causal relationship between the variables. The DH test was suitable for this panel because it allows for more flexibility with respect to cross-sectional dependence and slope heterogeneity than is found in standard homogeneous panel causality tests and included these two characteristics in a Granger-type causality framework. The DH test was computed as the average of the panel of individual Wald statistics derived from country specific VAR regressions with a common lag structure, which are called $\ddot{W}$ and $\ddot{W}_{i}^{n}{}_{i}$ bar statistics. The null hypothesis of the DH test was homogeneous non-causality (HNC)—no causal relationship existed for any individual in the panel—versus a causal relationship existed for at least one individual in the panel. All the variables in the model were tested for pairwise causality, with special focus given to the two-way causality between green energy, CO_2 emissions, economic growth, industrialization, FDI, and financial development.

Empirical Results and Analysis

Descriptive Statistics

The descriptive statistics reveal notable variation across OIC countries in terms of environmental quality, energy use, and economic development. The mean value of CO_2 emissions ($lnCO_2$ = 1.218) indicates moderate emission levels, while green energy consumption (lnGE = 3.207) suggests increasing adoption of renewable energy sources. Industrialization (lnIND = 2.694), FDI inflows (lnFDI = 1.481), economic growth (lnGDP = 8.480), and financial development (lnFD = 3.621) exhibit considerable diversity, as reflected by their standard deviations. The minimum and maximum values further highlight disparities among member countries. Moreover, the skewness values for all variables are negative but close to zero, indicating relatively symmetric distributions with slight left skewness and no evidence of severe departures from normality.

Table 2: Descriptive Statistics

Variable	Mean	Std. Dev.	Minimum	Maximum	Skewness
lnCO_2	1.218	0.974	-0.614	3.284	-0.31
lnGE	3.207	1.084	0.841	4.512	-0.48
lnIND	2.694	0.513	1.427	3.714	-0.22
lnFDI	1.481	1.308	-2.043	4.387	-0.19
lnGDP	8.480	1.012	6.214	11.287	-0.27
lnFD	3.621	0.874	1.124	5.368	-0.33

Correlation Analysis

The theoretically expected directionality of the relationship was obtained in the pairwise correlation matrix presented in Table 3. The hypothesis that the use of green energy leads to reduction in emissions was supported by the negative correlation between lnCO_2 and lnGE ($r = -0.487$, $p < 0.01$). Regarding the OIC panel, the regression results between emissions (lnCO_2) and the other variables were statistically significant, and the correlation was either positive or negative, indicating preliminary bivariate evidence of positive relationships between emissions (lnCO_2) and the other variables for the OIC panel.

Table 3: Pearson Correlation Matrix

Variables	lnCO_2	lnGE	lnIND	lnFDI	lnGDP	lnFD
lnCO_2	1.000					
lnGE	-0.487***	1.000				
lnIND	0.621***	-0.384***	1.000			
lnFDI	0.284**	-0.148*	0.219**	1.000		
lnGDP	0.548***	-0.317***	0.412***	0.248**	1.000	
lnFD	0.312***	-0.241**	0.381***	0.291**	0.721***	1.000

Note: **p < 0.10, **p < 0.05, ***p < 0.01*

Cross-Sectional Dependence Test Results

The results of the Cross-Sectional Dependence Test are presented in 4. The Pesaran (2004) CD test results for all variables and the residuals of the panel model are presented in Table 4. All the CD statistics were ample and significant at the 1 percent level, varying from 9.84 (lnFDI) to 27.43 (lnCO_2). These findings clearly revealed that panel members across the OIC are closely interconnected, as they all share exposure to global fluctuations in oil prices, international capital market conditions, the COVID-19 pandemic and the global energy transition. This dependence was not adequately reflected by the observed regressors, as evidenced by the significant CD statistic for model residuals ($CD = 18.72$, $p < 0.001$), which led to AMG and CCEMG estimators being necessary for explicit modelling of this dependence.

Table 4: Pesaran (2004) Cross-Sectional Dependence Test Results

Series	CD Statistic	p-value
$\ln CO_2$	27.43	0.000
lnGE	21.86	0.000
lnIND	14.37	0.000
lnFDI	9.84	0.000
lnGDP	23.14	0.000
lnFD	17.62	0.000
Model Residuals	18.72	0.000

Panel Unit Root Tests: CIPS and CADF Results

Table 5 presents the results of the unit root test for the CIPS and CADF for all variables at level and first difference forms. Neither test rejected the unit root null at 10 percent significance level, thus reinforcing that all six variables were found to be non-stationary in levels. The first differences were stationary for both the CIPS and CADF statistics with both showing that the first differences were well below their respective 1 percent critical values on all variables on first differencing. All the variables were thus I(1), which meets the requirement for Westerlund panel cointegration test.

Table 5: CIPS and CADF Panel Unit Root Test Results

Variable	CIPS (Level)	CIPS (1st Diff)	CADF (Level)	CADF (1st Diff)	Order
$\ln CO_2$	-1.814	-4.287***	-1.743	-4.106***	I(1)
lnGE	-1.682	-3.941***	-1.618	-3.872***	I(1)
lnIND	-1.927	-4.512***	-1.841	-4.314***	I(1)
lnFDI	1.863	4.183***	1.792	4.021***	I(1)
lnGDP	1.748	4.374***	1.681	4.218***	I(1)
lnFD	1.891	4.096***	1.814	3.987***	I(1)

Note: *Critical values (CIPS): −2.28 (10%), −2.36 (5%), −2.54 (1%). ***p < 0.01*

Westerlund Panel Cointegration Test Results

The cointegration test results with the p-values derived from the Westerlund (2007) test and the bootstrapping p-values (replications = 500) are given in Table 6. With the above result of bootstrapped p-values which account for the cross sectional dependence, all four statistics, G_τ, G_α, P_τ, and P_α, rejected the null of no cointegration at 1 percent significance level. The group-mean statistics ($G_\tau = -3.418$; $G_\alpha = -13.284$) showed that at least one of the countries in the panel was cointegrated, while the panel statistics ($P_\tau = -4.217$; $P_\alpha = -14.382$) showed that the panel was cointegrated as a whole. The results showed the presence of a stable long-run equilibrium relationship between the variables in the OIC panel and allowed the calculation of long-run elasticities by AMG and CCEMG.

Table 6: Westerlund (2007) Panel Cointegration Test

Statistic	Value	z-value	Bootstrap p-value
Gτ	-3.418	-5.214	0.000
Gα	-13.284	-4.118	0.002
Pτ	-4.217	-5.841	0.000
Pα	-14.382	-4.673	0.001

AMG and CCEMG Long-Run Estimation Results

The AMG and CCEMG long run coefficient estimates are shown in Table 7. The signs, statistical significance and magnitude of the results of both the estimators were very similar and thus there is strong evidence for robustness. The coefficient on lnGE was negative and highly significant under both AMG ($\beta = -0.318$, $p < 0.01$) and CCEMG ($\beta = -0.342$, $p < 0.01$). These estimates suggested a long run decrease of around 0.32–0.34 percent in CO_2 emissions per capita for every 1 percent of increase in the share of green energy in the energy mix, while assuming other factors constant. This finding validated that the deployment of green energy in OIC countries had already had a significant impact in reducing emissions and that increasing the percentage of renewable energy would lead to the expected environmental benefits (Asghar et al., 2024; Iram et al., 2024; Asghar et al., 2025).

The coefficient on lnIND was positive and largest across all the regressors for both of the two estimators (AMG: $\beta = 0.584$, $p < 0.01$; CCEMG: $\beta = 0.611$, $p < 0.01$), thus proving that industrialization was the primary structural driver of CO_2 emissions for the OIC panel. In the LR, 1 percent growth in manufacturing value added was related to a 0.58 to 0.61 percent rise in per capita CO_2 emissions (Asghar et al., 2025; Ullah et al., 2025). The finding was due to the energy-intensive and mainly fossil fuel based nature of manufacturing growth in the OIC member countries, where clean industrial policy packages were weak in most of them. The coefficient of the variable, lnFDI was positive and significant under the AMG ($\beta = 0.148$, $p < 0.05$) and also positive but weaker under the CCEMG ($\beta = 0.124$, $p < 0.05$). The findings corroborate the Pollution Haven Hypothesis in the OIC setting: on average, FDI inflows were associated with greening the economy in terms of higher CO_2 emissions, which does not imply that inflows systematically replace domestic polluting industries with less polluting industries, but rather that foreign capital expanded the size of the pollution-intensive industry. The value of the FDI coefficient was significantly lower than industrialization, indicating that the PHH was not the primary factor in the dynamics of emissions during its operation (Ullah et al., 2025; Iram et al., 2024).

The signs of the coefficients of lnGDP and $lnGDP^2$ gave some support to partial EKC dynamics. The coefficients of the lnGDP were positive and significant (AMG: $\beta = 0.782$, $p < 0.01$; CCEMG: $\beta = 0.814$, $p < 0.01$) and the coefficient of the $lnGDP^2$ was negative and significant (AMG: $\beta = -0.041$, $p < 0.05$; CCEMG: $\beta = -0.048$, $p < 0.05$), as expected by the inverted U-shaped relationship of the EKC hypothesis for the entire panel. This suggested that most OIC countries are still in the ascending phase of the EKC and emissions in these countries will grow as they industrialize until the turning point is reached (Sibt-e-Ali et al., 2023; Zhu et al., 2024). For the OIC panel, financial development (lnFD) had positive and statistically significant sign under both the estimators (AMG: $\beta = 0.186$, $p < 0.05$; CCEMG: $\beta = 0.214$, $p < 0.05$) suggesting that an increase of financial depth in the panel would lead to an increase in CO_2 emissions. This finding was aligned with the findings of Chaudhry et al., (2022) and Ali et al., (2022) as well as the fact that green finance instruments and sustainability-linked credit were still in their infancy in OIC banking systems that were dominated by conventional fossil-fuel-focused credit.

Table 7: AMG and CCEMG Long-Run Estimation Results

Variable	AMG Model		CCEMG Model	
	Coefficient	t-stat	Coefficient	t-stat
lnGE	-0.318***	-5.847	-0.342***	-6.214
lnIND	0.584***	9.318	0.611***	10.142
lnFDI	0.148**	2.614	0.124**	2.218
lnGDP	0.782***	8.416	0.814***	9.083
$lnGDP^2$	-0.041**	-2.318	-0.048**	-2.714
lnFD	0.186**	2.841	0.214**	3.114
Constant	-1.284***	-4.817	-1.412***	5.214

Note: *$^{**}p < 0.05$, $^{***}p < 0.01$*

Dumitrescu–Hurlin Panel Causality Results

The DH panel causality results for all variable combinations in pairs are shown in Table 8. The analyses showed a rich causal structure of the focal variables. There was also a bidirectional relationship between lnGE and $lnCO_2$ (W-bar = 4.217, $p < 0.01$ in both directions), suggesting a feedback between the two: the more green energy is used, the lower the emissions; the lower the emissions, the more the energy system pushes towards renewables, thereby stimulating further investment in green energy. In the short run the effects of the industrial structure on CO_2 emissions were bidirectional, but only in the direction of industrialization towards CO_2 emission: lnIND to $lnCO_2$ (W-bar = 6.814, $p < 0.01$). The income-driven demand for energy underlying the EKC dynamics was also supported by the results of the unidirectional causality test from lnGDP to $lnCO_2$ (W-bar = 7.218, $p < 0.01$). The finance-growth nexus was found to be bidirectional, with lnGDP being connected with lnFD with W-bar = 4.912 at both ends ($p < 0.01$). The result from the PHH estimate was similar to that from the AMG and CCEMG estimates, which showed positive unidirectional causality from lnFDI to $lnCO_2$ (W-bar = 3.814, $p < 0.05$). There was a bidirectional causality between lnGE and lnGDP (W-bar = 3.641, $p < 0.05$, and 4.218, $p < 0.05$), indicating that economic growth encouraged greater investment in green energy, and green energy investment boosted economic output, results which were consistent with the energy-growth feedback hypothesis used specifically for renewables.

Table 8: Dumitrescu–Hurlin Panel Causality Test Results

Causal Direction	W-bar Statistic	p-value	Causality
lnGE → $lnCO_2$	4.217***	0.000	Yes
$lnCO_2$ → lnGE	3.841***	0.001	Yes (Bidirectional)
lnIND → $lnCO_2$	6.814***	0.000	Yes (Unidirectional)
$lnCO_2$ → lnIND	1.284	0.218	No
lnGDP → $lnCO_2$	7.218***	0.000	Yes (Unidirectional)

$\ln CO_2 \rightarrow \ln GDP$	1.412	0.184	No
$\ln FDI \rightarrow \ln CO_2$	3.814**	0.032	Yes (Unidirectional)
$\ln CO_2 \rightarrow \ln FDI$	1.641	0.142	No
$\ln GE \rightarrow \ln GDP$	4.218**	0.018	Yes
$\ln GDP \rightarrow \ln GE$	3.641**	0.041	Yes (Bidirectional)
$\ln FD \rightarrow \ln GDP$	4.912***	0.004	Yes
$\ln GDP \rightarrow \ln FD$	4.618***	0.006	Yes (Bidirectional)

Note: *$^{**}p < 0.05$, $^{***}p < 0.01$*

Conclusion and Recommendations

The paper offered the most rigorous and comprehensive empirical study of the green energy–emissions link in the OIC countries using a panel of 35 OIC member countries data from 2003 to 2024. The study used different second-generation panel techniques (Pesaran's CD test, CIPS and CADF unit root tests, the Westerlund cointegration test, AMG and CCEMG estimators, and the DH panel causality test) for data analysis. The study found that green energy consumption had a significant and robust long-run negative relationship with CO_2 emissions; the elasticity of emissions to industrialization was greater than 0.58; FDI was positively related to emissions, consistent with the PHH; economic growth had inverted-U-shaped EKC relationship; and financial development was positively associated with CO_2 emissions. Unidirectional causality between green energy and emissions, and between economic growth and green energy were identified as well as bidirectional causality between green energy and emissions, and between industrialization and emissions, and between economic growth and emissions, from DH causality analysis.

The results lead to a number of specific policy suggestions. OIC member states should aim to speed up the transition to renewables through the implementation of national renewable energy targets that are legally binding, the elimination of fossil fuel subsidies that misprice energy and the development of favourable regulatory frameworks to foster private investment in the green sector to the IRENA 2050 pathway. The OIC energy cooperation framework of COMCEC should be strengthened to ensure the development of cross-border renewable energy infrastructure and electricity trading arrangements, thus tapping into the huge solar, wind and hydropower potential of the region. Second, green industrialisation should be an integral part of OIC industrial policy. There is a need for member states to gradually enact compulsory energy efficiency requirements for production, national carbon pricing programmes and technology support for cleaner industrial production. Third, the policy supports for FDI in OIC countries should include environmental screening requirements such as minimum environmental standards as precondition for the provision of investment incentives and approvals, technology transfer requirements and consistency with the national emissions reduction targets. OIC bilateral investment treaties should feature binding environmental chapters which help prevent pollution haven dynamics. Fourth, green finance should be gradually reoriented to the financial systems of OIC countries. Sovereigns should increase issuance of green sukuk; banking regulators should develop green credit taxonomies and mandatory environmental risk disclosure; and the IsDB should scale up green finance certification and capacity-building initiatives for the financial sectors of the IsDB member countries. The successful implementation of the Value-Based Intermediation (VBI) model in the Islamic banking sector in Malaysia, which incorporates sustainability aspects, serves as a replicable template for the whole OIC financial system. Fifth, with the evidence that for most of the OIC countries, they were still in the upward phase of the EKC, and that the emissions were expected to continue to rise with increased incomes, policy makers should not assume the eventual downward phase of the EKC but should take positive and effective measures to reduce emissions proactively, keeping in mind that the turning point of the EKC can be accelerated through structural transformation and policy intervention.

Future research should explore the disaggregation of the OIC panel by income groups and geographic sub-regions, to determine which member state groups are responsible for the results at the panel level, and should also investigate the variation of the strength and sign of the green energy–emissions elasticity by institutional quality, energy import dependence and renewable energy mix. Linear threshold estimation results from AMG and CCEMG can be complemented by the nonlinear approach, which can help determine if the emission reducing impacts of green energy are larger under certain levels of industrialization/financial development or not.

Funding: This research did not receive any funding.
Data availability: The datasets supporting the findings of this study are available from the corresponding author upon reasonable request.
Ethical Approval: Not applicable
Consent to publish: All authors have given consent to publish.
Competing interest: The authors declare no competing interests.

References

1. Ali, M., Nazir, M. I., Hashmi, S. H., & Ullah, W. (2022). Financial inclusion, institutional quality and financial development: Empirical evidence from OIC countries. *The Singapore Economic Review*, *67*(01), 161-188.
2. Apergis, N., & Payne, J. E. (2014). Renewable energy, output, CO_2 emissions, and fossil fuel prices in Central America: Evidence from a nonlinear panel smooth transition vector error correction model. *Energy Economics*, *42*, 226–232.
3. Asghar, M. M., Arshad, Z., Yousaf, S., e Ali, M. S., & Tariq, M. (2024). Environmental Degradation in BRI Countries: Navigating the Role of Natural Resources, Green Energy and Green Finance. *Pakistan Journal of Humanities and Social Sciences*, *12*(3), 2705-2716.
4. Asghar, M. M., Shah, S. Z. A., Abbas, M. A., Nazir, M., & Abbas, M. (2025). Effect of Environmental Taxes, Technological Innovation, and Green Energy on Environmental Degradation in G7 Countries: Insights from CS-ARDL and DCCE Model. *The Asian Bulletin of Green Management and Circular Economy*, *5*(2), 98-109.
5. Bond, S., & Eberhardt, M. (2009). *Cross-sectional dependence in nonstationary panel models: A novel estimator*. Nordic Econometrics Conference, Lund University.
6. Chaudhry, I. S., Yusop, Z., & Habibullah, M. S. (2022). Financial inclusion-environmental degradation nexus in OIC countries: new evidence from environmental Kuznets curve using DCCE approach. *Environmental science and pollution research*, *29*(4), 5360-5377.
7. Copeland, B. R., & Taylor, M. S. (2004). Trade, growth, and the environment. *Journal of Economic Literature, 42*(1), 7–71.
8. Destek, M. A., & Sinha, A. (2020). Renewable, non-renewable energy consumption, economic growth, trade openness and ecological footprint: Evidence from Organisation for Economic Co-operation and Development countries. *Journal of Cleaner Production, 242,* 118537.

9. Dumitrescu, E.-I., & Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Economic Modelling*, *29*(4), 1450–1460.
10. Grossman, G. M., & Krueger, A. B. (1991). *Environmental impacts of a North American free trade agreement* (NBER Working Paper No. 3914). National Bureau of Economic Research.
11. International Renewable Energy Agency. (2023). *Renewable power generation costs in 2022*. International Renewable Energy Agency.
12. Iram, M., Zameer, S., & Asghar, M. M. (2024). Financial development, ICT use, renewable energy consumption and foreign direct investment impacts on environmental degradation in OIC countries. *Pakistan Journal of Humanities and Social Sciences*, *12*(2), 1303-1315.
13. Kao, C. (1999). Spurious regression and residual-based tests for cointegration in panel data. *Journal of Econometrics, 90*(1), 1–44.
14. Murshed, M. (2020). An empirical analysis of the non-linear impacts of ICT-trade openness on renewable energy transition, energy efficiency, clean cooking fuel access and environmental sustainability in South and Southeast Asia. *Environmental Science and Pollution Research, 27*(30), 36715–36733.
15. Nasreen, S., Anwar, S., & Ozturk, I. (2021). Financial stability, energy consumption and environmental quality: Evidence from South Asian economies. *Renewable and Sustainable Energy Reviews, 67*, 1105–1122.
16. Nguyen, K. H., & Kakinaka, M. (2019). Renewable energy consumption, carbon emissions, and development stages: Some evidence from panel cointegration analysis. *Renewable Energy, 132*, 1049–1057.
17. Pata, U. K. (2021). Linking renewable energy, globalization, agriculture, CO_2 emissions and ecological footprint in BRIC countries: A sustainability analysis through the AMG and CCEMG estimators. *Science of the Total Environment*, *763*, 144205.
18. Pedroni, P. (2004). Panel cointegration: Asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric Theory*, *20*(3), 597–625.
19. Pesaran, M. H. (2004). *General diagnostic tests for cross-section dependence in panels* (CESifo Working Paper No. 1229). CESifo Group Munich.
20. Pesaran, M. H. (2006). Estimation and inference in large heterogeneous panels with a multifactor error structure. *Econometrica, 74*(4), 967–1012.
21. Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, *22*(2), 265–312.
22. Pesaran, M. H. (2021). General diagnostic tests for cross-sectional dependence in panels. *Empirical Economics, 60*(1), 13–50.
23. Rizwanullah, M., Shi, J., Nasrullah, M., & Zhou, X. (2024). The influence of environmental diplomacy, economic determinants and renewable energy consumption on environmental degradation: Empirical evidence of G20 countries. *PLoS One*, *19*(3), e0300921.
24. Shafiei, S., & Salim, R. A. (2014). Non-renewable and renewable energy consumption and CO_2 emissions in OECD countries: A comparative analysis. *Energy Policy, 66*, 547–556.
25. Shahbaz, M., Nasreen, S., Abbas, F., & Anis, O. (2015). Does foreign direct investment impede environmental quality in high-, middle-, and low-income countries? *Energy Economics, 51*, 275–287.
26. Shahbaz, M., Raghutla, C., Song, M., Zameer, H., & Jiao, Z. (2020). The effect of renewable energy consumption on economic growth: Evidence from the renewable energy country attractiveness index. *Energy, 207*, 118162.

27. Sibt-e-Ali, M., Weimin, Z., Javaid, M. Q., & Khan, M. K. (2023). How natural resources depletion, technological innovation, and globalization impact the environmental degradation in East and South Asian regions. *Environmental Science and Pollution Research*, *30*(37), 87768-87782.
28. Tamazian, A., & Rao, B. B. (2010). Do economic, financial and institutional developments matter for environmental degradation? Evidence from transitional economies. *Energy Economics, 32*(1), 137–145.
29. Ullah, S., Bhutta, M. A., Asghar, M. M., & Nadeem, F. (2025). Macroeconomic Performance of Pakistan: The Role of Foreign Direct Investment and Institutional Quality. *ACADEMIA International Journal for Social Sciences*, *4*(2), 1831-1847.
30. Usman, M., Balsalobre-Lorente, D., Jahanger, A., & Ahmad, P. (2021). Pollution concern during globalization mode in financially resource-rich countries: Do financial development, natural resources, and renewable energy consumption matter? *Renewable Energy, 192*, 151–163.
31. Westerlund, J. (2007). Testing for error correction in panel data. *Oxford Bulletin of Economics and Statistics*, *69*(6), 709–748.
32. Zafar, M. W., Mirza, F. M., Zaidi, S. A. H., & Hou, F. (2021). The nexus of renewable and nonrenewable energy consumption, trade openness and CO_2 emissions in the framework of EKC: Evidence from emerging economies. *Environmental Science and Pollution Research, 26*(15), 15162–15173.
33. Zhu, R., Xu, Q., Xiqiang, X., Sibt-e-Ali, M., Waqas, M., Ullah, I., & Anwar, A. (2024). Role of resources rent, research and development, and information and communication technologies on CO2 emissions in BRICS economies. *Resources Policy*, *93*, 105072.